A Greener Hawaiʻi: Policy Analysis of Carbon Sequestration Potential for Urban Forests and Green Spaces

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II. EXECUTIVE SUMMARY

In this policy analysis, we generate recommendations for the Greenhouse Gas Sequestration Task Force to advance their goals for the state of Hawaiʻi. This document examines urban forestry as a potential sector for greenhouse gas sequestration and how policy and programs help support increasing canopy cover and benefits received by urban forestry. Currently, there are a number of programs and organizations that are working to improve urban forestry and the benefits that urban forests provide. Assessments and inventories of canopy cover in Honolulu have show that canopy cover is decreasing annually. Our approach is to Following our analysis, our policy recommendation is the expansion and further development of current policies and urban forestry programs. Part of this development is providing further funding for the many organizations that are involved in the urban forestry sector. Creating a type of unified committee to ensure that funding is available and efficiently distributed.

Within our analysis we considered four policy goals: 1) increase carbon sequestration through urban vegetative cover via the use of trees, parks, fields, and gardens, 2) ensuring equity by increasing access and proximity to urban trees and green spaces, benefiting as many residents as possible, 3) political feasibility for the proposed policy alternatives and stakeholder support, and 4) the economic efficiency of these recommendations. We began by identifying impact categories of increased urban canopy cover, increased green space, sociocultural benefits, stakeholder engagement and sequestration potential per unit cost. We suggest six policy alternatives for analysis: the status quo, tree removal permitting, urban tree credits, a stormwater fee discount, tree rebate, and current policy expansions. Our team used a five-point Likert rating scale from low to high and assigned scoring values of one through five for each rating. After totaling these scores, we found that expansion of current policies was the best policy alternative. We recommend our clients ensure that funding is available for the associations and organizations working within the urban forestry sector.

III. INTRODUCTION

Greenhouse gases (GHGs) generated from human activity are collectively increasing in the atmosphere and driving climate change. This global phenomenon is linked to environmental, economic, and social consequences that can be understood as common pool resource market failures, where GHG emitters do not pay the full social costs of their emissions to society and the environment. These costs are seen as large-scale negative externalities throughout Oceania in the form of increased storm frequency and severity, loss of reefs through ocean acidification, and the impacts of rising sea-levels on low-lying islands (Kingsford & Watson 2011).

In 2016, Governor David Y. Ige developed the Sustainable Hawaiʻi Initiative to mitigate the negative impacts of climate change with the goal of achieving 100% carbon-neutrality by 2045 (Ige 2018). Governor Ige then established the Greenhouse Gas Sequestration Task Force (hereafter referred to as “the client”) through the passage of Act 15, in order to identify mitigation options utilizing natural-based solutions for carbon storage and sequestration across four sectors: urban forestry, agroforestry, agriculture, and aquaculture. This policy analysis has been completed at the request of the client to determine the carbon sequestration and storage potential of urban forests and green spaces throughout the state. This report will begin by defining the issue and examining the scope of current programs and policies, followed by a diagnosis containing analysis goals and constraints. The methodology section presents the proposed policy alternatives and the metrics used to assess them, based on qualitative and quantitative analysis. The report concludes with analysis results, predicting the impact and value of each alternative and the proposed recommendations. A clear plan-of-action is provided to guide the client in utilizing the recommendations to incorporate urban forests and green spaces in achieving carbon-neutrality.

IV. BACKGROUND

The State of Hawaiʻi is currently a net emitter of GHGs and has committed to becoming carbon-neutral by 2045 to mitigate climate change impacts. The 2017 Hawaiʻi Sea Level Rise and Vulnerability Adaptation Report states that a sea-level rise of 3.2 feet, which is expected to occur before the end of the century, would effectively eliminate 28,500 acres of land and 6,500 coastal structures across the state. This lost of land and infrastructure would result in an economic loss of 19 billion USD and displace nearly twenty thousand people. Ocean acidity in the Pacific is expected to increase 40-50% by 2100 (EPA 2016). Climate change induced ocean acidification is creating conditions in which coral reefs will likely not exist, reefs that annually gross $800 million in Hawaii (Davidson et al. 2003), and will likely decline the health of ocean ecosystems irreversibly. In an effort to prevent these catastrophic human health, economic, and environmental consequences, the client has requested an analysis of urban forestry and green space policy alternatives to support state mitigation goals.

Urbanized areas in developed countries are large sources of atmospheric CO_2 but can mitigate impacts through the use of urban forests and green spaces (Yang et. al 2005). Urban forestry is defined as all trees within an urban area, on both private and public lands (Novak et. al 2001) while green spaces refers to parks, sports fields and gardens (WHO 2016). Within this context, Honolulu county, on the island of Oʻahu, contains the largest percentage of urbanized areas in the state, providing a multitude of opportunities for GHG storage and sequestration. Urbanized areas are defined as containing 50,000 people or more (HSDC 2013). There are three urbanized areas in the State of Hawaiʻi and two of them are in Honolulu county. Of Hawaii’s ~1.4 million citizens, nearly one million reside in the 219 square miles of Honolulu county urban areas (HSDC 2013), the creation and persistence of which has resulted in negative environmental externalities such as loss of urban canopy cover, accumulating pollution, rising temperatures (urban heat islands), urban sprawl, and detrimental health human impacts (EPA 2016).

The scope of this policy analysis considers all available urban forests and green spaces within Honolulu county, as this is where the largest potential for GHG storage and sequestration can be realized. The client has requested this analysis be restricted to lands and waters within the state's jurisdiction, therefore military properties and other federally-owned lands were not included. The transportation industry (airplanes, cruise ships, shipping companies etc.) is another limitation, as the client requested this analysis focus on natural mitigation alternatives as opposed to regulation of existing industries.

The City and County of Honolulu currently has six major policies and programs established in support of urban forests and green spaces, although the primary focus is on tree preservation and planting. This includes the Exceptional Tree Program, the Tree Acquisition Program, tree mapping through the Citizen Forester Program, urban tree canopy assessments, the Community Recreational Gardening Program, and Trees for Honolulu's Future. These programs are operated by government agencies, non-profit organizations, and collaborative partnerships. Table 2 in the appendix section includes a list of agencies relevant to the sector of urban forests and green spaces. Each of the six programs are described below.

Current Programs and Policies

A. The Exceptional Tree Program

The Exceptional Tree Program is a protection program created through the exceptional tree act, Act 105 (HI Rev § 41-13.1(a)). Act 105 addresses the rapidly decreasing urban canopy in Hawaiʻi while improving the quality of life of its citizens as the presence of exceptional trees "promotes the general welfare and health of Hawaiian citizens while preserving the environmental character of Hawaiʻi". The legislation mandates an Arborist Advisory Committee be established in all Hawaiian counties and these committees are overseen by the Division of Urban Forestry, within the Department of Parks and Recreation. The Arborist Advisory Committee in the City and County of Honolulu is tasked with recommending trees for protected status, as well as advising property owners on maintaining their Exceptional Trees. Property owners may also nominate a tree or palm using an online application. In order to be nominated as an exceptional tree, one or more of the following criteria must be met:

- Historic or Cultural Value
- Age
- Rarity
- Location
- Size
- Esthetic Quality
- Endemic Status

Once deemed worthy for status, an exceptional tree is protected from removal and specific actions under HI Rev Stat § 41 - 13.(1975). Approval permits must be issued for any action done upon an Exceptional Tree, including: pruning, reshaping, and removing. Any person who violates HRS 41-13.8 is eligible of a fine up to $1,000. Landowners hosting exceptional trees receive a tax deduction for Exceptional Tree maintenance under HI Rev Stat § 235-19 (1975). HRS 235-19 allows for an individual tax deduction up to $3,000 per exceptional tree once every three years. This tax deduction is intended to cover expenses associated with maintaining an Exceptional Tree on the taxpayer's real property so the deductible is not allowed to exceed “expenditures deemed reasonably necessary by a certified arborist”.

B. The Tree Acquisition Program

The Tree Acquisition Program is operated by the Horticulture Services Branch (Division of Urban Forestry) through the Department of Parks and Recreation. The Branch employs certified arborists, tree workers, and tree risk assessors, as well as a landscape technician. A responsibility of the HSB involves the planning, planting, and maintaining of trees, species form an Official Street Tree List, along public roads (planting strips) and city parks. Additionally, the HSB issues all permits required for citizens, businesses, and developers to replace, remove, plant, or trim a street tree. Any person removing or altering a street tree without a permit is subject to a $500 fine or 6 months in prison. The HSB, however, retains the right to remove potentially hazardous portions of any tree on any private property without granted permission of the landowner. Furthermore, the HSB provides horticultural and arboricultural services for an island-wide beautification program and clears branches and debris from City properties. The acquisition program accepts donated trees from the public, to be delivered as gifts to the City. Once trees are inspected and accepted, they become City property and are removed and relocated. As stated in the tree guidelines for assistance and requests, “it is the City's goal to preserve as many trees as possible. To this end, trees will not be removed unless dead, dying diseased, or severely damaged” (Guidelines for Tree Inquires).

C. Citizen Forester Program

The Citizen Forester Program is a collaborative project of federal, state, and city partners that trains and supports community volunteers to collect urban tree inventory data. The Urban Forestry Section of Hawaii’s Forest Action Plan (FAP) identified that there is no current formal inventory of trees currently being used in Hawai‘i, which can hinder efforts to manage, monitor, maintain, and plan for disasters in the urban forest. The goal of a complete inventory will aid in city planning as well as assessing public and environmental health. The Hawai’i FAP also participates in outreach as it identified improving the public perception of the value and benefits of urban trees as a key strategy. The Citizen Forester program engages communities in their urban forests through the use of citizen science to develop an urban tree inventory. Volunteers have mapped over 5,600 trees in Kailua since June 2016 and over 1,100 trees in Honolulu since October 2017. Volunteers collect data on a weekly basis as the project includes a systematic inventory of City trees in urban areas.

