# Agroforestry Development Planning in State Correctional Facilities

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## Introduction

Modern sustainability frameworks focus upon improving human life while living within the capacity of supporting ecosystems and incorporating dimensions of social, economic, environmental, cultural and political factors (Langston & Lincoln 2018). From a sustainability perspective, the health of a landscape is reciprocally connected to the health and well-being of its people (Kimmerer 2011, Lyons 2012). Restoration and stewardship of ecosystems and social well-being are inherently linked; thus ecological restoration of ecosystems and cultural restoration require one another (Kurashima et al 2017).

Though research on sustainability and environmental management has often been confined to the academic, non-profit, or private sectors, other types of public institutions may also act as effective venues to explore innovations in wide-spread sustainable practices (Ulrich & Nadakarni 2008). With rising concerns of food sovereignty, environmental stewardship and justice for marginalized communities in Hawaiʻi, institutions that address the needs of the people (Mamaril et al 2018) are needed. Marginalized native and non-native Hawai'ians face immense social, political, and economic challenges including poverty, homelessness, abuse, health problems and high rates of repeat incarceration, commonly referred to as recidivism. (Kanaʻiaupuni et al 2005, Moy et al 2010, Kamehameha Schools 2014). Incarceration rates in Hawaiʻi have increased over 840% in the past four decades (HCR 85 TaskForce 2017). Incarceration of a disproportionate number of native Hawai'ians, the mentally ill, and women has begun to inspire incremental institutional change (HCR Task Force 2017).

The Women's Community Correctional Center (WCCC) of Oahu has taken steps toward piloting an agroforestry professional development program that incorporates dimensions of sustainability and place-based rehabilitation in Hawaiʻi. The program intends to provide a professional development resource for inmates and an opportunity to support ecosystem services and natural resources at the existing facility in Kailua, Oahu. Specifically, the project aims to incorporate Pacific Island agroforestry with existing hydroponics and horticultural projects in cooperation with local collaborators. This place-based approach to increasing local food production will improve the quality of life for people experiencing incarceration. The program's mission is focused on the intersection of culturally appropriate training, the production and sale of specialty crops, job creation and environmental sustainability.

The WCCC aims to become a community leader using agriculture as a means of rehabilitation and professional development in an institutional setting in Hawaiʻi. Examples of successful programs like this are throughout the United States and internationally, though no "blueprint" exists for developing a place-based, culturally relevant agribusiness project within a state institution. Successful program design and implementation account for a holistic range of objectives to be sustainable and scalable while also being economically feasible.

## Background

*Correctional Institution Project Initiatives*

High rates of incarceration in correctional institutions and the subsequent rates of recidivism result in ever-increasing state and federal costs and personal trauma for those experiencing incarceration. Recidivism rates in the United States are as high as 83% within nine years of release and cost state and federal institutions billions of dollars per year (Alper et al 2018). In recent years, correctional institutions have implemented a variety of successful strategies to reduce crime and recidivism rates; the most effective being rehabilitative, educational programs, instead of traditional punitive measures (Mackenzie 2007).

A more nature-based and rehabilitation focused approach has shown great promise in improving social, economic, and environmental conditions associated with correctional institutions. Participation in "green prison programs" that incorporate ecological stewardship, environmental education, and occupational therapy have been shown to reduce recidivism rates to as low as 10-24% (Van Der Liden 2015). These programs are founded on the premise that the political, cultural, and natural worlds are inherently connected, and acknowledge that environmental education and stewardship must take politics, and society into account (Hall & Clover 1997). This inclusivity and interdisciplinarity is essential to program success, and the inter-relatedness of ecological systems with community values can lead to positive social action and more sustainable communities (Jansen 1995). Combining social, economic, and ecological factors is crucial to the implementation and long-term success of these systems. Agricultural training and involvement in local economic markets and communities combines social and environmental concerns to create innovative and sustainable solutions (Power 2010).

One of the most successful national projects is the Sustainability in Prisons Project (SPP) pioneered by the Washington State Department of Corrections and Evergreen State College (Sustainable Prisons Project 2011). The partnership began in response to increases in environmental degradation and mass incarceration rates. It focuses on shifting the traditional punitive paradigm to one that incorporates ecological stewardship, environmental education, and occupational therapy. The SPP approach includes programs like horticulture training, animal husbantry, composting, recycling and native habitat restoration (Ulrich & Nadakarni 2008, LeRoy et al 2012). Over 20 states have implemented SPP programs in prisons across the nation (Leroy et al 2012, Aos et al 2006).

Other correctional institution programs, such as the Insight Gardening Program and Planting Justice also promote agricultural development and environmental education as a tool for human and environmental rehabilitation (Van Der Liden 2015). Multiple case studies and meta-analyses of correctional programs which include skill-oriented training and use behavioral or cognitive behavioral elements exist, and have been shown to be more effective than other types of programming (Andrews et al 1990, MacKenzie 2006). Hydroponic and traditional gardening programs have been successfully implemented globally and are particularly successful in sustainability based institutional programs (HCR  85 Task Force 2017). Horticultural programs act as "a treatment modality that uses plants and plant products to improve the social, cognitive, physical, psychological, and general health and well-being of its participants" (Simson & Straus 2003).

Over 6,000 incarcerated adults are housed in state institutions throughout Hawai'i (Hawai'i Department of Public Safety 2015). Recidivism rates within the state exceed 50%, with more than 60% reoffending within 12 months, and more than 85% offending within 24 months (Wong, 2018). Hawai'i currently spends $211 million annually on corrections, though is not adequately supporting the current or post-release well-being of persons experiencing incarceration according to a 2017 HCR Task Force Report (HCR Task Force Report 2017). In 2018, Hawai'i State Legislature passed House Bill (HB) 1552 with support from the Hawai'i Department of Public Safety. This bill prioritizes "additional Native Hawai'ian culture-based programs, with an emphasis on healing and reducing recidivism for the inmate population. (Hawai'i State Department (HB) 1552 2019). Place based programs like this offer an opportunity to reduce state funding pressure while also supporting inmate well-being and community benefits (Van Der Linden 2015, Ziller & Phibbs 2003).

Agricultural production and habitat restoration volunteer programs are in place in some Hawai'i correctional institutions, however, they generally exclude educational and professional development components, and occur off-site. Bringing the projects "on-site" and creating opportunities for professional development have been shown to increase inmate participation and post-release benefits such as employment, sense of belonging and social responsibility (Clarke 2011). An opportunity exists to create more complex and culturally significant systems within these institutions to support local food production and ecological stewardship (Langston & Lincoln 2018, Elevich 2015).

*Pacific Island Agroforestry*

Agroforestry generally refers to dynamic, ecologically based farming systems that use synergistic principles in productive natural ecosystems. These systems integrate a variety of trees, woody perennials and crops occupying distinct layers of the ecological system that mimic natural ecosystems (Elevich & Rangone 2018). These systems work efficiently across 3-dimensional space and successional timeframes (Damour et al 2017). Historically, agroforestry acreage in Hawai'i was comparable to wetland taro and other food production methods (Kurashima et al 2017). Hawai'ian agroforestry landscapes are productive, low input systems that sustained the Hawai'ian people for centuries (Elevich 2015, Ticktin et al 2017). Agroforestry system design is a complex process and research into both traditional and novel systems has increased in the past two decades (Lincoln & Vitousek 2017). The productivity of today's agroforestry systems can exceed that of monocultures by 10–60% and they are more adaptable to changing markets because their marketable product production is diverse. (Elevitch & Ragone 2018, USDA 2019).

