He Ana Hoʻākoakoa O Ke Kula Nui O Maui

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Introduction

Kaulunani Urban Tree Canopy

Kaulunani Urban and Community Forestry Program of the Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW), and Private Forestry developed The Kaulunani Urban Tree Canopy in Hawaiʻi tool as an interactive web-based ArcGIS platform that displays a complete tree canopy layer for Hawaiʻi including other information—such as the extent of ahupuaʻa boundaries, canopy and census statistics, tree canopy, urban canopy cover, population, Native Hawaiian population, SNAP recipients, socioeconomic and health data, and urban heat severity maps, to name a few.

These datasets provide information to help us understand differences in the distribution of tree canopy and available biocultural resources across communities. They can also aid in prioritizing urban restoration goals (e.g., tree planting, monitoring, and maintenance) to equalize the benefits of tree canopy across all communities. This project was made possible by the support of the Kaulunani Urban and Community Forestry Program of the DLNR Division of Forestry and Wildlife, and State and Private Forestry, branch of the U.S. Forest Service, Region 5.

O ka lāʻau o ke kula e noho ana i ka ʻāina, o ka lāʻau o ka ʻāina e nalowale aku ana.

The trees of the plains will dwell on the land; the trees of the native land will vanish—a prophecy uttered by Kalaunuiohua. Trees from the plains of other lands will grow here, and our native trees will become extinct.

-ʻŌlelo Noʻeau #2413 (Pukui 2011)

Kauluwehi Biocultural Restoration Project (KBRP)

KBRP is at the University of Hawaiʻi Maui College (UHMC) in Kahului, in the northern part of the island of Maui, one of the Major Hawaiian Islands (MHI). KBRP was a capstone project for an aquaponic and greenhouse technician non-credit certificate emphasizing added value to ethnobotanical flora (biocultural) resources (Morishige et al., 2018). Our higher education journeys are shaped by those who have come before us—those who created and sustained a cultural kipuka for our development (Meyer, 2003).

Kauluwehi is home to diverse native and introduced nā lāʻau (plants) (Abbott, 1992), promoting cultural resources and sustainable food crops that feed the community. A priority of Kauluwehi is to ensure that living laboratories become a source of biocultural, regenerative, and added value to different species of flora that support the healing of kānaka ʻōiwi communities as well as reconnecting pilina (relationships) with the natural environment. Kīpuka (opening in a forest) divides the garden into different zones: dry land forest, cultural sections for hula (dance to describe kanaka ʻōiwi history), lei (garland of lāʻau), lāʻau lapaʻau (medicinal lāʻau), māʻawe (fiber arts), and waihoʻoluʻu (dye) in the southern entrance, a central section for traditional farming māla maloʻo (dry garden) kalo *(Colocasia esculenta), ʻ*uala (*Ipomoea batatas*)*,* maiʻa *(Musa spp.),* and ʻōlena (*Curcuma longa.)*; the northern section māla lāʻau huaʻai (orchard) features a variety of tropical fruit trees. Over four years, Kaluwehi distributed nearly 9,000 pounds of kalo, maiʻa, ʻulu, exotic fruits, and cassava (*Manihot esculenta*) to native Hawaiian community entities, which have easily distributed these quantities. There is, therefore, potential for considerable expansion with proper support. Being able to provide healthier food sources is essential for a healthy lāhui. The next step is to develop a ranking system to value **nā kumu lāʻau** (trees) appropriately by conducting interviews with practitioners, **kūpuna** (elder), and **kumu** (source of knowledge). Participants at Kauluwehi practice **kilo** (careful environmental observations) and draw on **ʻike kūpuna** (ancestral knowledge) as indigenous and intergenerational science finds new relevance to modern projects and lifeways across our **pae ʻāina** (archipelago).