D. Citizen Forester Inventories

Citizen forester inventories were conducted for Honolulu county as a collaboration between Smart Trees Pacific, Kaulunani Urban & Community Forestry Program, Division of Forestry and Wildlife, US Forest Service, Department of Agriculture, and the City and County of Honolulu (Smart Trees Pacific, 2012). An initial assessment of land cover in urban Honolulu was done in 2012 to determine a baseline for existing and potential urban tree canopy. High-resolution satellite imagery and LiDAR data from various land cover metrics including existing tree canopy, impervious possible tree canopy, vegetated possible tree canopy and areas not suitable for growth were examined (MacFaden & O'Neil-Dunne, 2012). A second assessment was conducted in 2016 to examine changes between 2010-2013 and found that urban canopy cover had decreased by nearly 5%, or approximately 76,600 trees (Smart Trees Pacific 2018). Residential zones totaled 355 acres, or 39%, of total urban canopy loss. Figure 1 and Figure 2 in the appendix show the percentage lost by district. This type of change analysis helps to identify priority areas that are experiencing the greatest losses. The 2016 assessment reported that 23% (2,892 acres) of Honolulu is occupied by tree canopy and there is room for an additional 64% (7,924 acres) through modifications to urban land areas (MacFaden et al., 2017). An important consideration raised by this study is that trees are usually not able to be assessed in radar imagery analysis for up to three years after planting due to size constraints. Once trees mature and develop, their contribution to canopy growth can be measured. This delayed effect is crucial to consider when calculating the costs and benefits of tree planting programs. Figure 3 in the appendix shows the new change in tree canopy area (acres) between 2010 and 2013.

E. The Community Recreational Gardening Program

The Community Recreational Gardening Program was established in 1975 in Chapter 13 of the Revised Charter of the City and County of Honolulu to provide people living in Honolulu's densely populated communities access to gardening plots. There are ten garden sites located throughout the county that community members can apply to manage. Membership costs includes annual dues, ranging from $5 to $20, and includes access to land and water provided by the City. All other improvements and services are provided by the volunteer gardeners and additional rules, such as no pesticides or herbicides and no commercial activity with the produce, are set forth by the City and the Garden Organization. These governing bodies conduct meetings, maintain the garden area, enforce the rules and policies and process the applications for garden plots. Violators of rules are not subject to a fine, rather violators risk having their plot revoked.

F. Trees for Honolulu's Future

Trees for Honolulu's Future (TFHF) is a non-profit 501(c)(3) organization whose goal is to increase Honolulu's urban canopy to 35%, currently at 25%, coverage by 2035 and reduce

O’ahu’s contribution to climate change. TFHF hopes to reduce Honolulu’s current canopy loss to 0% net loss by 2020. TFHF’s focus on canopy cover stems from the belief that the leaf surface area that is the main driver behind the tremendous co-benefits of an urban forest- particularly the reduction of the urban heat island effect. Honolulu’s Mayor, Kirk Caldwell, declared, in 2018, March 9th to be *Trees for Honolulu’s Future Day* where he announced Honolulu’s commitment to the goal of achieving 35% urban canopy by 2035 and to plant 100,000 urban trees by 2025. TFHF is determined to meet their goal through many avenues, including:

- Facilitate and fund raise for the planning, planting, and maintenance of trees in public spaces & street trees
- Coordinating with, and reinforcing, the efforts of non-profit organizations and governmental agencies & in building the urban canopy
- Assist in developing curriculum for schools
- Outreach to promote the important environmental, economic, social, and health benefits of an urban canopy

V. Market and Government Failures

The notable lack of urban forests and green spaces in Honolulu County can be attributed to several market and government failures through an economic framework. A range of such failures are related to urban forests in Hawaiʻi, that has resulted in the current status quo scenario. An overview of market and government failures in the context of climate change is provided and specific failures are examined for their connection and contribution to the urban forest and green space sector.

A. Market Failures

Clean air is a pure public good, meaning it is both non-rivalrous and non-excludable. The atmosphere however, is a global commons into which firms and individuals can emit pollution, leading to overconsumption and congestion of this rivalrous resource. The continual use of carbon-based fossil fuels has resulted in climate change. This market failure can be understood as a tragedy of the commons where competing resource users are incentivized to consume more quickly and in greater quantities, to increase their utility relative to their competitors (Weimer & Vining 2017). Carbon dioxide (CO_2) is the most abundant GHG in the atmosphere as well as the most significant contributing gas to climate change as it is estimated to be accountable for about 80% of human-caused climate change (Lashof & Ahuja 1990), therefore reducing global CO_2 emissions is critical for mitigating additional climate change impacts.

In the context of urban forests and green spaces in Hawaiʻi, three market failures were identified:

1. Positive externalities

    a. The positive benefits gained from urban trees and green spaces cannot be internalized or monetized by any one individual, therefore the availability of these benefits depends on proximity. These positive externalities include, air and water purification, temperature and energy-use reductions, reduced terrestrial runoff, higher property values, and community beautification.
    b. These positive benefits are often not incorporated into planning and development projects as potential cost-offset and are not recognized for their value.
2. Information asymmetry
    a. The average resident likely does not perceive the full range of direct and indirect benefits they receive from having trees or other vegetative cover placed strategically around their property. This can lead to loss of benefits if trees are removed or if they aren‘t planted in the ideal location.
3. Endogenous preferences
    a. Species selection is a major consideration if trees are to be utilized for GHG sequestration. The majority of tree species being used for urban planting are non-native and not ideal in terms of their canopy cover (i.e. coconuts and other palms). The City and County of Honolulu passed Ordinance 14-6 in 2014 requiring that native or Polynesian introduced tree species be used for plantings, whenever feasible, although the effects from this law have not yet been seen.

B. Government Failures

Urban forests and green spaces are sustainable design strategies for carbon storage and sequestration that should be incorporated into urban development as they provide a host of environmental, social, and economic co-benefits (Novak & Dwyer 2007). Due to barriers, such as funding and political will, these types of public goods are not being planned for across the Hawaiian urban landscape and are undersupplied as a result. The Trust for Public Land ranks U.S. cities on the ParkScore Index, which measures how well the 100 largest U.S. cities are meeting the need for parks. Honolulu ranks number 48 on the list, with an average number of 14 people served per park compared to the top-ranked city of Minneapolis, which serves 82 people per park with half the population size of Honolulu (ParkScore 2018). This lack of supply is a government failure that can be remedied through increased funding and support from the public and private sectors. The ParkScore index shows that the average Minneapolis resident spends a total of nearly $250 on parks while Honolulu residents spend less than $60 for similar park services and benefits.

In the context of urban forests and green spaces in Hawaiʻi, three government failures were identified:

1. Bureaucratic supply
    a. Public goods are inherently undersupplied as government resources for public expenditures are frequently stretched to their limits.
2. Limited regulation and enforcement

a. The current policies that exist in Honolulu County are not able to restrict tree removals on private properties, allowing residents to remove as many as desired. One estimate put the loss of trees on private properties in Honolulu at nearly 75,000/year, resulting in a significant contribution to net canopy loss. Restricting tree removals and other actions that contribute to loss of canopy and vegetative cover should be regulated by local governments and communities.

VI. GOALS

The policy alternatives assessed in this analysis were developed to achieve specific goals within Honolulu's urban forestry and green space sector. The preceding discussion on the current state of the sector identifies that there are several needs to be addressed if Hawai'i is to achieve the 2045 carbon-neutrality target. This analysis considers four goals, to address Act 15 as well as to ensure the policy recommendations produced are supported, accepted, and feasible. The first goal is to **increase carbon sequestration through urban vegetative cover through the use of trees, parks, fields and gardens**. The second goal is considers **equity** by **increasing access and proximity to urban trees and green spaces**, benefiting as many residents as possible. A third goal of this analysis considers **political feasibility** for the proposed policy alternatives and whether or not they will be supported by stakeholders. The fourth goal, that is foundational to the others, is **economic efficiency**.

All of these goals are to be achieved through the most cost-effective and economically efficient recommendations possible. Efficiency will be assessed based on the metrics used in the iTree Eco model, which the Citizen Forester Program has used to conduct previous urban tree canopy assessments for Honolulu and Kailua. The iTree software calculates the carbon sequestration and storage potential of individual trees based on species, age, size, health and other variables that are recorded during tree mapping surveys. The software can also produce a summary report of eco benefits and provide an overall monetary benefit estimate, based on ecosystem services provided. These survey results were extrapolated to other urban areas that have not yet been surveyed to assess additional potential benefits and determine the efficiency of different actions.

VII. POLICY ALTERNATIVES

Five policy alternatives have been developed to address the five goals discussed above. Each alternative considers the current policies and programs in Hawaii and seeks to enhance the co-benefits of urban forestry. The alternatives were developed after an extensive literature review, as well as three informal interviews with experts in the field. The interviewees included Shannon Rivera from the Division of Urban Forestry, Matt Gonser from the Office of Climate Change, Sustainability and Resiliency, Myles Ritchie from The Outdoor Circle, Wei Lee, the executive director of Smart Trees Pacific, and Corey Bassett, an arborist from Smart Trees

Pacific. These interviews led the analysis of existing data from the Citizen Forester Program and two GIS layers (state parks and land cover) from the Department of Planning.

