Precision agroforestry inventory monitoring in the Marshall Islands

Ryan L Perroy

University of Hawai'i at Hilo

Pacific Geospatial Conference 2022

Nov. 30th

Collaborators & Project Partners

This project is a collaboration between:

- U. of Hawai'i at Hilo SDAV Lab
- Marshall Islands Conservation Society
- Republic of Marshall Islands Government
- U.S. Forest Service
- U.S. Geological Survey

Eszter Collier, Timo Sullivan, Aloha Kapono, Nai'a Odachi, Patricia Perez, Erin Weingarten, Dean Gesch, Dolores deBrum Kattil, Jason Henson, Charlie Tommy, Lakjit Rufus, Iva Reimers-Roberto, Martin Romain, Rémi Andreoli, Mark Stege, Katie Friday, and many others…

SDAV UH HILO

MICS Marshall Islands Conservation Society

USGS science for a changing world

FOREST SERVICE US DEPARTMENT OF AGRICULTURE

BLUE CHAM

Project Funding

This work is partially funded by:

- USDA Forest Service, Forest Stewardship program
- U.S. Geological Survey Pacific Islands Climate Adaptation Science Center (USGS PI-CASC)
- The Republic of the Marshall Islands Ministry of Natural Resources and Commerce
- The Global Environmental Facility (GEF) to the RMI Government with implementation support from the United Nations Development Programme (UNDP)