Traditional Hawai'ian agroforestry systems like Kaluʻulu for example, are open canopy systems dominated by Breadfruit, kukui and ʻōhiʻa ʻai co-planted with an understory of ʻolena, pia, kalo and ʻawa among others (Lincoln & Vitousek 2017). Novel modern  systems include highly marketable crops such as ti (*Cordyline fruticosa*), cacao (*Theobroma cacao*) and coffee (*coffea spp.*) and are gaining popularity with local large and small scale farmers (Somarriba et al 2001). In addition to their productivity and cultural significance, agroforestry systems have been shown to support a variety of ecosystem services including erosion control, water retention, soil health, disease resistance, and drought tolerance (Wood 2015, Steppler & Nair 1987). These systems may also incorporate marketable specialty crops or culturally significant endemics into novel systems. Many potential combinations of canopy and understory trees and crops are not well researched due to system complexity, long successional timeframes, and lack of test sites (Ulrich 2015).

Hawai'i currently imports 80-90% of its food supply and is ranked as the 48th worst state in terms of farming outlook (Loke 2013, UCS 2018 Report). Government legislation such as the farm to school bill and USDA specialty crops bill show state and federal support of utilizing public land for food production and environmental stewardship (USDA Sustainability Report 2015). After a 2015 agriculture land use baseline study, the Hawaiʻi Department of Agriculture set forth an initiative to double local food production by 2020. Various incentive programs within this initiative support diversified agriculture in the private and public sector (Melrose et al 2015). Significant potential exists for marketable crops, internal food production for inmates, community outreach, and environmental stewardship of significant amounts of underutilized lands in correctional institutions in Hawai'i.

*Women' Community Correctional Center*

The Women's Community Correctional Center (WCCC) in Kailua, Oahu has embraced institutional change to incorporate professional development, agricultural production, and rehabilitation to change incarceration experiences for the better. This agroforestry program will utilize overgrown and unused acreage on the grounds of WCCC in Windward Oahu to increase the supply and consumption of the specialty crops breadfruit (‘'ulu, *Artocarpus altilis)*, māmaki (*Pipturus albidus*), ti (*Cordyline fruticosa*), turmeric (‘olena, *Curcuma longa*) and butterfly pea (C*litoria ternatea),* with a wider selection of edible understory crops as the program progresses.

The program intends to train women in agroforestry principles and related skills and certifications to support post-release employment and community involvement while increasing overall wellbeing within the facility. Participants will primarily be women approaching release, who can utilize these skills in their own communities through a variety of employment pathways post release. Beyond industry specific training, the program will empower women to connect with the land and build a wide range of life skills. Alongside the commercial supply chain agreements, a percentage of every harvest will be supplied to the kitchen and culinary programs at WCCC, allowing the entire population (including staff) to benefit through both exposure to and consumption of locally produced food and products. Areas of impact include improved physical and emotional health, an improved sense of self and sense of place, and professional development.

**Goals & Objectives**

The Agroforestry program proposed for WCCC aims to combine professional development, agricultural education and place based rehabilitation. It builds on the small scale agricultural initiatives already in operation, and provides mechanisms to expand sustainable local food production and provide educational opportunities to the inmate community. Achievement of the following objectives will result in directly applicable outputs for the WCCC. These outputs will guide project development and assist the WCCC in securing further support and funding for program implementation and expansion. Objectives are as follows:

- Design a planting plan for the site based on program director objectives, environmental constraints, and local economic markets.
- Create a flexible budgeting tool to explore critical assumptions and allocate resources efficiently over time.

- Perform a Cost-Benefit Analysis to determine the economic feasibility of implementation and continuation of the proposed program.

**Approach**

Project development requires a framework to aid in decision making. This framework was developed through interviews with managers, various stakeholders, and agricultural professionals in accordance with similar program development procedures. It can be used by other state, non-profit, and public organizations that wish to implement an integrated agroforestry program. The following sections of this report discuss the theory and practical application of this decision-making framework.


*Figure 1. Decision-making Framework Outline.*

## Agroecological Plan

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**Site Description**

The WCCC property encompasses 122-acres located approximately 1.5 miles inland from Kailua Bay on windward Oahu. The site is located in the Ka'elepulu watershed in the Ko'olaupoko region (*moku*) and is situated north of Kalanianaole Highway and south of Kailua High School

(Figure 2 & 3). Elevations range between 98 and 360 feet and rainfall ranges from 30-120 inches annually (Juvik and Juvik 1998, USDA-NRCS 2017). Downslope from the property to the north is Hamakua Marsh, which connects Kawainui Stream to Kaelepulu Stream and to Kailua Bay. To the east is Kaelepulu Pond, commonly referred to as Enchanted Lake; a man-made lake that discharges into Kailua Bay via the perennial Kaelepulu Stream, which is considered by the Department of Health to be an impaired stream and a high priority for TMDL development (WCCC EIS 2019). The small unnamed waterway mapped within the WCCC site and an adjacent fringe wetland are also located within the greater WCCC property. This perennial stream originates at a culvert north of the highway and runs north to the WCCC property boundary and incorporates stormwater drainage from the road and WCCC facilities. It is recommended that this waterway be managed to decrease streambank erosion to minimize sediment impacts to vulnerable downstream ecosystems like Kawainui Marsh or Kailua Bay reef ecosystems.