A. Tree Protection Permitting

The focus of this alternative is creating a Tree Protection Permitting policy for the city of Honolulu in the State of Hawaiʻi. The purpose of such a policy is to create a permitting system in which private landowners must apply for, and be approved of, before removing trees from their property. Such a permitting policy does not currently exist in Hawaiʻi. As the Horticulture Services Branch (HSB) through the Division of Urban Forestry currently handles tree services within the public division including inquiries on public permitting, the private landowner permitting could be developed within this branch. These private tree removal permits would first create the limitation of only allowing the removal of invasive tree species and some non-native species, with the exception of the removal off sick or dead native species that pose a health or economic risk to the landowner as determined by a certified arborist. Trees within the non-native category will also be assessed in a similar manner for signs that removal is necessary due to the risk they impose. Invasive tree species should be granted a removal permit, but the removal process must follow the recommendations of the arborist. The purpose is to remove the invasive species to prevent its further potential propagation. The intention of this permitting policy is to limit the reduction of canopy cover on privately owned lands. - Develop implementation; how to monitor or even know when trees are removed without a complete inventory of trees since private lands weren't considered in the tree inventory or even the initial inventory

B. Urban Tree Credit Systems

Many cities in the U.S. and around the world have adopted policies to grow their urban canopy through the use of incentives and credits awarded to landowners hosting productive and beneficial vegetation on an individual tree basis. Several of the interviewees suggested that a first step in reversing the declinding canopy trend is to focus current efforts on the conservation of the forest Honolulu already possesses rather than large-scale planting projects. According to Vargas, et al., 2008, the current street trees in Honolulu have a **replacement value of $1,665 per tree.** Urban tree credits are largely designed for the conservation of existing trees, as well as the planting of new ones. Interviewees also described a severe lack of enforcement and monitoring that has made expanding the urban canopy particularly difficult. Incentivising programs and policies may prove to be the most effective method for preserving the canopy as it provides landowners with the utility-boosting drive to contribute to the overall urban forest conservation and growth even if trees were not of their previous concern. Implementation of crediting policies would serve in parallel to the Exceptional Tree Program so that Exceptional Trees may keep their exceptional standards while the credits provide incentives for a much broader range of trees to be preserved. For this analysis, we considered four monetary credits that may be equivalent to the tree's determined value in terms of stormwater retention, impervious surface reduction, carbon sequestration, and energy savings.

1. Stormwater Management Credit

Over the past decade in the U.S., there has been a general shift in state-level policies away from structural BMPs and towards non-structural solutions for stormwater runoff like the preservation and planting of trees. Hawai'i's Office of Planning- Stormwater Management should consider creating a system of robust credits to be awarded during development and redevelopment projects that encourage the use of natural stormwater retention methods. The value of the credit given may be equal to the cost of treating & mitigating the stormwater that, without the tree(s), would have been present as well as the determined benefit cost to society based on the reduction of pollution transport and increased nutrient & sediment retention- encouraging the use of alternative methods of reducing runoff through the planting and conservation of trees on private lands. Vargas et al. 2008, found that, on average, an inventoried street tree in Honolulu was valued at **$1.08 per tree/year** in avoided pollutants and **$7.99 per tree/year** in runoff reduction. Mass load removal of total nitrogen (TN) and total phosphorus (TP) are of particularly great interest, especially in Hawai'i to protect our downstream coral reefs, and the credit associated with intercepting these nutrients should reflect their vital importance. Because hydrologic benefits are better understood than water quality benefits of trees, a relationship can be determined between runoff and pollutant reduction, which can be used to determine the credit in regards to pollution. There have been many studies focused on determining the driving factors of urban tree mortality, growth, and condition, these studies may "inform recommendations on the urban tree credit by supporting qualifying conditions for water quality credit assigned to trees planted in the urban landscape, and supporting projections of ultimate tree size and mortality rates for use in determining the appropriate water quality credit for tree planting." (Center for Watershed Protection, 2017).

A stormwater management crediting system would determine credit values off of a property's ability to minimize the negative impacts of stormwater runoff in conjunction with the projected health and effectiveness of the trees present. The success of a crediting system like this would be dependant on having a strict evaluation process and monitoring plan by the State as well as landowners and developers being aware of this program and having a willingness to partake. Landowners with a pre-existing high percentage pervious coverage are more likely to be able to benefit from these credits with more ease than property owners who are hindered by a majority of their land being impervious. Large trees have the greatest effect in runoff reduction, as well as other co-benefits of urban forests, so they will likely be the selected species when selected for this credit, which is ideal when wanting to build an urban canopy. Carbon sequestration, however, will likely not be an important consideration for landowners and developers seeking this credit so the most effective species in terms of GHG sequestration may not be chosen- rather they will likely be ornamental species.

2. Impervious Surface Reduction

As an alternative to stormwater management credits, there can rather be an impervious surface reduction credit introduced that has the same ultimate end goal- to reduce the detrimental environmental effects of stormwater runoff. This credit assists in reducing runoff rates as well as better ensuring that young trees are able to survive to maturity as available soil is one of the most commonly cited factors affecting tree growth and survival. Recommended open soil coverage is about 100-200 square feet (largely depending on species) for a newly planted tree, and half the canopy coverage area for existing trees. Healthy and mature urban canopy cover can be expected to grow with the expansion of pervious surfaces as soil availability is such a strong component of a tree's well-being. For the sake of feasibility and equity, there should be an upper limit as to how much impervious surface a single tree can be credited with reducing, usually this limit lays around a reduction of 25% (Moore, et al. 2014). To be equitable across plot sizes, credit shall be awarded based on percentage of the landowner's property rather than square footage or some other metric. Furthermore, in order to create an impervious surface reduction credit equitable, credits awarded should be only given for ground-level impervious surface reduction and for trees that are/were near a pre-existing impervious surface.

Once more this crediting system's success largely depends on private landowners knowledge of its existence and willingness to partake. Since there is no tree-specific requirement for the obtainment of this credit, this crediting system may yield less of an initial canopy than that resulting from a stormwater management credit. Yet, an impervious surface reduction credit may yield a larger reduction of stormwater runoff as more landowners are likely able to participate and the canopy cover resulting from this crediting system is predicted to a healthy, success one.

3. Carbon Sequestration

Many cities across the U.S. utilize carbon crediting systems, like offsets, in order to achieve carbon neutrality. States with large metropolitan areas, strong economies, and massive industrial production have taken advantage of cap-and-trade carbon credits/markets and carbon offsets that, more often than not, provide co-benefits to an area far from the urban center. With our focus solely on the urban (Honolulu) canopy, and being situated in Hawaii, a carbon sequestration credit should created and be catered to the isolated, tropical urban environment, where Vargas et al. 2008, found that, on average, an inventoried street tree in Honolulu was valued at **$0.51 per tree/year** in terms of carbon dioxide sequestration. The most feasible carbon crediting system in Hawai'i would be a voluntary one, compared to a regulatory one, where local government, organizations, or corporations (supported by local government) act upon their sense of social responsibility and provide individuals with incentives to increase their sequestration of carbon dioxide from the atmosphere through the use of urban trees. Urban forestry typically involves higher implementation costs than that in forested areas due to the high price of land in urban areas and the challenges of canopy health in congested areas, yet, urban forest still prove to have a substantial potential to sequester carbon and outstanding provide co-benefits to the surrounding community. The carbon sequestration potential of an individual tree is dependant upon its species, size, age, environment and health, so the certified carbon credits to be awarded per tree is on an individual basis. If a landowner believes a tree(s) on their property is highly efficient in sequestering carbon, or plans on planting tree(s) that are believed to be sufficient in carbon sequestration, then he or she shall have a certified arborist evaluate the tree(s) and determine the appropriate credit to be awarded.

Implementation of a carbon sequestration credit for trees would encourage the preservation, and planting, of the most carbon efficient species which will maximum the carbon sequestration potential of Honolulu’s urban forest but may limit the amount of landowners who are able or willing to benefit from this credit system.

4. Energy Consumption Reduction

Tree credits may also be considered through an energy consumption lens, where the value is based on energy savings, largely from cooling and heating, in terms of the utility used by the individual but made efficient when considering the negative externalities of energy production. Awarding a tree credit based on energy consumption reduction will be largely based on the reduction in an individual's energy usage, evident on their utility bills. Vargas et al. 2008, found that, on average, an inventoried street tree in Honolulu reduces 1,943 MWh, or **$8 per tree/year**, through shade and transpiration. Assessing the trees to determine their actual contribution to the energy reduction may prove a bit of a challenge as height, size, leaf-area, species, proximity to building, and directional orientation of the tree all play a role in the reduced need for energy.

This tree credit will encourage the preservation and planting of tall,broad, leafy-canopy tree species, which is ideal when building an urban canopy and attempting to maximize the co-benefits of an urban forest. The use of this credit should prove to be very efficient in carbon sequestration and reduction in production because trees that will yield the largest energy reductions are the leafiest and largest species, which typically sequester and store the most carbon, and the reduced energy requirements will be reflected in lower emissions from energy production plants. Equity of this tree credit is satisfactory as the quantity of woody mass increases with the size of the property to reduce comparable energy usage.

- After evaluating the four possible crediting program for Hawaii, it has been determined that the most effective, equitable, and feasible credit system for Honolulu would be the **stormwater management urban tree credit.** This credit incentivizes the protection of the current canopy as well as the expansion of it by offering credits to landowners who reduce their runoff via natural methods like trees.

C. Conservation & Planting Incentives

There are four incentives, besides crediting programs, that were assessed in this policy analysis: development incentives, stormwater fee discounts, grants, and rebates.

1. Development Incentives

Like the stormwater management credits, these incentives are targeted largely at developers designing a new development or redevelopment project. The creation of development incentives, like expedited permits, special zoning exceptions, and modified stormwater mitigation structural requirements, can be incorporated in the development process to influence an increased use of green infrastructure methods for runoff interception. The implementation of these incentives may spark small-scale retrofit projects to transition to more natural methods of runoff regulation.