US Dept of State Geographer
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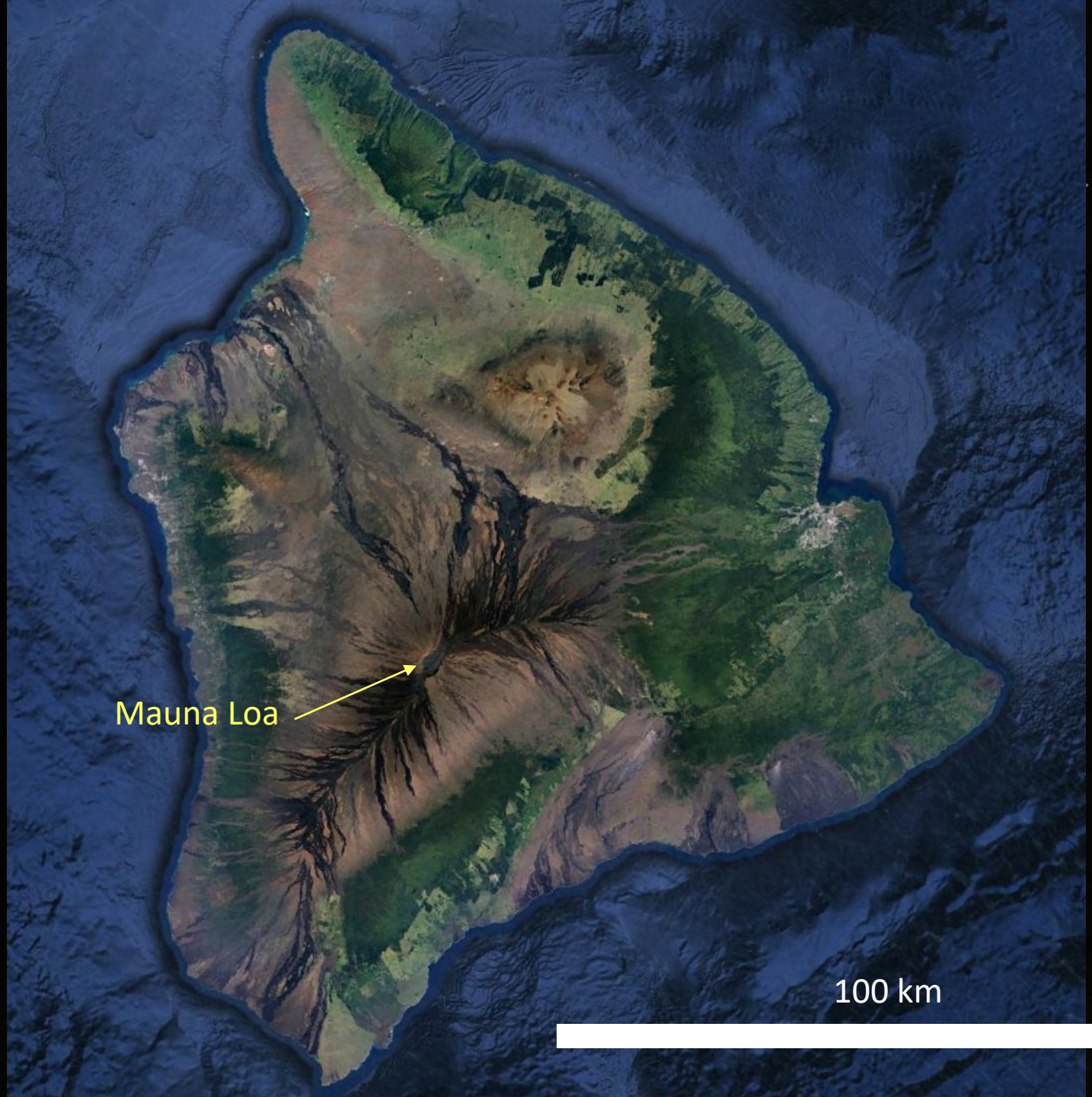
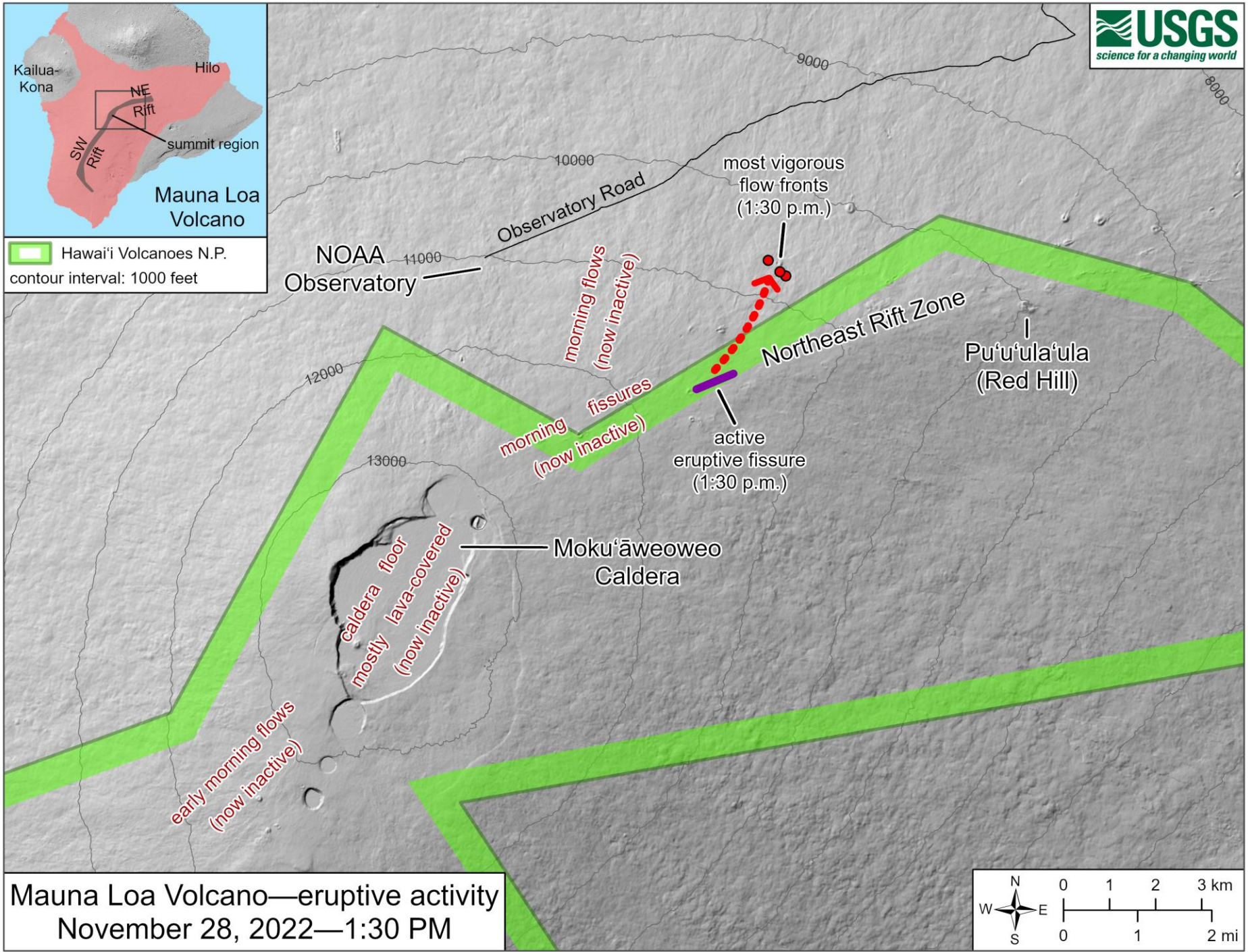
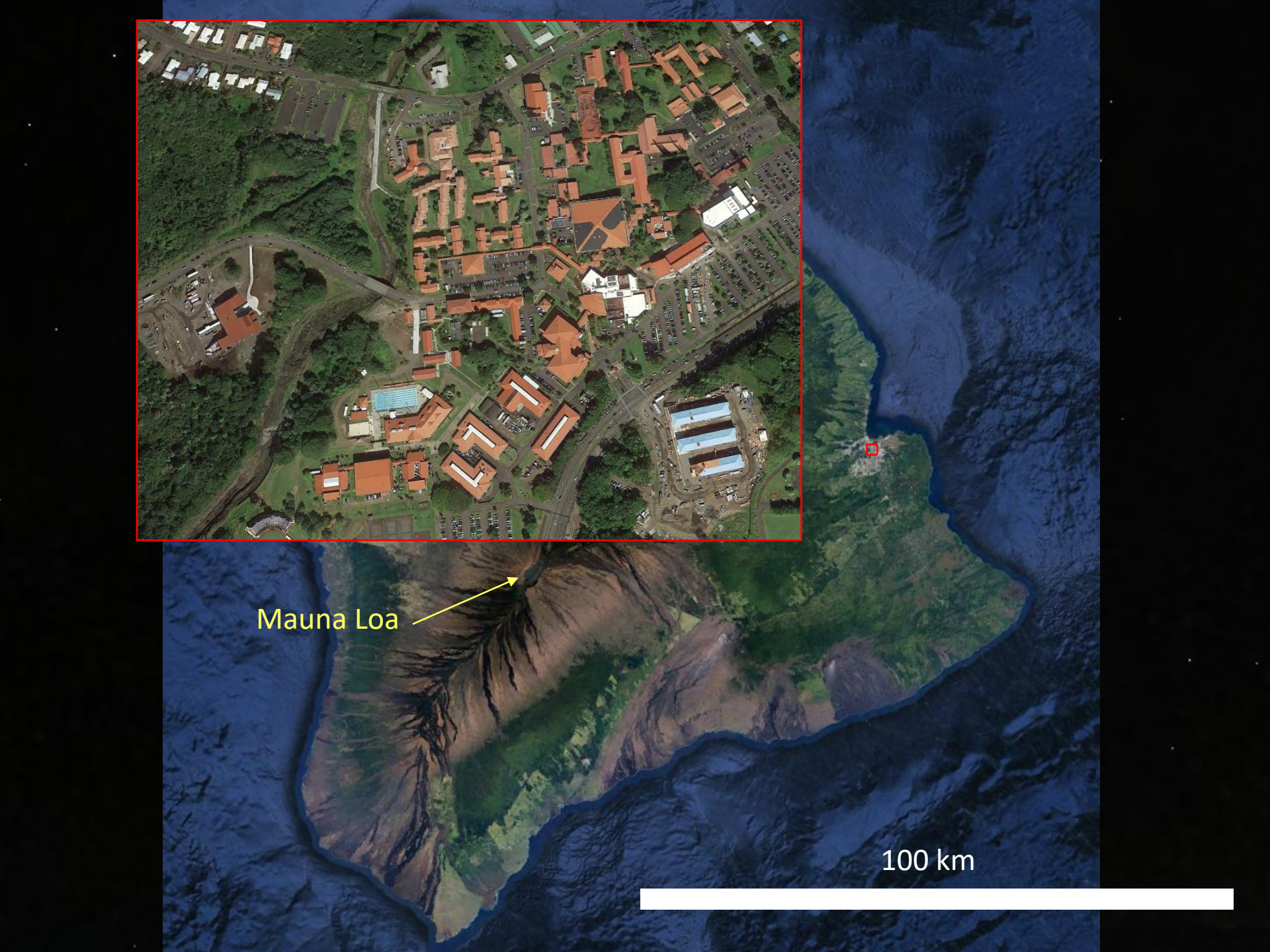
Data SIO, NOAA, U.S. Navy, NGA, GEBCO