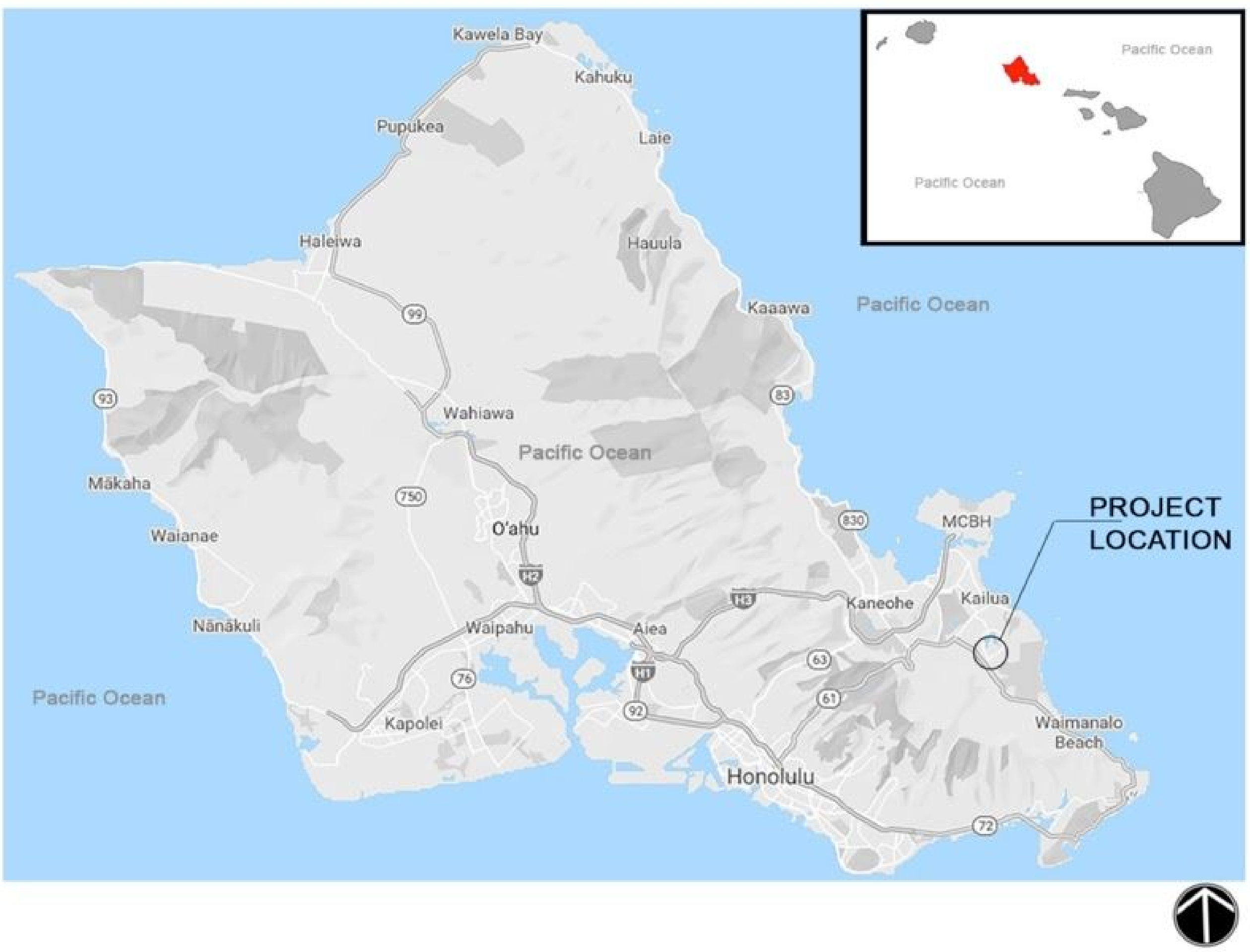


*Figure 2. Project location delineation on the island of Oahu, Hawai'i.*

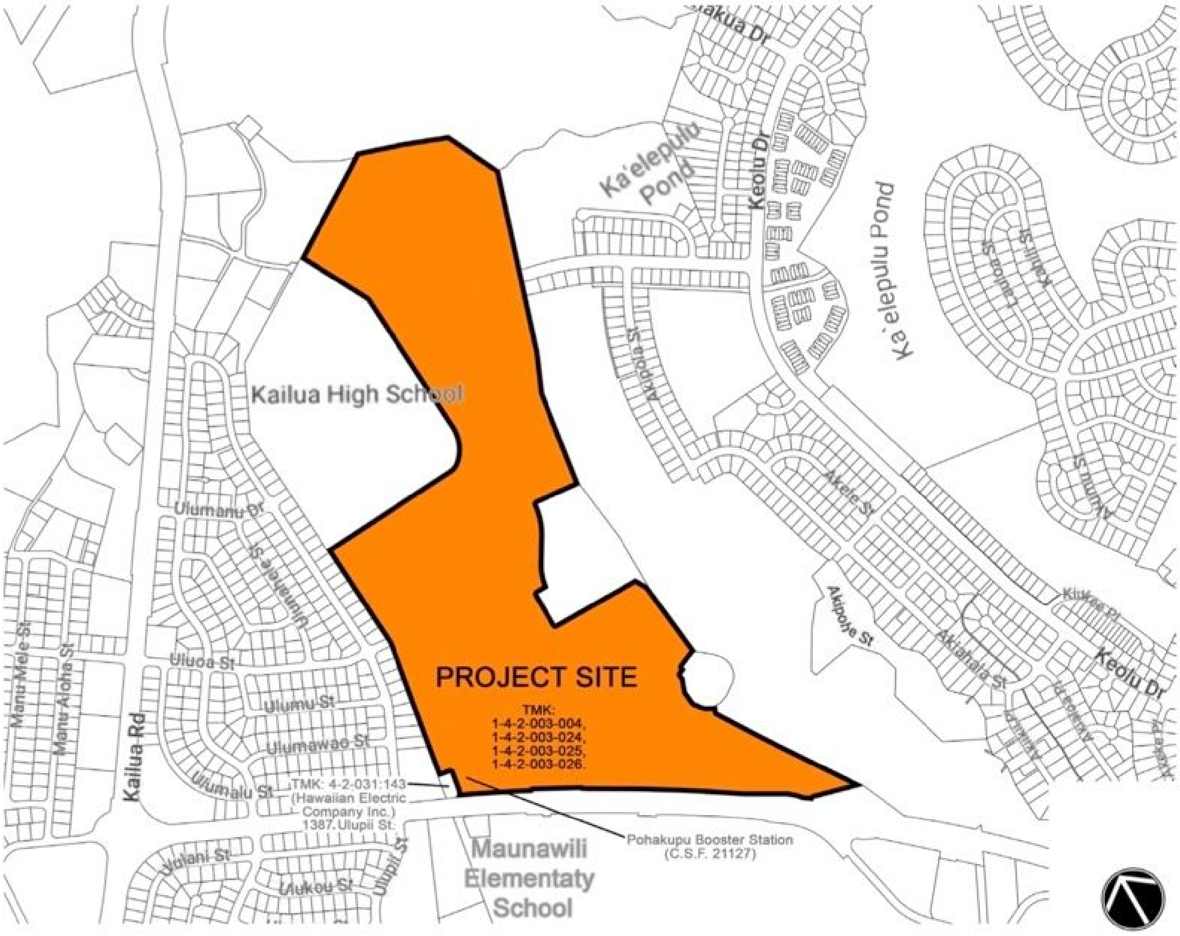


*Figure 3. WCCC property line delineation and surrounding landmarks.*

Prior land use at the WCCC site includes cattle ranching and plantation agriculture of pineapple, sugar cane, and other export crops throughout the mid-twentieth century (WCCC EIS 2019). The property was acquired by the State of Hawai'i in the 1950's and developed into the Hawai'i Youth Correctional Facility. Current WCCC facilities were built between 1952 and 1999, and expansion of those facilities may commence in 2020 as part of a statewide prison renovation project. The sites of interest for the agroforestry program and the existing agriculture program infrastructure will not be modified or disrupted based on preliminary expansion plans.

The location of the program site is based on existing infrastructure and ecological factors. The surrounding area includes a lei and market garden, goat enclosure, tree nursery, toolshed and classroom. Existing programs include a goat husbandry program, a hydroponic produce program that supplies local grocers, and a nursery program that supports Hawai'i's annual Arbor Day plant giveaway. An existing road splits the project sites into two adjacent areas across an existing mango grove and maintenance road.

Site A is an existing bench terraced hill that was installed over 30 years ago and includes an existing breadfruit orchard on the lower two terraces. The area includes 15% slopes, but the existing terraces increase plantable area and minimizes erosion concerns. The site covers an approximate area of 22,553 square feet (Figure 4).

Site B is located on a 0-3% slope field adjacent to the existing lei garden, and covers approximately 4,800 square feet (Figure 5). This site was chosen based on its soil suitability and proximity to existing maintenance and irrigation infrastructure associated with the existing horticultural programs. The total acreage included in the proposed plan is 2.9 acres.