Development incentives are usually extremely cost-efficient as it costs the governing body near nothing to expedit permits, make zoning exceptions, or allow the bypass of otherwise required stormwater mitigation structures. The developer is often able to operate with a smaller budget if utilizing green infrastructure correctly and to its fullest extent. The incorporation of trees as a mean of mitigating runoff also concurrently beautifies the property and thus increasing its property value. Vargas et al. 2008, found that, on average, an inventoried street tree in Honolulu raised property value by **$72 per tree/year**. The increased property value of the plots within the development outturns then higher property taxes that the government receives and then may put towards efforts to support the growth of an urban canopy. Development incentives may prove to be extremely effective in producing an urban canopy within new or redeveloped areas, but may not be so quick or effective in growing the urban canopy in established neighborhoods.

2. Stormwater Fee Discounts

Stormwater fee discounts are commonly used in the U.S. and are often extremely successful in encouraging private landowners to maintain less impervious surfaces. In order to implement a stormwater fee discount incentive, there must first be the establishment of a stormwater fee in the municipality of Honolulu. For homeowners, the fee can be added to their water bill in some amount proportional to their water usage or determined by their tax bracket. Homeowners will be encouraged to apply for a fee reduction or exemption if their property hosts vegetation that significantly increases water retention. Landowners of industrial and commercial properties shall pay a fee relative to the percentage of impervious surface on their property. This policy, in regards to industrial and commercial properties, will require monitoring via GIS platforms to apply determine fees for these landowners based on their impervious surface coverage. A landowner's stormwater fee would be discounted in accordance to how much theorized runoff volume is reduced due the impact and efficiency of their area of maintained permeable ground area. The fee can be further discounted, or eliminated, if enough natural stormwater mitigation methods are implemented on property, i.e. tree plantings and impervious surface reduction. To make this policy most effective, a 100% fee credit should be offered for landowners who take on large-scale green infrastructure projects such as green roofs, rain gardens, or tree planting.

This incentive benefits the municipality greatly because as more private landowners reduce their runoff, it lightens the burden upon public infrastructure and thus less maintenance and service should be required (Moore et al. 2014). Furthermore, the fees collected should then be put towards efforts of GHG sequestration, in particular, increasing the urban canopy. Beginning a stormwater fee system, and its discount, may prove difficult at the onset for it will most likely have to be voted into legislature by residents. The fee will deter landowners from removing trees on their property in order to avoid paying the fee and this step towards conserving our existing urban forest is absolutely crucial. Outreach events prior to voting on the implementation of this fee may prove to be beneficial for citizens may learn how much return on benefit they would ultimately receive from their small fee. A stormwater fee discount would include every landowner within the city limits and thus will be an effective tool in gaining involvement in the preservation of the urban canopy.

3. Landscape Grants

Landscape grants, to be distributed annually, could be developed in Honolulu to landowners who exceptionally maintain their land as a native landscape that delivers maximum co-benefits to the community including aesthetic, pollution removal, water & nutrient retention, carbon sequestration, endemic habitat, heat reduction, noise reduction, and cultural value. Grants are a powerful incentive that may inspire private and public landowners to maintain an efficient, natural landscape worthy of receiving the grant. Incentivizing programs such as this has proven successful in U.S. cities, but it is important to closely monitor and maintain performance standards for the trees that were credited. There is concern that landowners seeking grants may not know how to best maintain and preserve their vegetation long-term to continue to provide the sweep of co-benefits, there must be insurance that the owner maintains soil quality and volume so that trees are able to mature and the incentives are truly effective.

While landscape grants may be highly efficient and effective at increasing canopy cover in concentrated areas, it is unlikely that they will be the onset of the reversal of the current declining trend of the urban forest.

4. Tree Purchasing & Installation Rebate

Rebates are the last incentive considered in this analysis where the State directly reimburses the individual landowners for the purchasing and planting of trees on their property. Getting sufficient citizens involved in government or non-profit organization efforts to build an urban canopy is an extremely difficult task, but one made easier when the upfront cost of purchasing and installing a tree on private property can be no burden on the landowner. In creating a tree purchasing and installation rebate program in Honolulu, it is imperative for its success that the trees covered by government funds are monitored throughout their lifespan to ensure that the trees are yielding the benefits that eventually outweigh the initial cost to the State. Any landowner wishing to utilize this rebate should be briefly educated on proper tree maintenance and strategies to ensure its health and survival to maturity. There should be an upper limit on an individual landowner’s use of the rebate, for instance one subsidised tree can be approved for every 300 square feet of pervious surface on one’s property, or, denying rebates to landowners who have utilized it two or more times previously but the refunded trees failed to last at least 5 years on property.

A tree purchasing and installation of rebate success would be highly dependant on the public's knowledge of the program and willingness to partake. Willingness to partake would be significantly higher if on the onset of this program there is a major outreach effort made to inform potential users of the importance and benefits of trees on your property and in your neighborhood. The use of a rebate would not be the most effective strategy in preserving the existing canopy but it may prove to be one of the strongest agents at getting new trees planted in urban areas. Furthermore, there is a lot of opportunity within a rebate program to encourage and discourage the planting of certain tree species. Installing large native trees, native & non-native trees efficient at sequestering GHGs, and native trees supporting an endemic habitat should all be 100% reimbursed to the landowner. While other smaller species of trees, and ones less efficient at sequestering GHGs, may be only 50-80% reimbursed. All invasive species however, or any species that would yield monetary benefits less than its initial cost (a large number of palm species) should not qualify for the rebate.

- After evaluating the four best-suited incentivizing policies for Honolulu's urban canopy growth, it has been determined that a **tree purchasing and installation rebate** would be the most impactful incentive to initiate in terms of canopy growth, sequestration potential, and political feasibility.
- A **stormwater fee discount** would be highly effective in producing co-benefits of green spaces and permeable surfaces but will likely face trouble in getting implemented in Hawai'i.

D. Current Program & Policy Expansions

The Exceptional Tree Program - The protection of Hawaii's abundant urban canopy ensures long-term reception of environmental benefits. The Exceptional Tree Act is one of the only protection and recognition policy for trees in the state of Hawaii. Through removal protection and tax rebates to those who maintain exceptional trees, owners are encouraged and incentivized to continue caring for nominated trees. We believe this policy is effective at protecting trees but that The Exceptional Tree Program should also be expanded. This can be done by creating additional incentives for potential owners to plant potential exceptional trees on private properties and residential zones, such as distribution of mature saplings of desirable species, ready to be planted and assistance with plantings from certified arborists. Additionally, we propose to increase the tax deductible offered to owners (maximum of $3000 every 3 years) for maintenance and to offset unexpected or hidden costs. This would encourage more people to participate in the program and expand the benefits received from the preservation and protection of exceptional trees to adjacent areas.

Aside from funding, the inclusion of non-monetary incentives may prove beneficial in the expansion of this program. Outreach and education are important components to increase participation in government programs, as community members may be uninformed about the availability of funding that programs provide. Defining and addressing knowledge gaps can help determine where to allocate time and effort in the expansion of these programs. Another potential to extend benefits would be to target specific communities that are not taking advantage of these this program. The application of GIS should be used to show which areas have potential exceptional trees and are not receiving tax incentives or protections. A primary recommendation for this program is to utilize GIS data to mail informational brochures to community boards and land owners that are eligible for nomination, based off their property locations and current existing trees. Finally, we suggest that additional recognition of exceptional trees be provided to tree owners in the form of a plaque or certificate. Providing recognition with a tangible object that owners can display in their homes, providing them with a sense of pride and kuleana to maintain their exceptional trees.

Citizen Forester Program - This program has already completed a significant amount of survey work on Oʻahu but still needs to complete the majority of the Urban Honolulu survey area. Through the use of citizen scientist volunteers, they are able to have a large impact at a relatively low-cost, making it an economically efficient program with great expansion potential. Through interviews with Wai Lee and Corey Bassett at Smart Trees Pacific, we learned that the data from this program is input into a software called iTree Eco v6, which uses tree parameters and characteristics such as species, height and DBH to estimate ecosystem services derived from urban forests. The sample report based off of the current program data This software was not designed for use in Hawaiʻi as it was created in California and the model is based off of information from species growing under different climate conditions or ecological systems. The primary suggestion for this program is to update the iTree calculator to reflect growing and health conditions of tree species in Hawaiʻi, which will improve the model parameters to produce more accurate reports.

Oʻahu Urban Tree Canopy Assessment - The joint State and Federal partnership that completed these assessments between 2010-2013 stated that their objectives were conduct island-wide tree assessments on an annual basis. To date, this has not happened. The primary suggestion for this program is to conduct annual assessments and maintain an updated database of existing tree data. The results from these assessments should inform the species to be used and locations to be targeted for future plantings as “planting the right tree in the right place” can increase GHG sequestration.

VIII. IMPACT CATEGORIES

The first goal for this sector is to increase GHG sequestration through urban vegetative cover. Growing trees presents a long-term investment as some may only reach maturity after 20 years and the level of environmental and socioeconomic services provided will change during their life cycles. However, these services and resulting benefits can be offset if tree species are not selected for their ideal environments (Dwyer et al. 1992). There are several factors that contribute to the success or failure of tree growth. The number of trees planted within a given space should be relative to variables such as size at maturity and the spread of below ground roots. It is important to plan accordingly so as to create or maintain the greatest amount of canopy cover, but also maintain tree health. Tree species selection is paramount when considering both environmental and socioeconomic benefits (Nowak et al. 1992). Each species provides an array of ecosystem services and varying degrees of hardiness within the context of the annual extreme minimum temperature of a region. For example, when considering ideal species for GHG sequestration in the City and County of Honolulu, the native *Acacia koa* (Koa) is recommended for hardiness zones 9-11, however the non-native *Araucaria heterophylla* (Norfolk Island Pine) is also recommended for zones 10-11 and is known to sequester more GHGs than its native counterpart (iTree, n.d.; Department of Transportation 2014). Selection between native and non-native species will always be dependent on prioritization which may vary within regions.