Mauna Loa
100 km

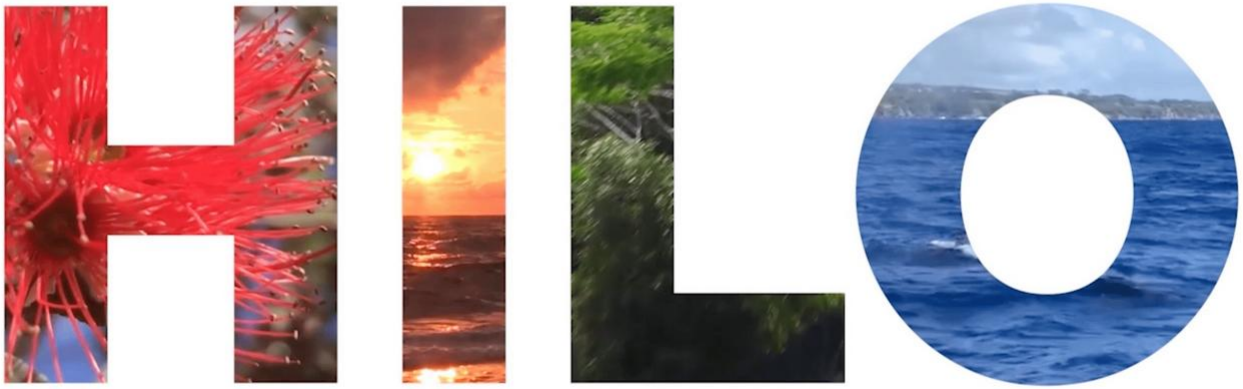
USGS photo by K. Lynn.



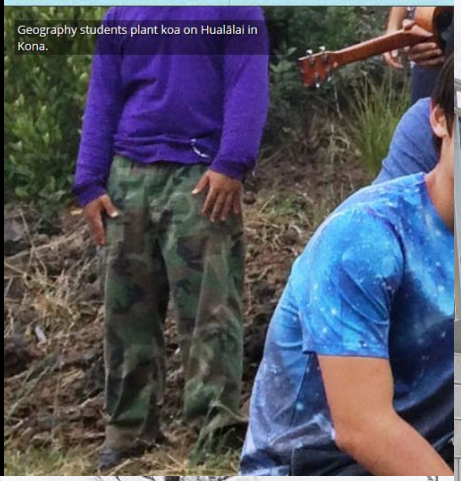
Mauna Loa Volcano—eruptive activity
November 28, 2022—1:30 PM


Mauna Loa
100 km

UNIVERSITY OF HAWAI‘I AT



Apply Now



Geography students plant koa on Hualālai in Kona.

Master of Science *in* Tropical Conservation Biology and Environmental Science

University of Hawai'i Hilo

Graduate education that focuses on environmental conservation in aquatic and terrestrial ecosystems.