*Figure 4. Map of proposed project areas, Site A and B.*

A Natural Resource Conservation Service (NRCS) web soil survey shows the soil types and suitabilities for agriculture (Figure 5). Hanalei silty clay (HnA) soils that encompass a peripheral portion of Site B are not considered prime farmland and are considered to have poor drainage associated with flood plains and traditional Lo’i cultivation, resulting in a slight risk of flood damage to crops. Pohakupu silty clay loam (PkB and PkC ) soils are considered well drained, prime farmland if irrigated. Steep slopes on the existing orchard on Site A are mitigated with existing bench terracing.


*Figure 5. Web Soil Survey map representing the soil orders on the proposed site.*

| Map Unit Symbol | Map Unit Name | Acres |
|---|---|---|
| HnA | Hanalei silty clay, 0-2% slopes | 0.4 |
| PkB | Pohakupu silty clay loam, 0-3% slopes, | 1.5 |
| PkC | Pohakupu silty clay loam, 8-15% slopes | 1.0 |
| **Total Areas of Interest** | | **2.9** |

*Figure 6. Categorization table of soil orders, their designation, and the percent area covered.*

**Soil Analysis**

Site specific soil samples were taken at each finalized site to gain further information about the fertility and crop suitability for each site. Specific soil analyses are important for understanding nutrient and pesticide management regimes associated with crop production. Site specific soil analyses are performed on all potential sites to better understand nutrient requirements and manage soil amendments appropriately.

Soil samples were collected according to Natural Resource Conservation Service (NRCS) protocols for the two selected sites (NRCS 2009). Analyses included pH, total Nitrogen to Carbon ratio, and macro-nutrient concentration (ppm, ug/g) of Phosphorous, Potassium, Calcium, and Magnesium, which are some of the most critical environmental factors and macronutrients for crop production. Analyses were chosen based on nutrient contribution to growth factors and testing availability through the CTAHR Agricultural Diagnostics Lab.

Analyses show that both Site A and B have high nutrient concentration and availability within the constraints of the tests performed. Both sites have a relatively high pH of approximately 6.5 which negates the need of lime application before planting. Carbon to Nitrogen ratios were measured well below 20 in both sites, which suggest that nitrogen availability to crops is high. Phosphorous, Potassium, Calcium and Magnesium concentrations are high in both sites. With these nutrient levels, compost additions are advisable in lieu of inorganic additions. Since this is an agroforestry design, heavy green mulching, compost, and brown mulch additions are considered suitable for crop production. Amendments with compost or inorganic fertilizers such as Sulfate of Ammonia can be incorporated with crop production areas during site preparation prior to planting.

Long exposure to agriculture and ranching on the sites has impacted the overall nutrient levels in the soil. The sites show relatively high concentrations of key nutrients critical to plant growth including Phosphorus and Magnesium. This reflects a long history of agriculture on this site; including traditional lo'i flood land agriculture and 20th century ranching operations. High soil fertility lends itself to agricultural program development, though testing for heavy metal or pesticide contamination may be considered as program development continues.

**Crop Selection & Planting Plan**

The goal of this plan is to encourage production by maximizing facilitation of positive ecological interactions, while managing competition to develop a sustainable production system. Trees and crops were chosen based on program manager objectives and agroforestry methodology. We worked with local businesses and producers to identify potential markets for locally produced tea products that suggest high demand and potential for growth. These selected crops are appropriate for site conditions and program objectives, and have high marketability in local tea and spice markets. This is a gridded agroforestry design, instead of the more traditional "food forest" design that is characteristic of Pacific Island agroforestry.

This design reduces maintenance and harvesting labor while still encouraging an agroecological system that supports facilitation of ecosystem services and community abundance. The plan includes the specialty crops breadfruit (''ulu, *Artocarpus altilis)*, māmaki (*Pipturus albidus*), ti (*Cordyline fruticosa*), turmeric ('olena, *Curcuma longa*), lemongrass (*Cymbopogon citratus*) and butterfly pea (C*litoria ternatea).* Details of the main marketable crops are as follows:

**Breadfruit (*Artocarpus altilis)***

Breadfruit has been a remarkably productive staple food crop in Pacific Island societies for over 3000 years and has a remarkable variety of cultivars across the region (Rangone 2018). The tree crop has high economic yields, and the cultural and ecological benefits associated with its cultivation are also significant (Lincoln & Vitousek 2017). Breadfruit trees produce an abundance of energy rich and nutritious fruit, require little maintenance, and thrive under a wide range of ecological conditions throughout the tropics (Rangone 2018). After decades of decline in many regions, community interest in breadfruit has increased, in part to its high nutritional content, importance in agroforestry, and potential as an income generating crop (Lincoln et al 2018).

Increasing breadfruit cultivation, especially in an agroforestry context, plays a key role in encouraging place-based development and community involvement. The tree itself requires relatively low maintenance and after initially bearing fruit in the first three to five years, may bear for over 100 years and can thrive in a range of tropical environments and soil orders (Elevitch & Rangone 2018). This tree represents a “tall” tree crop in the system. Each may reach a height of 40-50 ft (12-15 m) with an intensive canopy if managed inadequately. Agroforestry guidelines suggest the canopy height and diameter should be kept to a maximum of 16-23 feet (5-8 m) to avoid risks from limb breakage and adhere to harvesting safety protocols. Annual, or biannual pruning beginning within the first 3-5 years is imperative to mitigate costs and harvesting safety risks (Elevitch & Rangone 2018).

*Figure 7. Existing WCCC Ma’afala breadfruit orchard after an air-layering workshop with Hawai'i Trees Pacific and program participants and a fruit example (Elevitch & Rangone 2018).*

The planting plan reflects these recommendations, and accounts for light infiltration and spacing associated with selected understory crops. The ten existing trees within site A are Ma'afala variety, which are characteristically smaller trees (<10 m height), with an average fruit weight of 1.8 lbs (Elevich et al 2018). Harvests begin in three to five years and, though research is limited on large scale cultivation, yields have been shown to increase in a linear pattern after at least seven years of cultivation before peaking at 20-50 years (Lincoln et al 2018).

**Māmaki (*Pipturus albidus*)**

Mamaki is an endemic Hawai'ian woody shrub in the nettle family Urticaceae which is found nowhere else on the planet. It typically grows wild as an understory shrub in the wet forests of the Hawai'ian Islands (Sugano et al 2018). Commercial production is scarce and efforts are ongoing to identify wild varieties and develop cultivation methods for this Hawai'ian medicinal plant. The leaves are used in traditional practices to ease childbirth, lower stress, and combat general listlessness and its high concentration of phenolic acids and antioxidants correlate with potent anti-microbial activities (Kartika et al. 2007, Locker 1995).  Mamaki also acts  as a host plant to the endemic and endangered Kamehameha butterfly *(Vanessa tameamea)* and well managed, organic cultivation may support this native insect (Kartika et al 2007).

*Figure 8. Existing mamaki seedlings in the WCCC market garden.*

It thrives in well drained, nitrogen rich soils which encourage leaf flush and high leaf yields. A level of 40-60% shade is optimal for co-planting as an understory crop, but full sun and full shade environments have led to high yields in various outplantings (Sugano et al 2018). Little published research into commercial mamaki cultivation exists. Literature review and farmer elicitation indicate that initial harvest begins after approximately 12-16 months and each plant yields up to four pounds of leaves per month. Mamaki has potential as a “medium” (2-5 m) crop and four square feet is required per plant with proper pruning and harvesting management regimes. Each plant has approximately fivr productive years and has the potential for both vegetative and sexual propagation for future cycles.