The age and health status of a tree can be determined by various non-invasive measures such as diameter of the trunk at breast height (DSH), which is about 4.5 feet above the ground. The DSH of a tree can determine the health of the tree with a comparison to the standardized measurements for that species. Symptoms of disease or pests can include leaf drupe, bark scarring, or extensive leaf loss. Something to consider when assessing tree health is that noticeable symptoms may be due to natural stages within the tree's life cycle such as leaf drooping or loss during seasonal dieback. It is important to note that these conditions will be species specific and should be assessed for success as such. Healthy, properly growing trees is the first step to creating increased canopy cover. It is critical that these trees maintain a healthy development to ensure both environmental and socioeconomic benefits of GHG sequestration in the long-term. Like with carbon sequestration, tree species selection is paramount for success in achieving carbon stock storage. Different species will provide varying levels of storage, depending on environmental conditions such as hardiness zones in the area of interest for planting. It is important to recognize that carbon stock storage is also dependent on the life cycle stages and the size of woody growth. As trees grow older, their mass size increases and they continue to store carbon (Stephenson et al. 2014).

To achieve equity and the desired socioeconomic benefits as a second goal, equal access to green spaces and canopy cover is necessary and not currently being met as there is an inequity of urban tree canopy distribution with the highest concentrations commonly found in wealthy neighborhoods. Green spaces can be developed at the local neighborhood scale or created on the county scale to provide that equal benefit (Nowak & Dwyer 2007). Not only do these spaces create aesthetically pleasing environments, they provide public spaces for leisure and recreation. If an effective plant/tree management plan is followed when creating these spaces, the benefits they provide should offset the initial cost over time (Nowak & Dwyer 2007). Therefore, equal distribution of these green spaces and the benefits they provide should be realized regardless of an area's economic status such as low-income areas.

Increased canopy cover provides several co-benefits for citizens such as air pollution reduction, heat reduction, energy savings, and preventing water runoff and flood reduction. Trees are known to remove harmful pollutants from the atmosphere. During photosynthesis, carbon dioxide is uptaken by leaves and other pollutants such as carbon monoxide, nitrogen dioxide, sulfur dioxide, and other particulate matter via leaf pores known as stomata. As tree and vegetation cover increases, more units are available to remove and reduce or process these pollutants leading to improved air quality. In the United States an estimated 127 million people are affected in some way by air pollution (Nowak & Heisler 2010). It is estimated that mature trees within the urban context can uptake up to 50 pounds of pollutant particulates within a year (Dwyer et al. 1992). A 2010 report estimated a value of $500 million in air pollutants was removed annually by urban park trees in the U.S. (Nowak & Heisler 2010). On the island of Oʻahu, an estimated annual $17,812 in air quality benefits was seen due to 12,347 pounds of pollutants removed (Smart Trees Pacific & Kaulunani Urban and Community Forestry Program).

Another co-benefit associated with increased canopy cover is a reduction in air temperature. As one might expect, an increase in canopy cover results in an increase of shaded areas, including areas over public and private buildings. Increased shade often results in a reduction in energy consumption. On the island of Oʻahu, an estimated annual monetary savings of $65,115, annual energy savings of 552,695 kWh, and annual natural gas savings of $3,694 was found (Smart Trees Pacific & Kaulunani Urban and Community Forestry Program). With increased canopy cover comes an increase in underground root mass and an overall increased uptake of water by the trees. This creates the co-benefits of a decrease in soil erosion and an increase in retention of water runoff helping to prevent flooding events within communities and the transportation of pollutants to nearnby water systems (Dwyer et al. 1992). On Oʻahu,estimated annual 10,148,000 gallons of runoff water was retained due to urban canopy with an estimated annual $101,937 in monetary benefits (Smart Trees Pacific & Kaulunani Urban and Community Forestry Program).

Considering feasibility as a third goal requires an assessment of stakeholder support. The stakeholders involved with the urban forestry sector range from citizens and private landowners, non-profit organizations that develop and conduct research on these spaces such as Smart Trees Pacific and The Outdoor Circle, state organizations such as the Hawaiʻi Office of Planning's GHG Sequestration Task Force, as well as several other organizations (Table 2 of the Appendix). Each of these stakeholders has varying priorities and goals of their own for either maintaining or creating urban forested areas, so support or lack of it may be a reflection of those. It is also important to recognize that the availability

In looking at efficiency as a fourth goal, the sequestration potential per cost is another aspect that will vary as it is species and location dependent. Within the urban context, the state of Hawaiʻi stored an annual 2,200,000 tonnes of carbon (Nowak et al. 2013). However, the cost of purchasing trees varies depending on the species selected, while planting and maintenance will vary depending on location as well as the hardiness assessment. Therefore

IX. POLICY ASSESSMENT

Overview

After researching policy alternatives and interviewing experts in the field, our urban forestry team will now assess potential future scenarios. In this section, we will detail our prediction of how each policy will be valued and assess the scale of impact. To accomplish this, our team will compare how well the status quo, tree protection permitting, credit systems, tree planting and installation rebates and current policy expansions meet our policy alternative goals. These alternatives will be further assessed by our four stated goals: greenhouse gas sequestration, efficiency, political feasibility, and equity. The ability of our policy alternatives to meet our goals will measure the overall effectiveness of each alternative. The rating system we use follows a five-point Likert scale of low, low/medium, medium, medium/high and high. The consideration of limitations and biases is essential to determining this measurement. Our team will also cover potential assumptions and uncertainties and how they relate to scenarios with and without policy interventions.

A. Status Quo

GHG Sequestration

Increased urban canopy cover, Low - If conditions remain on the current path, we can expect to see a continuation in the loss of canopy cover. As noted above from the Urban Canopy Assessments between 2010 and 2013, Honolulu is experienced a net loss of nearly 5% of urban canopy cover.

Increased green space, Low - Pressures from urban sprawl and development of urban areas is expected to decrease available green space. For the status quo, we rate this impact category with a low score because additional urban development will leave less available land for parks, gardens and planting trees. While we do consider an opportunity for rooftop gardening in high rises and residential lanais, we see this as an unrealistic and minimal contribution in comparison to the amount of loss due to construction of residential buildings and businesses in our current model.

Equity

Sociocultural benefits, Low - Urban areas in Honolulu are experiencing a high percentage loss of canopy cover compared to non-urban areas. This means that the effects from the status quo on sociocultural benefits are not equally distributed. We rank this impact category as being low/medium because urban and non-urban areas would receive these benefits unequally.

Political feasibility

Stakeholder engagement, High - Current trends suggest that stakeholders engagement is improving and that collaborative efforts between organizations have increased in recent years. When stakeholders work collaboratively and align in their goals, we expect to see a increase in productivity and desired results. While engagement across organizations and stakeholders is increasing, we suggest that there is still room for improvement. Many of the challenges faced by various stakeholders are similar and moving forward, we see potential for development of reports and policies to support each other.

Efficiency

Sequestration potential per cost, Low/Medium - As current trends continue, it can be determined that loss of canopy cover will maintain its net loss trajectory. Development and expansion of urban areas make it increasingly difficult to protect and expand areas that can be used for as potential sequestration sites. This means that per dollar spent in the status quo, we will have less area available to sequester carbon. We expect these trends to continue, resulting in additional loss in sequestration potential per cost, resulting in a ranking of low.

B. Tree Protection Permitting

GHG Sequestration

Increased Urban Canopy Cover, Low - Canopy cover will be the main variable affected by implementing permits. The purpose is to at least maintain canopy and support further cover by protecting trees on private lands. If enforcement and compliance by private landowners is achieved

Increased Green Space, Low - A permitting policy would only affect trees on private lands and would not pertain to green spaces such as parks, fields, and gardens. Again, this permitting process is meant to maintain trees on private lands and minimize the removal of native and non-native species deemed beneficial. However, it still allows for the removal of trees from these private green spaces and can be an inherent reduction. Therefore the potential for this policy to increase green spaces is low.

Equity

Sociocultural Benefits, Low/Medium - Maintaining canopy cover provides co-benefits to private landowners and neighboring or passing citizens. However, the responsibility of applying for the permit and the cost of cutting a tree down falls to the private landowner. If they forgo the permitting application process, then they are monetarily responsible for the fee and the loss of a tree indicates the loss of co-benefits and equal access to citizens. If private landowners do choose to support and comply with the permitting process, then those co-benefits can be provided or maintained, though the permitting process is meant for the removal of trees and therefore there is an inherent loss in benefits.

Political Feasibility

Stakeholder Support, Low - Private landowners are the primary stakeholder within this permitting plan and improvement in canopy cover benefits is dependent on their willingness to support this new policy. If provided with sufficient information on the monetary, environmental, and health benefits, these stakeholders could actively engage in the process. However, this is dependent on their willingness to take these extra steps. Enforcement is also required, but is currently lacking in other policies that are in effect.

Efficiency

Sequestration Potential, High- Implementing a tree protection permitting system allows for control of tree cover on private lands that would otherwise go unchecked. Requiring private landowners to apply for a permit to cut down their trees will help to maintain current canopy cover and in doing so support GHG carbon sequestration. Carbon sequestration is dependent on tree species and environmental conditions. As these trees may be native or non-native and likely weren't chosen for sequestration but rather ornamental purposes, the level of sequestration will vary and may be inefficient. However, this is dependent on the willingness of private landowners to comply with and actively take on the responsibility of this new permitting system. Carbon storage stock is also dependent on the willingness of private landowners to comply and support this tree protection permitting system. It is also dependent on what tree species are already in place, just as carbon sequestration is. The desired rate of carbon storage stock may not be ideal, but if carbon is being stored then it contributes to a more efficient storage system. The level of storage is also species dependent and will vary.