Thesis Track

The Tropical Conservation, Biology, and Environmental Science (TCBES) thesis track provides students with the necessary academic training for employment in environmentally related fields including conservation, sustainability, and marine and terrestrial resource management in technica
wish to ent

Find more

Professional Internship Track

Complementing our thesis track is the TCBES Professional Internship track option. Along with engaging students in natural and social science courses, this professionally oriented track provides students the opportunity for immersion in substantial and guided internships. Students have the option to intern with government management or non-governmental environmental and conservation agencies with established relationships to the TCBES program, or to develop their own internship with a professional organization. Students graduate prepared to actively contribute as scientific professionals with social and policy-related skills and experience.

Spatial Data Analysis and Visualization Labs

University of Hawai'i at Hilo

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Specializations:
Geographic Information Systems
Remote Sensing & Photogrammetry
Small Unmanned Aerial Systems
Land Cover Change Analysis
Structure from Motion Analysis

Roberto Rodriguez, Ph.D.

Geospatial Research Specialist
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Specializations:
Remote Sensing & Photogrammetry
Small Unmanned Aerial Systems
Aerial Agricultural Management Techniques
Structure from Motion Analysis

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Geospatial Analyst
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Satellite Imagery Processing & Analysis
Rapid Ohi'a Death Monitoring
Invasive Species

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Specializations:
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Computer Vision
Software Engineering
Information Technology
Phonology/Phonetics

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Structure-from-Motion Photogrammetry

Andrew Meyer

Research Assistant
andrewl4@hawaii.edu

Specializations:
Geographic Information Systems
Structure from Motion Analysis

disseminate geospatial tools and knowledge to the larger is
through education and outreach activities. Our lab utilizes a

UH Hilo Geographers
mplete Pilot Project to
igitize County's Public
Access Files
July 09, 2021
UH Hilo Stories

UH Hilo Prepares
Aeronautical Science
Program
February 08, 2019
Hawaii Tribune-Herald

remote sensing

MDPI

Article

Comparing Interpretation of High-Resolution Aerial Imagery by Humans and Artificial Intelligence to Detect an Invasive Tree Species

Roberto Rodriguez III [1,*], Ryan L. Perroy [2], James Leary [3], Daniel Jenkins [1], Max Panoff [4], Travis Mandel [5] and Patricia Perez [6]