A growing market exists locally and internationally in tea markets. Managers of the program identified the high marketability of this tea crop to local businesses. Local collaborator, Shaka Tea, has expressed a need for mamaki leaf production and can provide reliable processing and marketing opportunities for initial program development. Based on farmer input and expert elicitation at a recent mamaki growers conference on the Big Island, mamaki varieties thrive in a variety of environments throughout the Hawai'ian Islands. It also has significant cultural significance and potential ecological benefits, making it an attractive cornerstone crop for this program. Encouraging the cultivation of endemic, woody perennial crops with ecological and cultural significance is a fundamental component of agroforestry systems.

**Turmeric (*Curcuma longa*)**

Turmeric (‘Olena) has significant traditional importance in Hawai'i, and production has expanded steadily in the specialty crop market both locally and nationally (USDA 2020). Domestic consumption and international export in its fresh rhizome form, and in value added products including teas, dried spices and oil are on the rise (Radovich et al 2020). The “Hawai'ian Red” variety was chosen for this project based on its local popularity, large size and high curcuminoid concentration of 5-6% (Radovich et al 2020). International prices for dried products are included in the partial budget, but excluded from the final cash flow to allow ease of calculation if added value production methods are adopted during program development.

*Figure 9. Turmeric experimental plot at the Waimanalo Research Station, Oahu.*

Turmeric occupies the low layer of this agroforestry system, and is a common agroforestry crop based on its tolerance to a wide range of light levels (Prasath et al 2018). Turmeric is propagated from the mother corms and/or finger pieces of previous harvests or purchased rhizomal material. The planting plan assumes that two square feet are needed per planted rhizome (Radovich et al., 2020). Harvest occurs nine to ten months after planting under proper conditions, which provides short term economic returns to the program. Cover cropping and heavy mulch and/or nutrient addition is recommended for commercial production (Prasath et al 2018). Fallow years and cover cropping are incorporated within the final planting schedule and rotation regimes are available at farm manager discretion.

**Lemongrass (*Cymbopogon citratus*)**

Lemongrass is a tropical perennial grass that yields an aromatic oil and is used dried in herbal teas and fresh in local markets for Southeast Asian cooking. Being a grass, this crop tolerates full sun and a wide range of soil conditions and is generally fast growing, requiring minimal nutrient inputs and overall maintenance. A planting area of three square feet is generally recommended per plant (Skaria et al 2006). Fresh, local lemongrass is in high demand by restaurants and farmers markets throughout Oahu, as the majority of fresh crop is imported from Asia or Central America (USDA 2020).

*Figure 10. Young lemongrass alley cropping.*

The fast growth and oil content of this grass minimizes the need for herbicides and pesticides and the productive cycle per plant lasts approximately three to four years. First harvests occur six to nine months after planting of “slips” and harvesting frequency starts at three harvests per year and increases to six to nine during years three to four. This production plan takes harvesting frequency into account, and assumes each plant will be in full production three years, then produce propagation material in addition to marketable products during the final year. Slips will be used to re-seed the planting area to cut costs and increase on-site cycling of resources.

**Butterfly pea (C*litoria ternatea)***

Butterfly pea is a perennial herbaceous nitrogen fixing legume (Family *Fabaceae*). It has been used historically as a forage crop for livestock, though it has gained considerable interest for medicinal applications, regenerative agriculture, and as a source of natural food colorants and antioxidants (Oguis et al 2019).

*Figure 11. Butterfly pea flowers and seed pods as a cover crop.*

It is used as a nitrogen fixing cover crop to increase nitrogen availability in soils and provide nutrient rich forage for livestock (Collins & Grundy 2005). It performs well in Hawai'i and other tropical climates and is noted as a relatively cost effective and low maintenance companion crop for relatively fertile tropical soils. It is tolerant of livestock grazing and green manure utilization in agricultural systems and is tolerant of most pests and diseases (Oram 1992). The flowers can be sold fresh to local restaurants as a garnish, and dried flowers command a high price in spirits and tea markets for their high antioxidant content and dyeing effects (Oguis et al 2019).

Use in this planting plan is based on slightly modified cover crop planting density of four kg per hectare (Collins & Grundy 2005). Density was decreased based on other tree and crop densities and regular “chop and drop” green manure maintenance is factored into the final cash flow. This crop is intended to provide weed competition while fixing nitrogen to provide onsite nitrogen contributions to all production crops.

**Planting Plan Methodology**

The existing breadfruit orchard in Site A includes ten Maʻafala variety trees that are approximately 11 years old. They are planted 25-30 feet apart within the lower two terraces. Though Maʻafala is a relatively small variety of breadfruit, this spacing is generally considered too close for agroforestry systems based on canopy diameter and limited light infiltration for understory crops (Elevitch et al 2014). This planting plan incorporates understory planting areas within these terraces, but decreases that planting density in the upper terrace of Site A and and all of Site B to reflect the recommended 40 foot spacing for agroforestry application (Elevitch & Rangone 2018).

The “area of cultivation” within each site is based on rectangular areas along each terrace or arable land grid between existing or planned breadfruit trees. Lengths vary between 12-20 feet long based on tree spacing, though each area is eight feet wide to allow maintenance between rows and along the terraced sections and to decrease risk of erosion. The square footage that each crop requires  is based on literature review into each crop and expert elicitation as mentioned above. The planting plans below are to scale, taking into account the expected square footage each individual tree and crop will take up within the cultivation area throughout their production cycle.