PC: Todd Mizomi, UHMC Manu view of Kauluwehi Biocultural Restoration Project

Projects like Kauluwehi can provide transparency of the needs of identified communities using the Hawaiʻi Urban Tree Canopy Viewer. The canopy can also help urban planners, decision-policy makers, and the general community to gain knowledge from public information on why it may be essential to reestablish native trees that may be more resilient to severe climate change.

Methods

I followed an ‘ike kūpuna, ‘ike ‘āina approach in my work with lā‘au, shaped by my hula training and conservation work experience. ‘Ike ‘āina kūpuna-based education is a Hawaiian ancestral knowledge framework drawing on Hawaiian cultural practices, including kilo (critically observing environmental changes), kanu (plant and harvesting lā‘au), oli(chants), mele (songs), ka‘ao (ancient stories), and kuahu (altar) to engage students in STEM education (Irvine, 2021). I was experiencing environments and ancestral frameworks key to engaging the intelligence of ‘ike kūpuna of lā‘au. Kilo utilizing ‘ike kūpuna, quantifying the qualitative knowledge of our ancestors, inspires us to perpetuate the wisdom of how they co-existed with nature and elemental deities for eons. Critically observing our surroundings, abiotic or biotic, was practiced by ancient people worldwide, including ancient kanaka ‘ōiwi. These practices led to researching the value of native Hawaiian trees, comparing them to non-native Hawaiian trees, and how to incorporate more Hawaiian flora into urban ‘āina (landscapes) (Deluze et al., 2023).

Kilo: Kauluwehi and UHMC Tree Survey

From a lepo (ground) view, I identified, surveyed, and mapped the trees on the Kauluwehi and UHMC campuses utilizing Locus Map Pro©. Locus Map Pro allows entry of individual trees with a photo and geolocation. We collected in physical and digital formats for a double verification system confirming correct data entry before data analysis. The study area included all publicly accessible areas on the UHMC campus divided into four polygon zones: Mauka North and South and Makai North and South. The survey included 1,213 individual trees with the following parameters: accession, scientific name, status (living and dead), vernacular name, ‘ohana name, and DBH (Diameter at Breast Height) in cm. Only trees with a minimum height of 1.3 meters (4.5 feet) or 3 cm minimum diameter were surveyed.

Following a format adopted by the University of Hawai‘i Mānoa Plant Finder (https://www.hawaii.edu/news/2023/04/21/grow-for-it-explore-uh-manoa-plants/), I classified trees as native if they colonized the islands via wind, water, or wings; this included endemic plants (found only in Hawai‘i), and indigenous plants (found in Hawai‘i and elsewhere) (Loope, 1998). Non-native species included plants introduced via wa‘a or post-(European) colonization. Additionally, we identified Hawai‘i Weed Risk Assessment (HWRA) risk scores for each species and recorded them in Google Sheets. I then compared the overall Kauluwehi Biocultural Restoration Project with the UH Maui College campus surveys.

Manu View: Near Real-Time Ecosystem Monitoring Tool Development

We explored innovations in satellite remote sensing to develop near-real-time applications for characterizing the tree canopy structure in UHMC over time. The spatial extent and overlap of the Kaulunani Tree canopy layer, Global Canopy Height Model, and Field Kumu La’au surveys were evaluated using a combination of Google Earth Engine, ArcGIS Pro, and ArcGIS Online.

The canopy height was determined using the global tree canopy height model for 2021(Lang et al. 2021). The Global tree canopy height model is derived from near-real-time Sentinel 2 satellite observations and spaceborne LiDaR from the Global Ecosystem Dynamics Investigation (GEDI). We investigated the integration of high-resolution (10m) Global Tree Canopy Height model data with the Kaulunani Tree Canopy Viewer to characterize the biophysical structure and properties of tree canopy in urban and community forests. We used field-based tree surveys to ground truth and evaluate the accuracy and potential limitations of the Global Tree Canopy Height model.

Preliminary results show > 90% agreement between the Kaulunani Tree Canopy layer and the Global Tree Canopy Model. We also found that DBH and Tree Canopy Height values were correlated with $R^2 = 0.667$, n=180. In areas where trees are short in stature and sparsely distributed, we found that both the Global Tree Canopy Height model and Kaulunani often failed to resolve these features.