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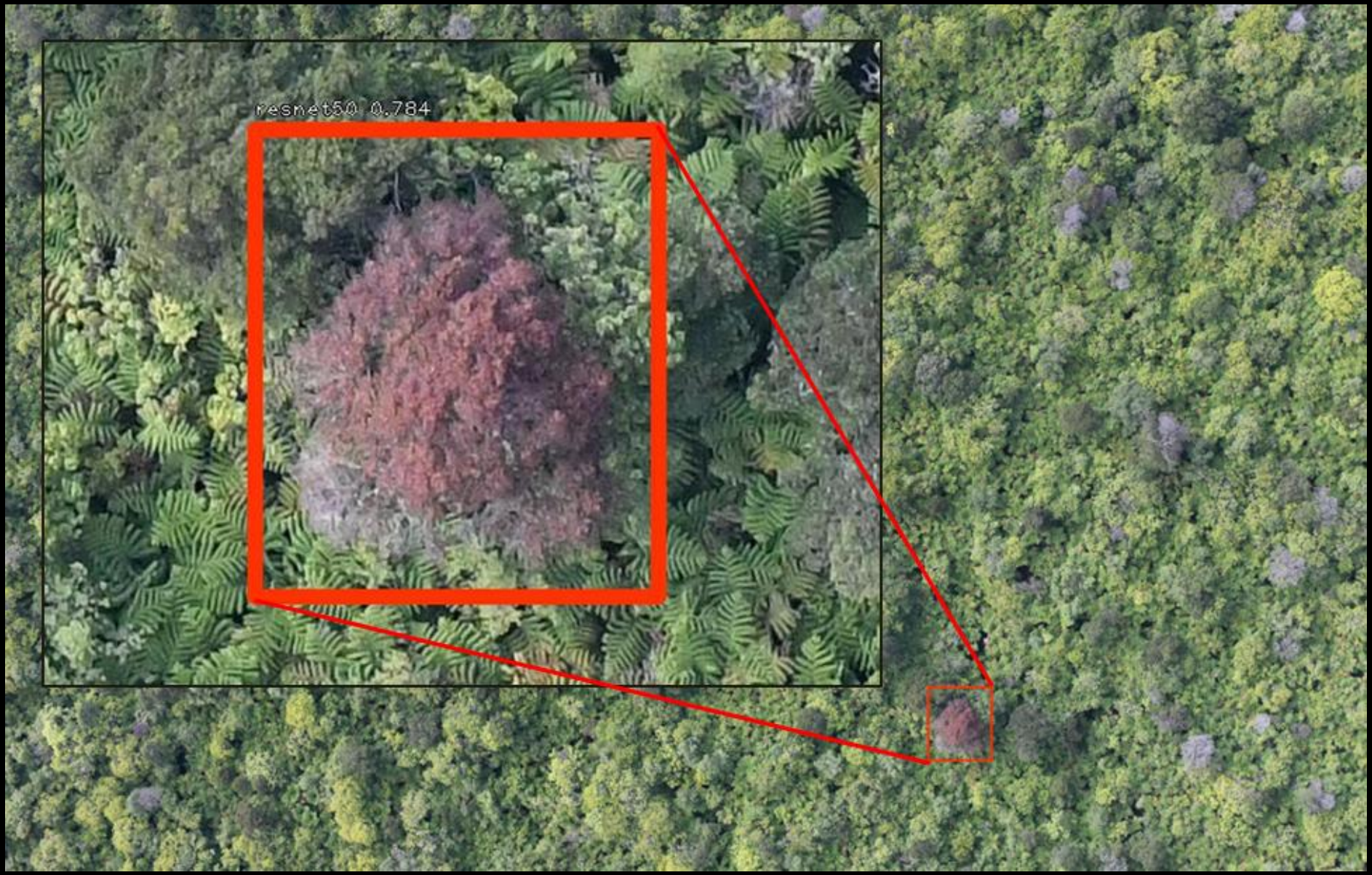
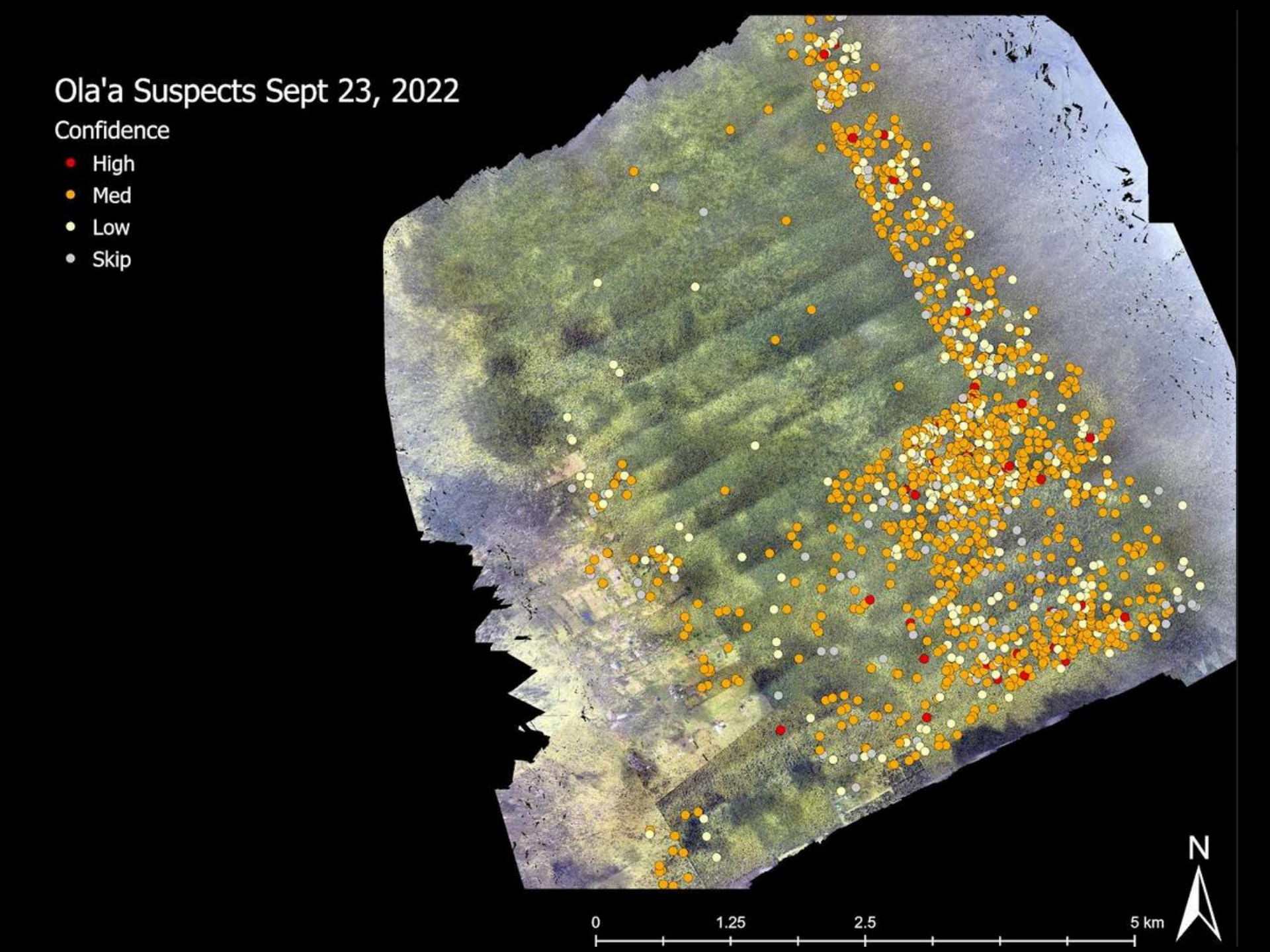
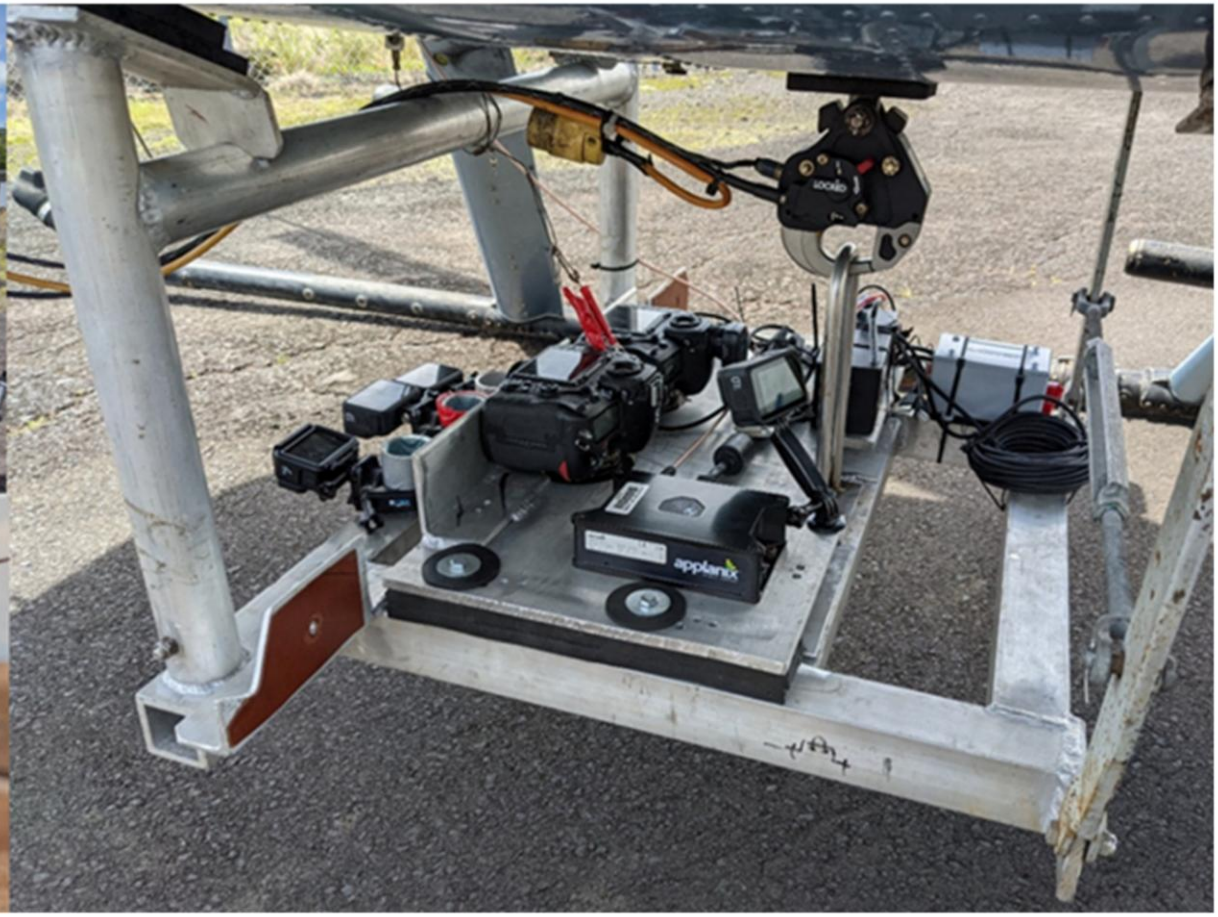
3 Center for Aquatic and Invasive Plants Aquatic and Invasive Plants, Department of Agronomy, University of Florida, Gainesville, FL 32653, USA; learyj@ufl.edu
4 Security in Silicon Laboratory, Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32653, USA; m.panoff@ufl.edu
5 Department of Computer Science, University of Hawai'i at Hilo, Hilo, HI 96720, USA; tmandel@hawaii.edu
6 Spatial Data Analysis and Visualization Lab, University of Hawai'i at Hilo, Hilo, HI 96720, USA; perezp34@hawaii.edu
* Correspondence: roberto6@hawaii.edu