**Breadfruit Orchard Planting Plan**

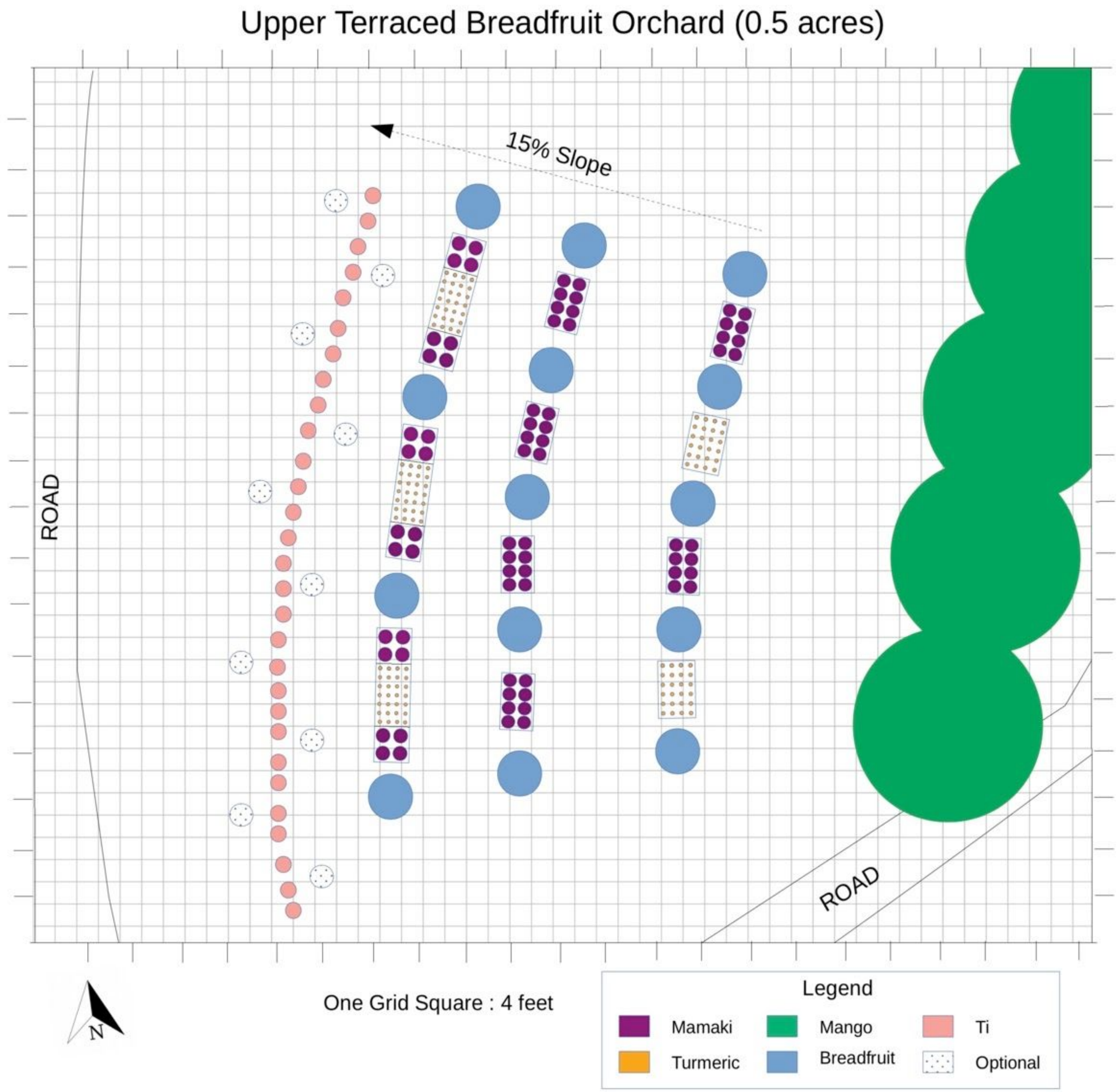


*Figure 12. Site A Planting Plan as decided by manager objectives & agroecological design principles*

**Lower Field Planting Plan**

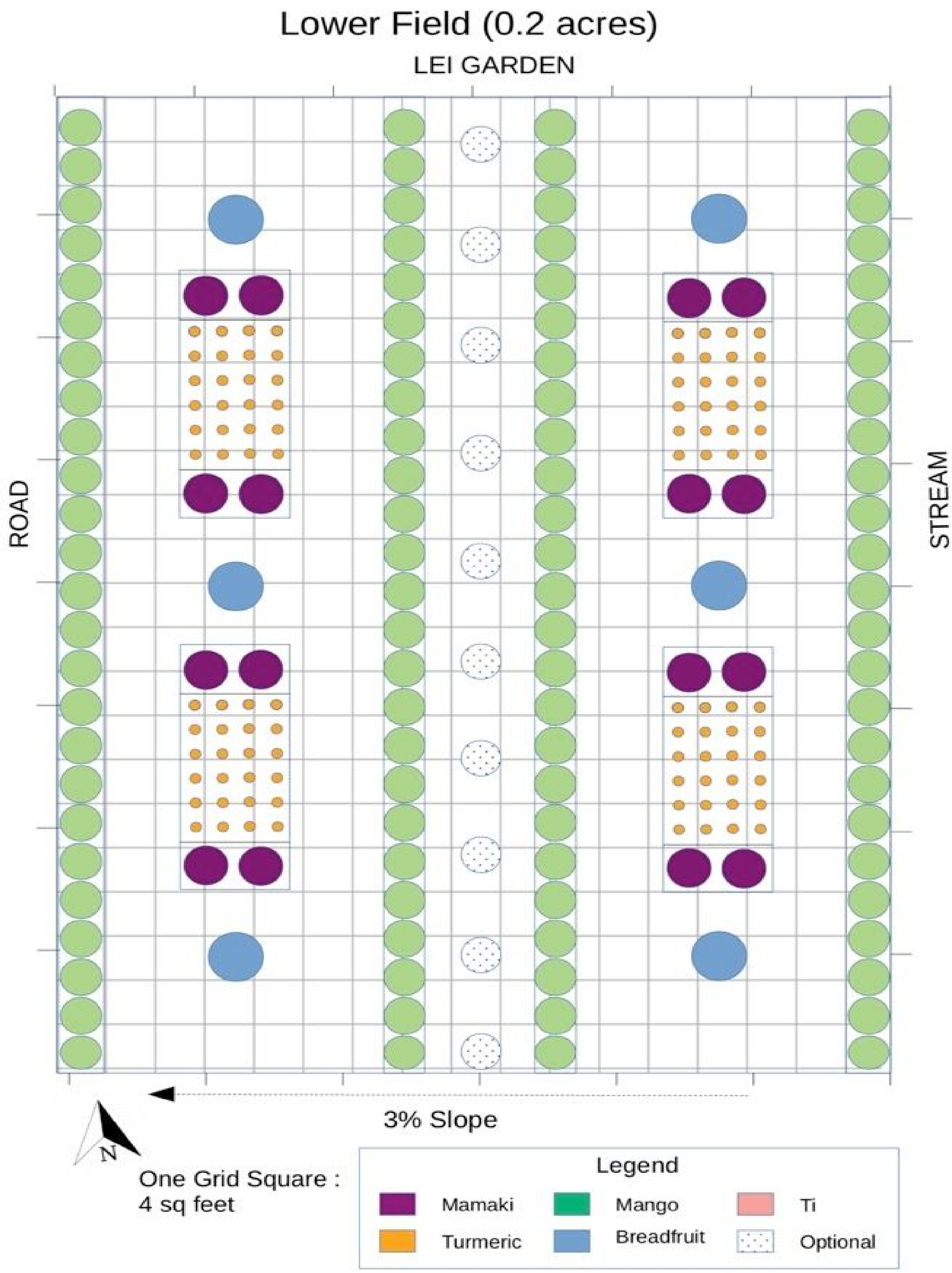


*Figure 13. Site B Planting Plan as decided by manager objectives & agroecological design principles*

## Planting Schedule

The planting schedule includes production cycles for each tree and crop, and appropriate fallow years and rotations. Agroforestry systems tend to require less rotation or fallow periods relative to conventional monocropping systems (Mercer 2004). Spaces within the planting schedule for crops such as turmeric can be filled with other crops such as green onion or other annual vegetables as needed. If certain crops do not meet production goals or experience conditional failure, other crops and trees may be substituted. The following substitution chart serves as a reference for suitable replacements and defer to farm manager discretion on modification and expansion of the current suggestions (Figure 14).

## Iteration & Expansion

This plan facilitates planning and budgeting of the initial program, though it is intentionally simple. Program & farm managers, collaborators and program participants are encouraged to modify and expand this initial plan to fit their needs as the program evolves. Additional crops and trees may be added over time as resources and information become available. This is an iterative system to ensure that options can be included to incorporate the same agroforestry layers with the ability to change their constituents based on objectives, ecological conditions and shifting markets.