Taken together, these preliminary results suggest that the Global Tree Canopy Height model may be helpful for both quantifying and tracking the structural properties of tree canopy in Kauluwehi and UHMC, where the canopy is relatively tall and or densely distributed. Further work on developing this application of the Global Tree Canopy Height model and the Kaulunani Tree Canopy layer to include primary production estimates and above-ground carbon density (Asner et al. 2016) will be explored in future investigations following this fellowship. We intend to expand the scope of the study to include additional sites beyond UHMC. Airborne LiDaR data provides an essential snapshot of an ecosystem's biophysical structure and distribution. However, repeat observations are often limited by funding constraints and or access to providers. The Global Tree Canopy Height model data can provide time-relevant observations of canopy height that inform adaptive management and planning for decision-making and future policies in urban and community forest spaces.

Results

Manu View

The map below (Figure 1) shows the UH Maui College campus and the Kauluwehi Biocultural Restoration Project, the survey site of the 1,213 photo points. Comparisons between the KBRP and the remaining part of the campus were further analyzed to define metrics for impacts from a small 1-acre project on the rest of the campus that could have correlations to the tree canopy (Figures 2 and 3).

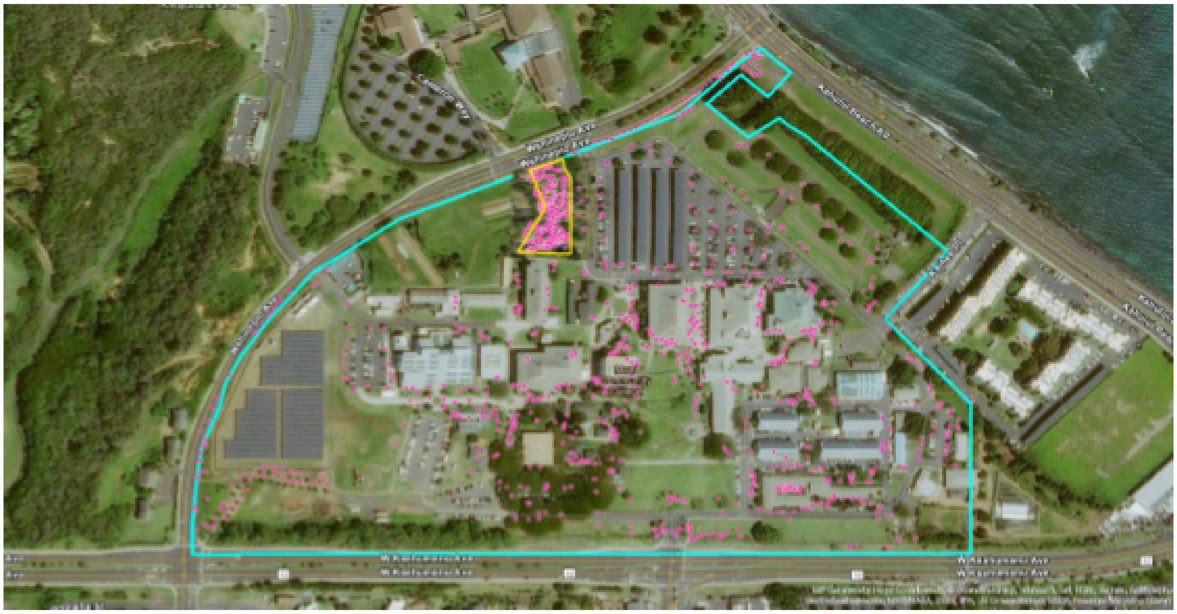

Figure 1: UH Maui College campus and the Kauluwehi Biocultural Restoration Project, the survey site of the 1,213 photo points.