Fire/Faya Tree
Morella faya

Rapid ‘Ohi‘a Death




Ola'a Suspects Sept 23, 2022
Confidence
High
Med
Low
Skip
0
1.25
2.5
5 km
N

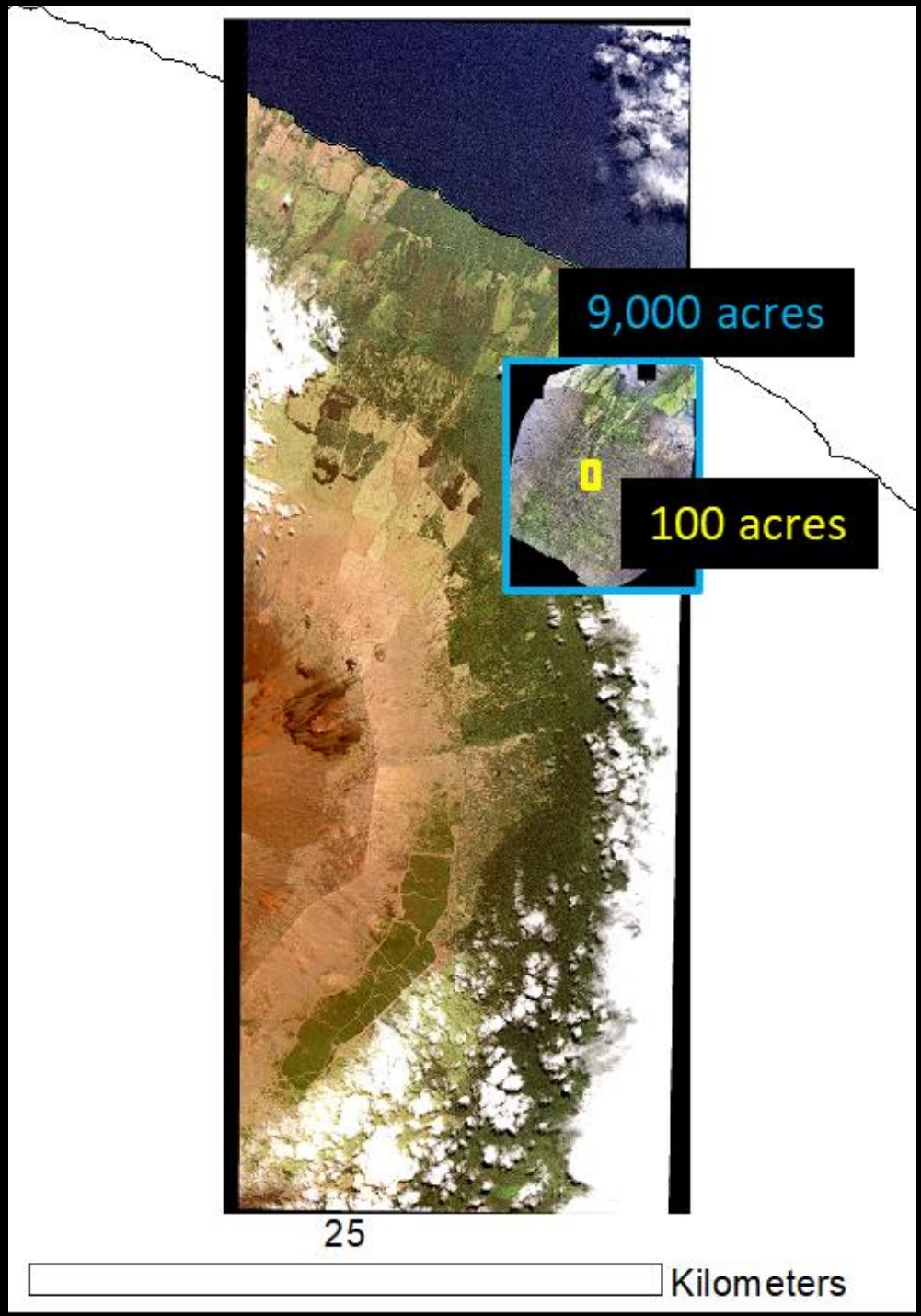

applanix

MAXAR Satellite Imagery
WorldView-3
(0.31 m panchromatic)

07/15/2021

WV2 Image

(125,000 acres)