C. Urban Tree Credit (Stormwater Management Tree Credit)

Equity

Sociocultural Co-benefits, Medium/High - One person in a neighborhood benefiting from utilizing the tree crediting system will subsequently benefit the homes around it too in terms of runoff reduction, heat reduction, increased property value, and beautification. A landowner does not need to pay to apply to receive these credits so there is no monetary roadblock restricting a landowner from applying. The addition of trees to a neighborhood creates a closer, healthier community.

Political feasibility

Stakeholder Support, Medium/High - Landowners and developers are the two largest stakeholders involved in the tree credit program. Developers might support these credits so they may incorporate trees and other natural mitigation methods in lieu of traditional structural runoff mitigation methods that typically come at a higher price. Landowners would have to opportunity to earn the credits while concurrently increasing their property value but some landowners may not want to live in a neighborhood dominated by trees or have their neighbors trees too close to their property line.

Efficiency

Potential GHG Sequestration, Medium - Implementation of a stormwater management tree credit system will slow the rate of the disappearing urban canopy and therefore should retain higher rates of GHG sequestration across the island. GHG sequestration rates should begin to increase after the implementation of this crediting system as more landowners and developers are incentivized to maintain & plant trees and incorporate trees into runoff mitigation plans, respectfully. In order for landowners and developers to gain the biggest benefit from these credits, they will most likely utilize trees that are most effective and efficient in retaining runoff water, which, is largely dependent on the tree's leaf-area being extensive and thick, and that is often a characteristic of trees that tend to sequester the more carbon than the average. Though, trees selected for this credit will likely balance between optimal stormwater retention potential and ornamental purposes. A major limitation to the potential GHG sequestration is that this credit system will only succeed in increasing sequestration if the credits are actually known by the public to be accessible and landowners are aware of what exists on their property, feasible additions they can make, whether or not they are eligible for a credit, and if they are capable of maintaining their trees.

Potential Canopy Growth, Medium/High - A major advantage of a stormwater management tree credit is that the urban canopy has great potential to grow in areas beyond that of public lands (i.e. parks, streets, and gardens) and rather extend the efforts of canopy growth into privately owned urban plots. Urban neighborhoods and suburbs, which make up the greatest portion of Honolulu, would be most affected by the implementation of this program and would see the greatest urban forest growth. If the urban tree credit is widely adopted and utilized by landowners, then it is to be expected that there will be a reversal of the decreasing urban canopy as there is now a factor persuading landowners to preserve their trees rather than remove them. Limiting factors again lay in the knowledge of the landowner but also the restriction of trees in certain areas due to power lines, over which Hawaiian Electric Company has control.

Environmental Co-Benefits, Medium/High - Though the implementation of a stormwater management tree credit program may prove high in cost to the State initially, especially when awarding credits to landowners over developers, the potential resulting values of the co-benefits can equal, if not exceed, the initial price. Citizens in Honolulu, in 2008, received **$2.98 in benefits from trees for every $1 spent on tree care** (Vargas et al., 2008). Meaning, urban street trees in Honolulu averaged at a **2.98 benefit-cost ratio**. The credit's main goal is to significantly reduce storm runoff (erosion, nutrient & sediment transport, pollution runoff), but in doing so, these trees are providing many other co-benefits. Many developers and landowners will select trees for beautification as well as function and this has a value both in property value, and a bit more abstractly, mental health and wellness. The trees most likely selected for runoff, will have large canopies which yield the largest benefits and provide the largest potential for heat reduction and energy savings.

D. Stormwater Fee Discount

Equity

Sociocultural Co-benefits, Low/Medium - The fee imposed on all private landowners will be attempted to be made equitable through adjusting the fee based on tax brackets or actual water usage. No matter, the fee will affect some landowners differently. Landowners with large plots will likely be able to benefit more from this program it may prove easier for them to implement permeable surfaces and trees. Some commercial institutions, like the airports, who cannot greatly reduce impervious surfaces, may suffer fees that significantly hinder their operations.

Feasibility

Stakeholder Engagement, Low - Since every landowner, public and private, will be subject to this fee, the stormwater fee and stormwater discount fee programs will likely need to be voted into legislature and the public, at this moment in time, does not possess necessary knowledge of the return value of trees to likely vote on implementing this new fee and understanding the motivation and true benefits behind it.

Efficiency

Potential GHG Sequestration, Medium - The cost of implementing this fee will not come at a large cost to the State, but the potential to sequester GHGs is hindered in the sense that there is not tree requirement for the fee reduction, rather just that there is a maintained or increased pervious groundcover. This policy though will pose as a strong incentive for commercial and private properties alike to maintain larger plots of permeable land, ideally soil. A tree is usually most productive in terms of sequestering GHGs when has reached maturity, and a tree's likelihood of surviving to maturity is greatly increased with an increase to bulk soil volume, which will be ideally improved through this policy.

Potential Canopy Growth, Medium - Since there is no tree requirement in order to receive the fee discount, this policy does not ensure optimal canopy growth but it can be assumed that trees growing in conditions created under this policy are likely to thrive and survive. Since this fee is applied to everyone within the city limits, it will greatly motivate private landowners to modify their land to be more efficient in terms of water retention, assumingly mostly through trees, to avoid the full fee and thus grow the urban canopy.

Environmental Co-Benefits, Medium/High - The cost of implementing this program will be relatively low for the State and will eventually be profiting from the stormwater fees which can then be allocated to other government and nonprofit organizations that support the growth of the urban canopy and the co-benefits of trees. Ideally a set portion of the fees collected will go into outreach programs to educate the public on the importance of an urban canopy. Since this fee is affecting both private and commercial land, the stretch of the benefits of this policy is far-reaching within the city limits and will produce great reductions in stormwater runoff.

E. Tree Purchasing and Installation Rebate

Efficiency

Potential GHG Sequestration, Medium - Since rebates can be manipulated to encourage the planting of certain kind of trees, 100% rebates can be offered for trees that are determined to sequester the most carbon for its environment as determined through iTree. It cannot be guaranteed that every time a landowner decides to utilize a rebate to install will be a maximum sequestering species-100% rebates should also be offered to large, native species as well and other native, and some non-native species, will just adjusted lower rebate rates ranging from 50-80%. In order for this incentive to be successful, landowners have to activity seek the use of the rebate, so knowledge of the program is required. In order for the incentive to be efficient in terms of GHG sequestration, the tree must be well-maintained and survive until maturity (when trees sequester the most carbon) to offset the price of implementation, and this may prove to be a challenge as most of these trees being planted will be their youth and it is the responsibility of the landowner to maintain it to maturity .

Potential Canopy Growth, Medium/High - This is the only policy alternative that focuses solely on the planting of new trees rather than boasting an aspect of the policy to maintain current canopy. The implementation of trees on private lands will be relieved of the initial price of hosting a tree on property, which may incentivize landowners to use the rebate and begin reaping the benefits of trees their private land.

Environmental Co-Benefits, Medium - The trees will be largely at mercy of the landowner once it is on his or her property. The landowner may not be knowledgeable on how to maintain a fully functional and healthy tree. The landowner may only host the tree for a short period of time before deciding to remove it, before it had time to provide all its potential co-benefits where Vargas et al. 2008, found that, on average, an inventoried street tree in Honolulu had **annual benefits of $90 per tree/year** and **$60 of net annual benefits.**

Political feasibility

Stakeholder Engagement, Medium/High - The largest stakeholders are local nurseries, who will participate in the rebate, landowners, who want to develop a canopy on their property, and State workers who will be responsible for trimming or removing trees on private land that were not well-maintain or planned and now pose a danger. Nurseries will likely see a boom in business, landowners will likely take advantage to plant trees on their land to enjoy the benefits, and the state may risk losing money in that if landowners do not maintain their trees until the point the cost-benefit breaks even or if the maintenance of threatening trees becomes too great. Vergas et al. 2008, determined that, on average, an inventoried street tree in Honolulu required **$30 of maintenance per year.**

Equity

Sociocultural Co-benefits, Medium/High - Rebates will hold stable for any landowner who wishes to partake and can prove their land is adequate to host a tree. Disadvantaged areas that before were not benefitting from current forestry programs could partake in the rebate and begin developing their urban canopy. Having a wide variation of rebates, and focusing on giving greater discounts to native tree species, may allow for a diverse native urban forest that satisfy the cultural desires for some landowners.

F. Current Policy Expansions

GHG Sequestration

Increased Urban Canopy Cover, High - The expansion of current policy calls for additional protections for trees from existing programs and organizations. We see the value and impact that current policies have and propose that limitations of current policies would be addressed if more funding or expansion of these programs was allowed. Our team rates this alternative as having a high impact rating meaning it will significantly contribute to the protection and planting of new trees to provide future canopy cover for Hawaiʻi.

Increased Green Space, Medium - Expanding policy that protects canopy cover aligns with the promotion and existence of green spaces. As tree plantings and protections are supported through additional funding, legislative initiatives and organizations, we expect to see an increasing support and emphasis for the designation and creation of green spaces. For this reason, we scored green spaces with a high impact rating for policy expansion.

Equity

Sociocultural Benefits, Medium - Expansion of current policy would ideally increasing funding and outreach for programs and organizations. Our team concludes that field work mapping and collecting inventories for trees in urban and non-urban communities would extend further. With these ambitions, we propose that benefits to society would be spread more vastly among both urban and non-urban populations in Hawaiʻi. We further determine that this would fall under a rating scale of medium in that some improvements would be observed, however, there are still limitations to how much these benefits would extend. We believe there are more equitable policy alternatives that could have a larger sociocultural impact considering the expansion of current policy is not widespread as it could be, thus receiving a rating of medium for this policy alternative and impact category.

Political feasibility

Stakeholder engagement, High - Due to the nature of this policy alternative, the expansion of current policies would result in higher stakeholder engagement. Current organizations are collaborating and generating data and reports that can be openly access and shared with the public and with other organizations. We expect these collaborations and stakeholder engagement to increase if additional funding and supportive policies were enacted and available. In regards to political feasibility, we rated stakeholder engagement with a high score in hopes that increases and expansions to current policies would foster further collaboration between programs and organizations.