Figure 2: Kaulunani Tree Canopy Viewer, University of Hawaiʻi Maui College, Kahului, Maui. Dr. Kealohanuiopuna Kinney

Lepo

The surveys identified diverse tree species throughout Kauluwehi and the UHMC campus. These included trees that are Endemic (20.5% Kauluwehi and 16.4% UHMC), Indigenous or Indigenous/Waʻa (10.4% Kauluwehi, 23.2% UHMC), Waʻa (49.7% Kauluwehi and 8.3% UHMC), and Post-Colonization (19.3% Kauluwehi and 52.1% UHMC). Overall 23.2% of Kauluwehi trees are Native (Endemic, Indigenous) compared to 17.3% for UHMC, and 69.0% of

Kauluwehi trees are Non-native, compared to 60.6% for UHMC. Trees that are both native and non-native were 7.7% (Kauluwehi) and 22.1% (UHMC), and include indigenous species that arrived without the assistance of humans or brought on a canoe with the Polynesians (example: hala, *Pandanus tectorius*). Figure 4 lists the top identified native and non-native species.

Figure 3: University of Hawai'i Maui College, Kahului, Maui Sentinel-2 + GEDI Fusion, Dr. Kealohanuiopuna Kinney.

However, fewer plants chosen for Kauluwehi are high risk. During campus landscaping in that era, invasive versus native species was not a consideration. In the remaining campus regions, 60.3% of surveyed trees were non-native, and 52.1% of tree canopy represented post-colonial introduction. Indicators of high-risk species on campus are 21.5% compared with the 3.9% of Kauluwehi. Please refer to Figure 5.