Many potential combinations of canopy and understory trees and crops are not well researched due to system complexity, long successional timeframes, and lack of test sites (Budowski 1993, Montagnini 2017). Collaboration with private community partners and university researchers provides an opportunity to increase professional development for inmates while increasing the common body of knowledge of agroforestry systems. Some options for crop selection diversification and substitution are shown below in Figure 14.

| Ground (0-1 m) | Low (Up to 2 m) | Medium (2-5 m) | Tall (5-8 m) | Overstory (8+ m) |
|---|---|---|---|---|
| Ginger *(Zingiber officinale)*<br>Taro (*Colocasia esculenta)*<br>Vegetables<br>Perennial Peanut (Arachis glabrata)<br>Clover (Trifolium repens) | Kava *(Piper methysticum)*<br>Cardamom *(Elettaria & Amomum sp.)*<br>Ti *(Cordyline fruticosa)*<br>Hibiscus *(Hibiscus spp.)*<br>Ko'oko'olau (*Bidens spp.)*<br>Pigeon pea *(Cajanus cajan*) | Cassava *(Manihot esculenta)*<br>Papaya *(Carica papaya)*<br>Banana *(Musa spp.)*<br>Cacao *(Theobroma cacao)*<br>Citrus *(Citrus spp.)*<br>Noni *(Morinda citrifolia)*<br>Starfruit *(Averrhoa carambola)*<br>Surinam Cherry (*Eugenia uniflora)* | Moringa *(Moringa oleifera)*<br>Ice cream Bean *(Inga edulis )*<br>Kukui *(Aleurites moluccana)*<br>Macadamia Nut *(Macadamia integrifolia)*<br>Sandalwood *(Santalum spp.)*<br>Tamarind *(Tamarindus indicus)*<br>Ylang ylang *(Cananga odorata)* | Coconut *(Cocos nucifera)*<br>Durian *(Durio zibethinus)*<br>Kamani *(Calophyllum inophyllum)* |

*Figure 14. A list of substitution options based on agroecological suitability and the role each plays within the agroforestry system.*

## Economic Considerations and Analysis

The planting plan and goals of the program managers were considered within an economic analysis. Cost of production and appropriate time frames are crucial to the longevity and viability of any agricultural or social program. First, the site survey provided the productive area and user objectives to develop an appropriate planting plan including scheduled production cycles and crop suitability. According to this plan, technical production guides were used to create partial budgets for each selected crop according to their estimated management and respective planting densities.

Partial budgets value the expenses and incomes associated with inputs and outputs for each step of crop specific production based on present market values, literature review, and expert elicitation. These partial budgets assist managers in evaluating the financial effect of incremental changes to specific crops within the planting plan. Partial budget variables include soil amendments, planting material costs, harvesting & maintenance labor, as well as market prices for the sale of each product based on projected yield per unit area. These values change throughout the life cycle of each crop, especially trees and woody perennials that may have no yields initially, or require different levels of maintenance throughout their life cycle. Each crop's partial budgets contain sections for separate establishment and management regimes and vary depending on the crop's production cycle.

Next, overhead costs, those costs associated with overall program operation, such as farm manager salaries, fencing, and irrigation infrastructure were configured. Partial budgets and overhead costs were compiled into a final cashflow over 20 years. This time frame was selected based on crop production projections and research constraints. Economic analyses of Net Present Value (NPV) and Internal Rate of Return (IRR) were performed on the final cash flow. These analyses are useful tools in comparing program alternatives over time. Finally, a Cost-Benefit Analysis (CBA) was performed to integrate non-market costs and benefits associated with the project with the net monetary profits determined in the financial analysis.


*Figure 15. Project methods within the developed decision-making framework.*

**Assumptions**

The cultural and agricultural practices described, and materials used were estimated based on present market values, site specific considerations, and expert elicitation. They are considered typical for a small scale farming operation in the region.  The costs, materials, and practices will not apply to all situations every production year. Practices and start up costs vary, and this analysis is meant only as a case study of implementation for a small scale agricultural project. Relevant assumptions made in the economic analysis are included in the final spreadsheets and calculations and are as follows.

**Labor.** Inmates within the program are compensated a wage determined by the state, approximately $1 per hour at the time of this report. Professional development or educational programs completed by inmates will be compensated fully as "on the job training" hours. The goal of this program is to provide compensated, professional development opportunities to participants.

This pay wage can be manipulated in the partial budget and overhead cost variable tables. Skilled labor costs are included for site preparation and managerial staffing. If assumptions change as the program progresses, or if external groups make use of the budgeting tool, labor costs can be modified accordingly and reflected in the decision making process.

**Site Preparation.** Approximately 0.5 acres were cleared and bench terraced 30 years ago. The lower field has been maintained as short grassland by existing maintenance staff. These sites were chosen based on proximity to existing infrastructure and the lack of need for contracted land clearing to minimize start-up costs. Planting preparation will be done with existing motorized tillers and facility tools including industrial mulchers, trucks and miscellaneous related equipment.

**Fertilizer.** Costs are based upon estimates from local compost suppliers in Oahu. Typical units of compost “yards" were converted into square footage for use in the partial budgets for each crop. These can be altered throughout the production cycle or as market prices shift. Each partial budget has space for costs of inorganic fertilizers, soil amendments, herbicides and pesticides to be easily added at the farm and project managers’ discretion. Since the program’s initial goal is to produce organic products, these costs were counted as 0 or “NA”. Compost was used in this case, and was considered an appropriate alternative based on the soil tests from each site as noted in the initial site survey and planting plan.

**Seedlings.** Seedling or propagation material prices were estimates based on present market values and quotes from local suppliers and market values. Planting densities were estimated based on literature review and production guidelines from local professionals and industry standards.

**Irrigation.** The breadfruit orchard and lei garden are irrigated by existing drip line irrigation fed by city water supply. Since the site relies on city water and this is a small scale project, there are no pressurization issues with expansion of the existing irrigation system. The WCCC programs already have at least 400 feet of polyline irrigation tubing and hookups to expand and maintain the system, but the irrigation costs for each partial budget include an annual estimate of $400 to cover maintenance costs since polyline drip irrigation is notorious for needing regular maintenance, especially in the tropics. Most trees and crops, as noted above, will need little irrigation due to the rainfall conditions of the site. Periodic watering after initial planting and dry summer periods will be necessary for overall system productivity.

**Yield -** Yields are crop specific and based on literature review, market estimations and expert elicitation. Market prices were estimated at current values and mean values were used in the final calculations. Yields are likely to fluctuate, though these numbers are reflective of local conditions and similar management scenarios. Estimated income and yields per unit area were based on planting density and market value within the plan. The harvesting frequency, yield, area and market price can be modified within each partial budget to accurately reflect profits per crop throughout its lifecycle.

**Skilled Labor.** Existing horticultural programs are managed by a diverse range of experts, volunteers and state employees. The lei garden, goat program, and hydroponic production are a collaboration between WCCC and Lani-Kailua Outdoor Circle Volunteers, and Hawai'i Trees Pacific oversees the arbor day tree nursery operations. Collaboration and volunteer opportunities increase program diversity and breadth, but employment of program staff is critical for program implementation and maintenance.

The Farm Director and Program Director position salaries are part-time and estimated based on comparable positions at other state facilities. The program director position is included for the first five years of the program to assist with curriculum development, marketing and expansion opportunities, and community outreach. This position was considered on a temporary basis as the farm director can continue the maintenance and expansion of the program after this time period. Extension of the program director position will rely on additional funding. Guard salaries were considered a sunk cost in this analysis. The program will not require the facility to hire any more guards, therefore, time spent regarding the program should be considered the same as the alternative.