Efficiency

Sequestration Potential per Cost, Medium - Current policy expansions will advance our sequestration goals. We suggest that programs such as the Exceptional Tree program, the Tree Acquisition Program, the Citizen Forester Program, Citizen Forester Inventories, the Community Recreational Gardening Program and Trees for Honolulu's Future are a step in the right direction. With continued funding and support, we believe that these measures will help Hawaii reach its goals. The downside to this approach, as with the implementation of any policy, is that the benefits received will take some time to accrue. Furthermore, the costs associated with programs may not always be as efficient due to program structure and management. In this scenario, we see high potential for expansion of current policy, however, we assume high costs and delayed timing for the implementation process.

Table 1. Copied from Vargas, et al. 2008 describing costs associated with various aspects of urban forestry.

		Inventoried trees		
Expenditures	**Entire population ($)**	**Total ($)**	**$/Tree**	**$/Capita**
Purchasing trees and planting	250,000	46,456	1.06	0.05
Contract pruning	2,000,000	371,645	8.48	0.41
Removal	300,000	55,747	1.27	0.06
Administration	300,000	55,747	1.27	0.06
Inspection/service	95,000	17,653	0.40	0.02
Infrastructure repairs	2,467,890	764,317	17.44	0.84
Other costs	20,000	3,716	0.08	0.00
Total expenditures	5,432,890	1,315,281	30.02	1.45

X. RECOMMENDATION

In this section, we will provide a recommendation for which policy alternatives have the best potential to meet the stated goals of this analysis. For visual representation, a policy assessment matrix shows the summary of our assessment for each policy alternative.

GOALS	IMPACT CATEGORIES	POLICY ALTERNATIVES					
		Status Quo	Tree Permitting	Urban Tree Credits	Stormwater Fee Discount	Tree Rebate	Policy Expansions
1. GHG Sequestration	Increased Urban Canopy Cover [Low-High]	Low	Low	Med-High	Medium	Med-High	High
	Increased Green Space [Low-High]	Low	Low	Med-High	Med-High	Medium	Medium
2. Equity	Sociocultural Benefits [Low-High]	Low	Low-Med	Med-High	Low-Med	Med-High	Medium
3. Feasibility	Stakeholder support [Low-High]	High	Low	Med-High	Low	Med-High	High
4. Efficiency	Sequestration Potential Per Cost [Low-High]	Low-Med	High	Medium	Medium	Medium	Medium

To evaluate and compare each policy alternative, we assigned a numeric scale from one to five following our qualitative rating scale from low to high. This allowed us to compute a final score for each policy alternative and rank them. Additionally, we placed a weighted emphasis on our our first impact category of increasing canopy cover by multiplying the scores in this category by a factor of two. The reasoning for this is that urban canopy cover itself is central to and an underlying basis within subsequent impact categories. The tables below show how these values were calculated:

Policy Alternative Final Scores	
Policy Alternative	**Weighted Score**
Current Policy Expansion	24
Urban Tree Credit	23
Tree Planting and Installation Rebate	22
Stormwater Fee Discount	18
Tree Permitting	11
Status Quo	11

Scale for Scoring	
Low	1
Low/Medium	2
Medium	3
Medium/High	4
High	5

Based off of the evaluation of the five policy alternatives, our analysis shows that several of the alternatives rank comparatively high. However, the expansion of current policies and proposals had the highest weighted score of 24 (out of a possible 30 maximum), making this the top policy alternative and our final recommendation. The greatest gains in GHG sequestration and the other stated goals of equity, feasibility, and efficiency will be made by expanding the existing framework for urban forests in Hawaiʻi, instead of re-inventing the wheel to develop and implement a new system that is likely to be politically unpopular. There are likely to be roadblocks and tradeoffs associated with these proposed actions mainly in the form of a lack of funding and manpower, as is often the case. Another trade-off associated with these proposals is that they primarily focus on tree preservation and planting, as opposed to the planting of new trees or creation of additional green spaces. The program changes we have proposed should help to overcome this particular tradeoff by expanding incentives to promote tree plantings.

To implement the proposed changes to existing policies and programs, we suggest that the GHG Sequestration Task Force establish a provisional committee to establish consistent funding for urban forest programs. There are a number of agencies and organizations involved in urban forests to varying degrees around the state. Providing a unified body focused on obtaining and providing funding for these groups would allow them to spend more of their human and natural resources conducting their work, and would ensure they have the necessary resources to continue doing so.

XI. CONCLUSION

A number of government and market failures have contributed to the loss of urban forests and green spaces throughout Hawaii. Lack of regulation and expanding urban sprawl have resulted in increasing development that impacts existing trees. As a result, co-benefits such as carbon sequestration, heat reduction, energy savings, and preventing water runoff from these green spaces has also decreased. In today's context, it is of utmost importance to address urban forestry as a potential solution to meet our carbon neutrality goals by 2045. The goal of this policy analysis was to identify natural solutions to increase GHG sequestration through the use of urban forests. After extensive research and review, we developed five policy alternatives (including the status quo) to evaluate in terms of their potential to increase GHG sequestration, while keeping equity, feasibility, and efficiency in mind. The result of our analysis and assessment shows that expanding the current programs and policies in Hawaiʻi that are established to support urban forests is the optimal policy recommendation to achieve all goals .

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XIII. APPENDIX

Table 2: Agency stakeholders relevant to urban forestry

Stakeholder	Structure	Contribution	Website
USDA Forest Service	Federal Government	- Urban and Community Forestry Program - Urban Research - Technology and Science Delivery	Link

		- Urban National Forests	
Department of Land and Natural Resources	State Government	- Funds and supports numerous urban forestry programs	Link
Division of Forestry and Wildlife	State Government	- Provide outdoor recreation - Facilitates partnerships, involvement and education - Manage watersheds & native ecosystem	Link
State of Hawaii Office of Planning	State Government	- Greenhouse Gas Sequestration Task Force	Link
Department of Parks and Recreation	City and County of Honolulu	- Honolulu Botanical Gardens - Horticulture Services Branch - Trims and maintains trees obstructing street lights, power lines and roadways - Issues permits for planting and removing trees	Link
Division of Urban Forestry	City and County of Honolulu	- Plant, remove, maintain trees along public roads & parks - Reviews & inspects subdivision plans - Grants special permits - Grows specimen trees - Conserves valuable trees from development - Maintain tree banks and 5 tree nurseries - Tree Acquisition Program	Link
Hawaiian Electric Company	Utility	- Energy provider for 95% of the Hawaiian population - Innovative energy leadership for Hawaii seeking cleaner, more efficient energy use -	Link
The Outdoor Circle	Non-profit	- Plant and protect trees - Defend view planes and open space - Promotes and sponsors community beautification	Link
Trees for Honolulu's Future	Non-profit	- Raise Public Awareness of Tree Benefits - Develop Curriculum for schools - Increase public and private funding of tree planting and maintenance	Link
Aloha Arborist Association (AAA)	Non-profit	- Promotes public education for shade trees - Hawaii Tree Climbing Championship	Link
Smart Trees Pacific	Non-profit	- Urban Tree Canopy Assessment - Citizen Forester Program - Arbor Day Hawaiʻi - Hoʻolāʻau: Communities Growing Trees Together	Link
HHF Planners	Private	- Environmental and facilities planning - Prepare master plans, site analysis/selection, feasibility assessments, landscape designs, environmental assessments and impact	Link

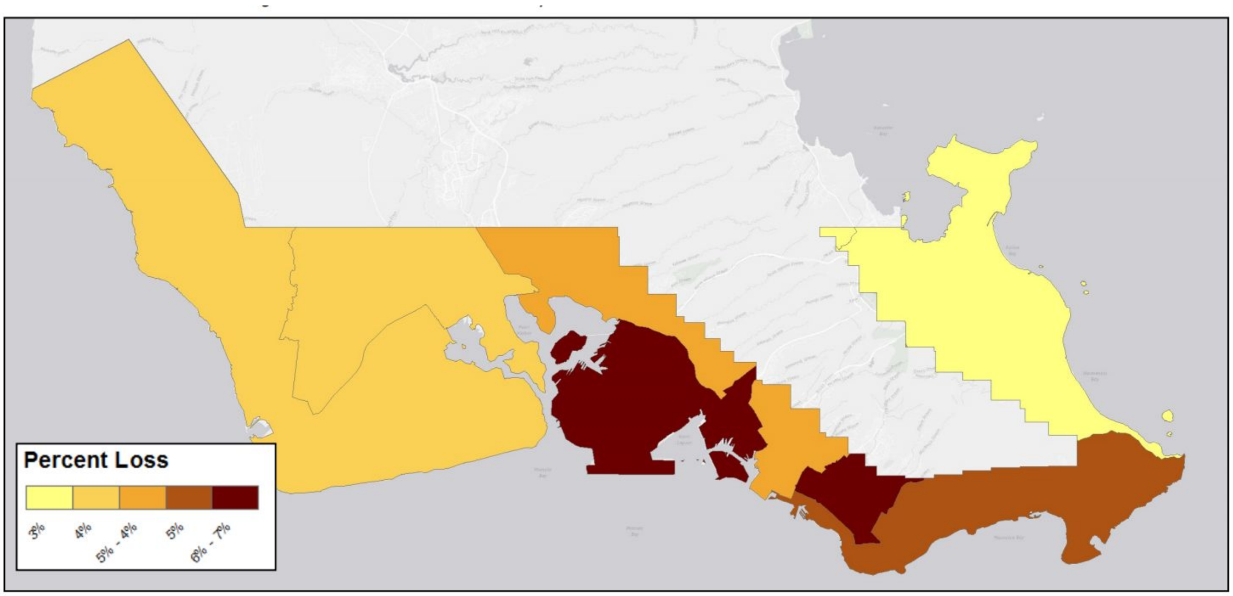

Figure 1: Tree canopy percent loss between 2010-2013 for Council Districts on O‘ahu