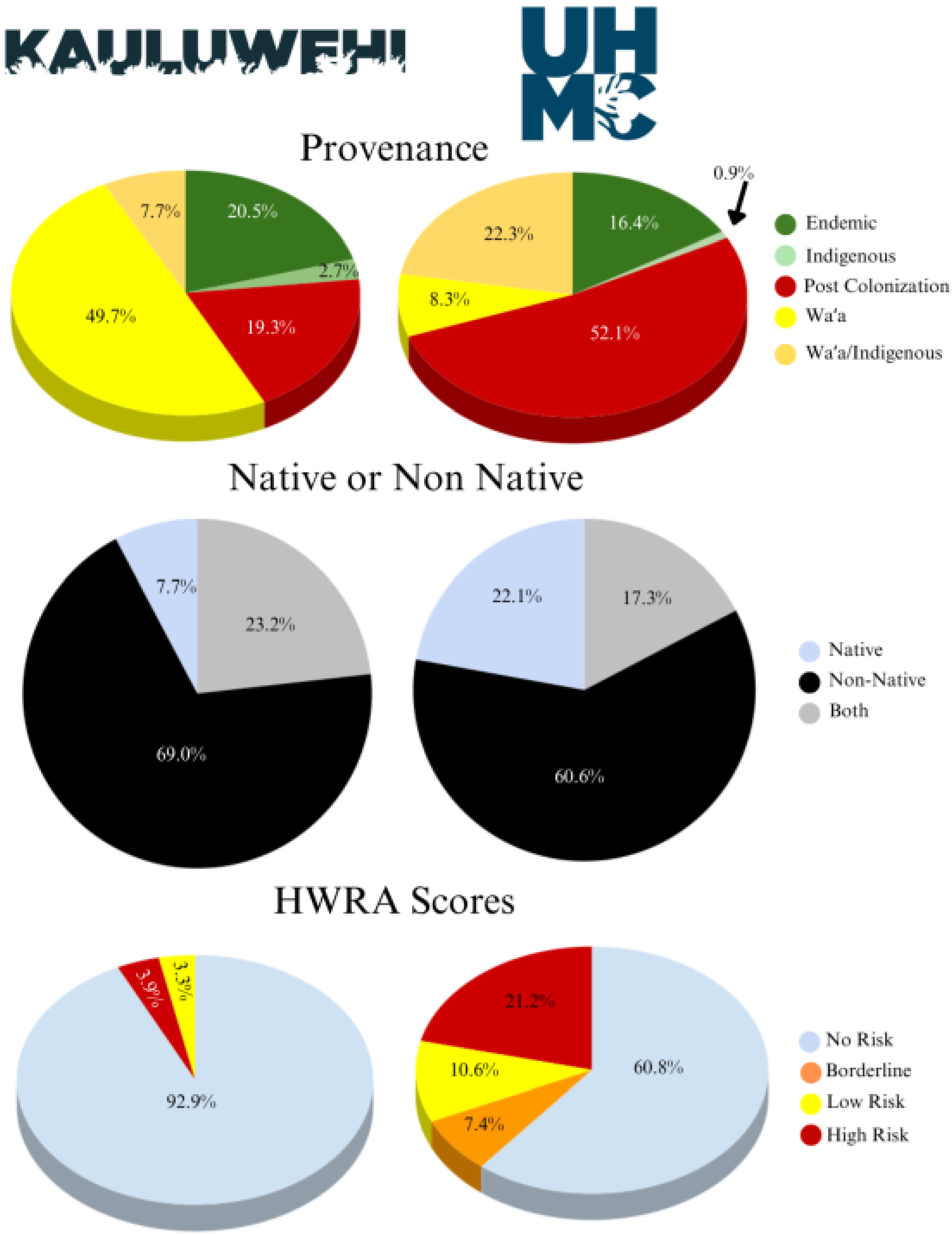

Figure 5: Pie charts describing the comparisons between Kauluwehi Biocultural Restoration Project and the University of Hawai‘i Maui College Campus.

Discussion

It took nearly three months to collect, record, and analyze the data and learn more about Pivot tables, ArcGIS online, and ArcGIS StoryMaps. Working with inspirational kānaka in academia added a more profound love and connection to developing biocultural indicators, remote sensing tools, and data management.

Using advanced technology and resources requires extensive time on the computer. This kind of project allowed me to understand why office staff spend so much time analyzing data. Learning to analyze unique large datasets with advanced programs was an exciting and educational experience that will continue because of the vast available options and tools.

Some concerns regarding ground and aerial photography with large datasets included the limitations of the tools using ArcGIS online. Datasets from LocusPro were challenging to work with, and photos and geolocations still need to be reconstructed.

Native flora restoration must occur for our urban spaces to provide ecosystem services providing shade cover, biocultural resources, and species that may be costly to manage. Before this fellowship and academic experiments, we must take on a larger kuleana and reconnect to our natural environments.

Future research

The vast amount of information included in nā mea Hawaiʻi (things about Hawaiʻi), moʻolelo (stories), nūpepa (newspaper), and scientific journals will allow me to continue this critical work creating biocultural and urban ʻāina restoration through the lens of our ancestors. As did our ancestors, we continue to look to the past for guidance and support to ma ka hana ka ʻike (through doing one learns) to become better kanaka ʻōiwi.

During graduate school, I plan to compare DBH and height extracted from the UHMC survey and LiDaR datasets so that future landscapers, urban planners, and decision-makers can choose more appropriate lāʻau Hawaiʻi to enhance ecosystem and biocultural services. I plan to prepare and conduct a community bio blitz using ArcGIS Survey123, which is an online ArcGIS app that will allow users to identify, geolocate, and add to the collective databases where native, non-native, or invasive species for land managers, planners, and decision-makers. I will need to locate reference materials and better identification aids for Palms and Ficus species, which are challenging to identify but commonly used and include many individuals on the Hawaii Weed Risk Assessment (https://plantpono.org/).

Conclusions and Recommendations

In the past decade, the renaissance and resurgence of Hawaiian culture continue to flourish, and our culture, traditions, practices, and language have inspired and changed how we understand

and look at the value of biocultural restoration. Identifying, recognizing, and restoring native flora builds on the tradition of pilina (relationship) with our natural environment. Kauluwehi Biocultural Restoration Project sets a foundation for the possibility of having urban kīpuka throughout the UHMC campus and other campuses to encourage this. kupukupu (growth) of traditional and ʻīke kupuna.