**Farm Equipment & Machinery.** A considerable amount of equipment associated with existing agricultural programs and general facility maintenance activities is available on site. This includes vehicles, tractors, motorized tillers, industrial mulchers and miscellaneous related equipment. Costs for miscellaneous equipment purchases, maintenance and repair are included as overhead costs in the final cash flow.

**Land Cost.** Since this program is to take place on existing WCCC property, no costs associated with buying property are included. The entire property has been under State of Hawai'i ownership for many years and, therefore, is exempt from property tax payments.

**Fencing.** Presence of feral pigs and domestic goats on the program site make fencing a critical purchase. The goat husbandry program is supported by the Women's Fund of Hawai'i and they have committed to partially fund goat and feral pig appropriate post & panel fencing. Cost estimates include fencing for the lei garden to integrate existing horticultural & animal husbandry programs with this newly proposed program. Completing installation “in house” will reduce costs and provide additional skill building opportunities for program participants.

**Depreciation.** Government programs are not impacted by depreciation. In adapting these partial and overhead budgets for private use, managers should incorporate depreciation based on government regulations and standard rates.

## Analysis Results

Cost-benefit analysis provides important information for decision-makers in situations where there is a choice of several alternative models of action. The final Net-Present Value (NPV) was -$253,781.00 with an Internal Rate of Return (IRR) of -5%. We considered the initial $400,000 investment as a state investment in the facility, instead of a grant or collaborative in-kind, or matched funding mechanism. In this estimate, the NPV will not become positive within the limited time frame unless substantial indirect, or non-market benefits are estimated and applied to the final analysis. Options exist for placing value on these benefits including carbon tax subsidies to provide tangible financial incentives for landowners to adopt carbon sequestration practices like agroforestry and native tree plantations.

Considering all expenses, revenues and capital costs, the program as described is estimated to be profitable by the end of the 8th year. After that time, the program would be making profit to sustain itself for at least the next 12 years, without the need for additional state funds. This suggests that the program has the potential to be economically sustainable while providing a range of ecological and social services.

These relatively successful results consider the high upstart costs associated with undertaking an agricultural initiative like this one. Managers identified fair compensation and support of employees and program managers as a mechanism to increase community involvement and social justice surrounding this program. The relatively low labor costs of implementing this project in a prison have a significant impact on the economic feasibility and cost structure. Private landowners or program managers can use this same model with higher general labor costs by using a different value in the partial budget and cash flows during analysis.

The focus of this analysis was on market values associated with cost of production, though incorporation of qualitative and indirect benefits and costs is also required for an effective Cost-Benefit Analysis. Determining which alternative is best both financially, and from the perspective of society is important for developing government programs in which non-quantitative variables such as human well being are relatively important (Broadway & Wildasin 1984). Quantification of all social and environmental costs and benefits were beyond the scope of this project, though they still should be considered when evaluating the true benefits and costs of such a program.

| Benefits | Costs |
|---|---|
| Professional Development & Skill Building | Other Community Farm Hiring Opportunities |
| Place-based Cultural Connection | Publicly Subsidized Production into Local Markets |
| Sense-of-place & Personal Agency | |
| Therapeutic Interaction with Nature | |
| Community Support | |
| Ecological Stewardship & Native Plant Cultivation | |

*Figure 16 Qualitative costs and benefits associated with the proposed program.*

Employing a Farm Manager and Program Director is a benefit to the program itself, but removes the chance for private farms in the community to hire those qualified workers. The production of specialty crops in the prison is less expensive, because labor costs are relatively low, so private farmers in the community may see prices fall as supply increases, and not have the excess income to compensate for lower returns (Figure 16).

Altogether financial costs and benefits considered, these qualitative values add to the overall appeal of the Cost-Benefit Analysis and contribute to the sustainability and holistic intentions behind this program. Incorporating any new program in a public institution will require state funds, but this program is intended to become economically self-reliant while acting as a vital resource for women experiencing incarceration. The costs savings from reduced recidivism and increased post-release employment are difficult to quantify, though wholly significant. The best way to maximize these savings is to prioritize funding opportunities for programs like this; those that use proven strategies and place based approaches to develop holistic and responsible practices.

**Scalability & Budgeting tool**

The variables and considerations within these spreadsheets apply specifically to the planting plan, goals and constraints of the proposed agroforestry program. They were developed as an interactive tool for program managers to compare alternatives, and change as constraints and goals shift over time. The tool is linked directly to the decision-making framework described previously so that it can be used to modify and expand this program under a range of program objectives, environmental constraints, and market conditions. It can also be used by a range of managers in other institutions and private small-scale agricultural operations. It uses practical inputs and outputs to facilitate ecologically sustainable processes dictated by plant functional traits, while allowing manipulations to increase productive capacity.

Variables within the spreadsheet are simple to change based on actual results and management decisions. Final numbers are based on the square footage of planting area per crop established in the planting plan. Critical variables fed into each function can be based on either plant number or square footage since we included tied key variable tables with square footage per plant, total area, and plant number based on recommended plant occupancy and spacing. The structure of these tables and budgets will be similar for any crop in any geographic area to increase the capacity for replicability and scalability.

Relying on the number of plants and the square footage, allows the user to assess profitability potential per unit area of the total production area. This allows managers to optimize profitability across crop constituents within the prescribed planting area of the entire project.
Profitability must be considered with agricultural design principles and environmental constraints to develop truly sustainable operations. This is a useful tool for predicting how changes in crop density, diversity, management regimes and farmer goals affect both short and long term profitability and net-benefits over time.

**Future use and expansion**

The crops chosen lend themselves to expansion and iteration of the program to incorporate a wide variety of professional development opportunities. Breadfruit and a variety of tea crops can be used as raw material for a processing & value added program extension. Incorporating processing operations, product marketing and local production opens up professional development pathways for participants. The variety of options for expansion and iteration will come with expert involvement and feedback from inmates within the program. Inmates should be encouraged to embrace their role in the program’s development and use the developmental & critical thinking skills this program provides to seek out diverse revenue streams and incorporate holistic collaborations and community involvement. Training program participants in a range of skills within the local food production market will support a diverse, resilient local workforce for reintegration into their communities.

**Conclusions**

When implemented, this project will be the one of the first of its kind in Hawai‘i. Creating a comprehensive economic and ecologically sound framework for implementation is the first step towards funding and execution for the WCCC and other correctional institutions in Hawaiʻi such as The Oahu Community Correctional Center and the Youth Correctional Institute. This novel approach creates opportunity for research into the planning, implementation and management of sustainable programs within social institutions. The close proximity to the University of Hawaiʻi Waimanalo Research Station increases the potential for collaboration and use of the pilot program as a model system and test site.

Potential exists for expansion of this program to include components such as endemic plant restoration, locally produced food processing facilities, and agricultural education curricula through partnerships with private collaborators and public initiatives. Furthermore, the WCCC program management team has the capacity to pilot specialized educational and professional development programs in agricultural production and entrepreneurship. Incorporating professional development opportunities such as nursery training and arborist certifications increases post-release skill sets and inmate well-being, while reducing maintenance and long term costs to the program.

The concepts and methods developed in this project will be useful tools for planning and execution of these kinds of programs, and will be important for future funding applications. With the trend towards both local food production and incarceration reform in Hawaiʻi State Legislature, this program's success would meet multiple state goals. The potential for rehabilitation, professional development, and environmental restoration support the overarching goal of reduced recidivism and the resulting increase in human well-being and social benefits.

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