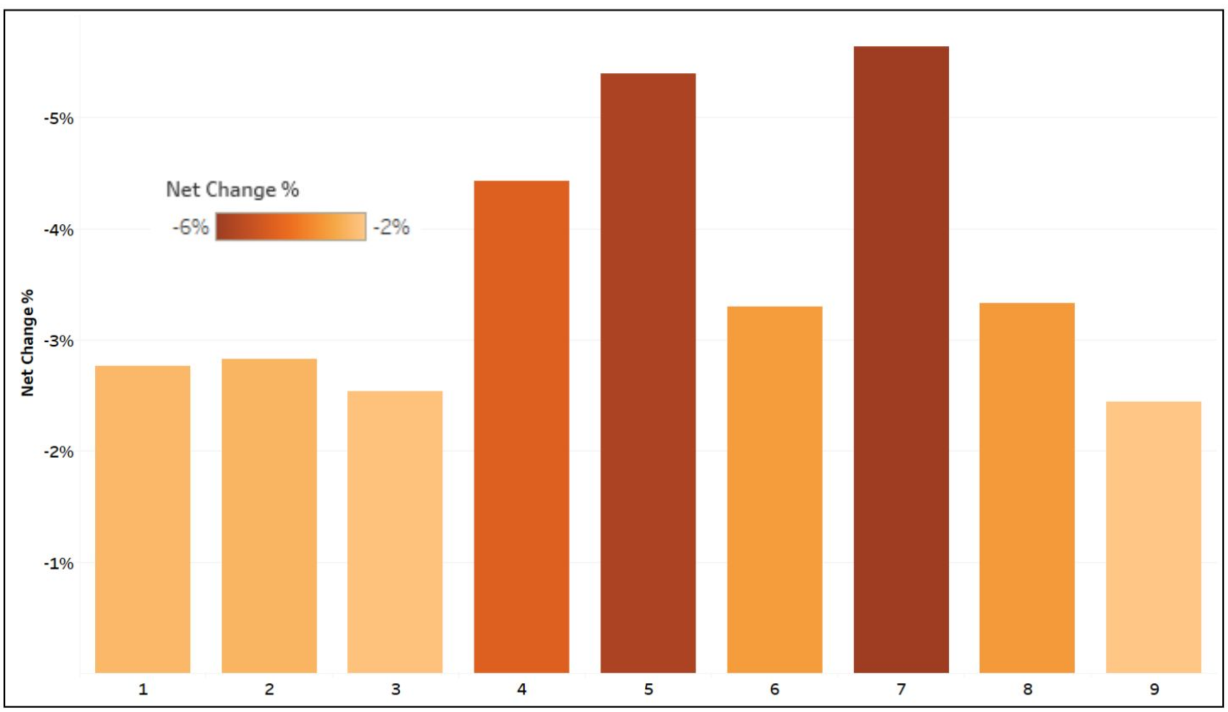

Figure 2: Tree canopy percent net change between 2010-2013 for Council Districts on O‘ahu

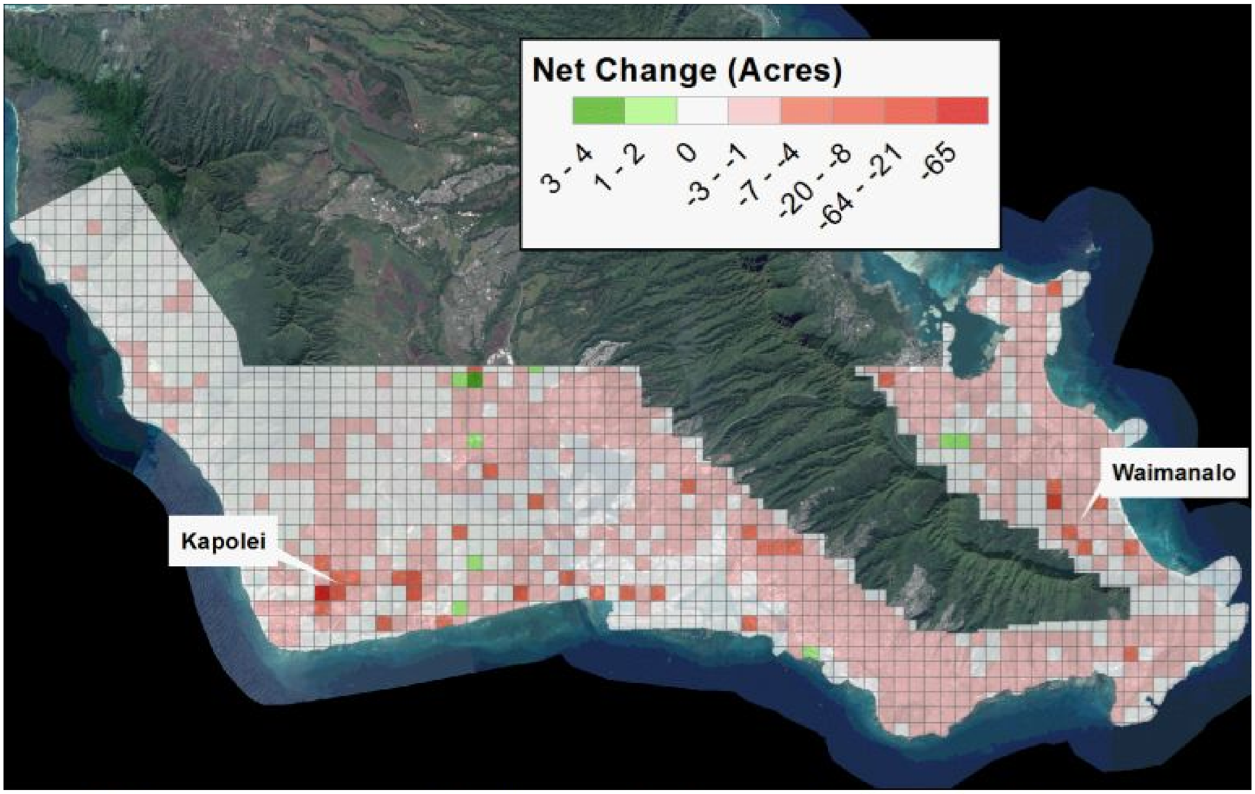

Figure 3: Net change in tree canopy area (acres) between 2010 and 2013. Cells in the grid measure 750 x 750 meters.

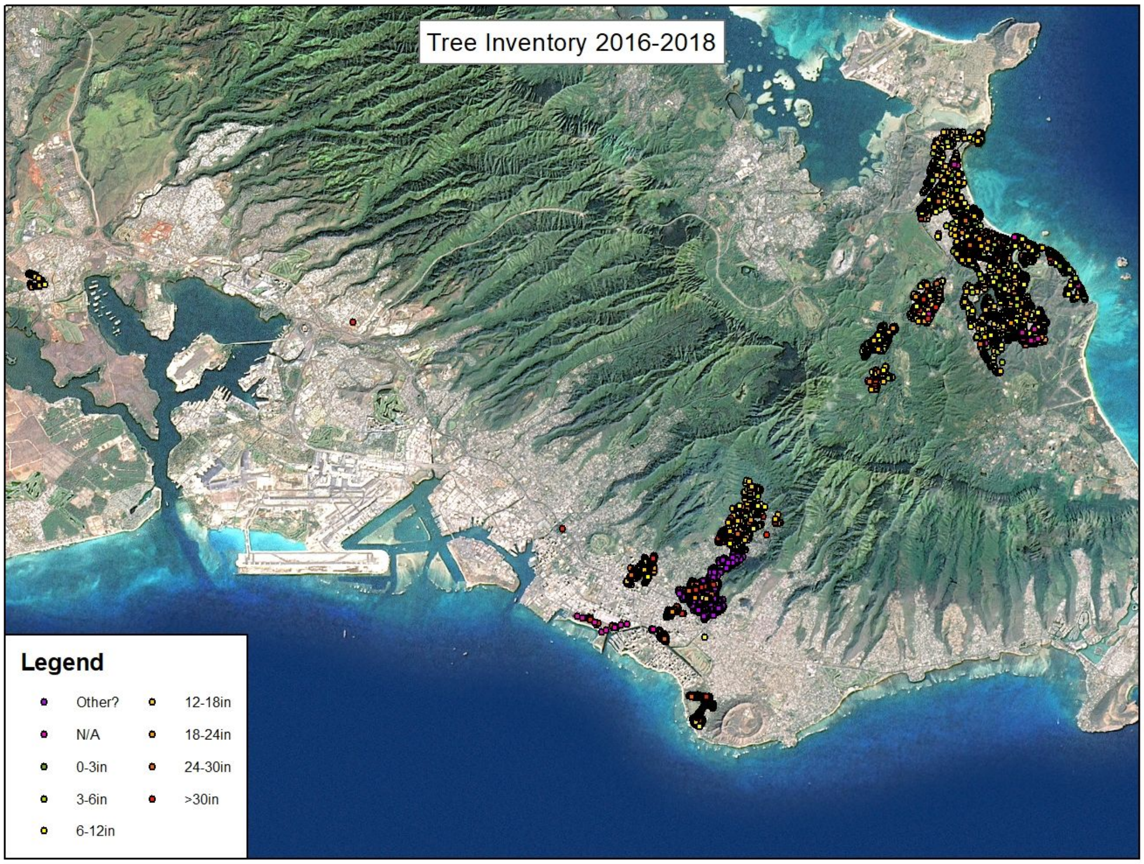

Figure 4: Urban tree locations surveyed through the Citizen Forester Program in the Tree Plotter Report according to DSH