Because of the overwhelming support of my mother, mentors, colleagues, and peers, the Kauluwehi project applied for the USDA Forest Service Urban and Community Forestry Inflation Reduction Act Notice of Funding Opportunity (NOFO), (https://www.fs.usda.gov/sites/default/files/UCF-IRA-NOFO-04122023.pdf). If funded, this study will further impact our lāhui by providing future biocultural restoration projects and generating future konohiki (land managers) using ʻike kūpuna. An ArcGIS StoryMap may be found here with additional media (https://storymaps.arcgis.com/stories/041b2a3daaac432db7836b8f126d1584) and public product.

"Ka Wā Ma Mua, Ka Wā Ma Hope"

When translated from our language, "ka wa ma mua" literally means "the time in front." However, in Hawaiian thinking, it describes the time that came before this time in which we live. In the same vein, "ka wa ma hope" literally means "the time in back" or from a Hawaiian perspective, the time which follows this time in which we live. "It is as if the Hawaiian stands firmly in the present, with his back to the future, and his eyes fixed upon the past, seeking historical answers for present-day dilemmas."

(Kameʻeleihiwa, 1992)

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Appendix A

This figure describes the geospatial processing that incorporates Sentinel-2, CNN, GEDI, which could be available as additional layers and parameters for the Kaulunani Tree Canopy Viewer.

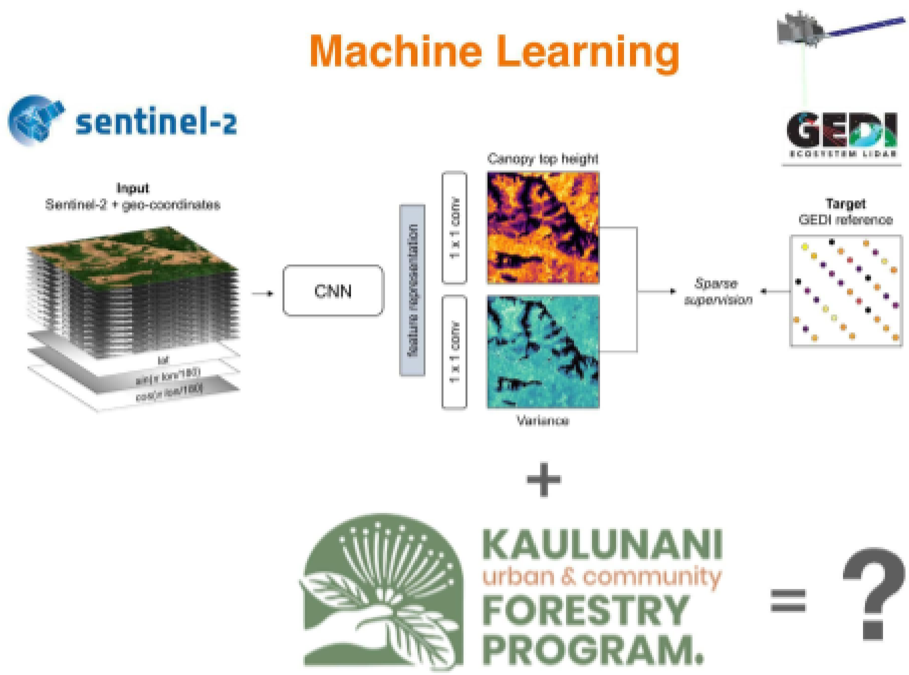

Figure 6: Machine learning process diagram. Sentinel-2 satellite images are processed through the Convolutional Neural Network (CNN), The fusion of datasets between Sentinel 2 (optical) made of 14 bands of light shortwave and near-infrared. Looking at all the spectral data in the relationship between height and the biome that the canopy used by GEDI (LIDAR). Dr. Kealohanuiopuna Kinney