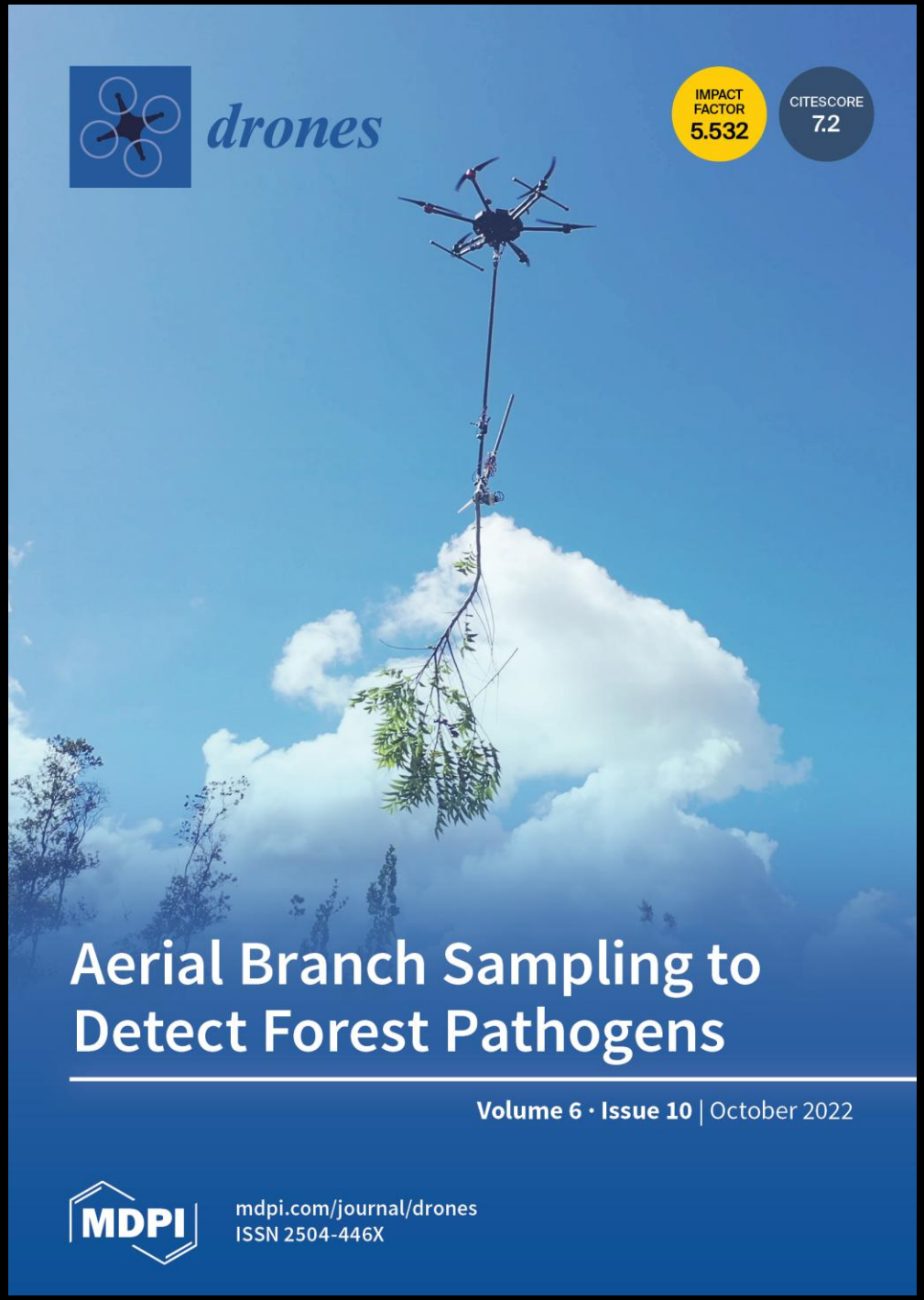


Aerial deployment of *Tectococcus ovatus* biocontrol for strawberry guava

drones

IMPACT FACTOR 5.532

CITESCORE 7.2

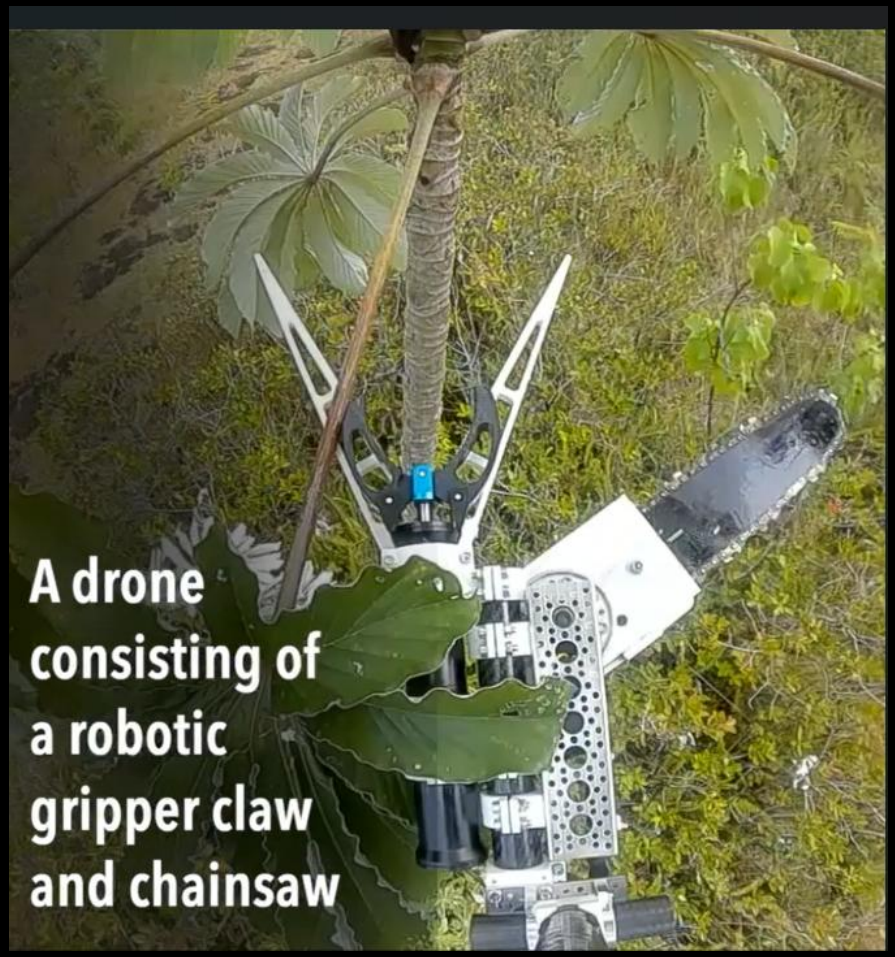


Aerial Branch Sampling to Detect Forest Pathogens

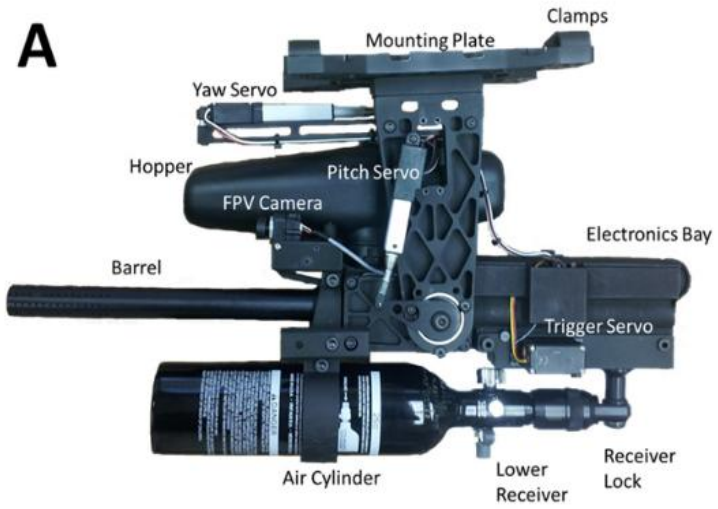
Volume 6 · Issue 10 | October 2022

MDPI

mdpi.com/journal/drones
ISSN 2504-446X

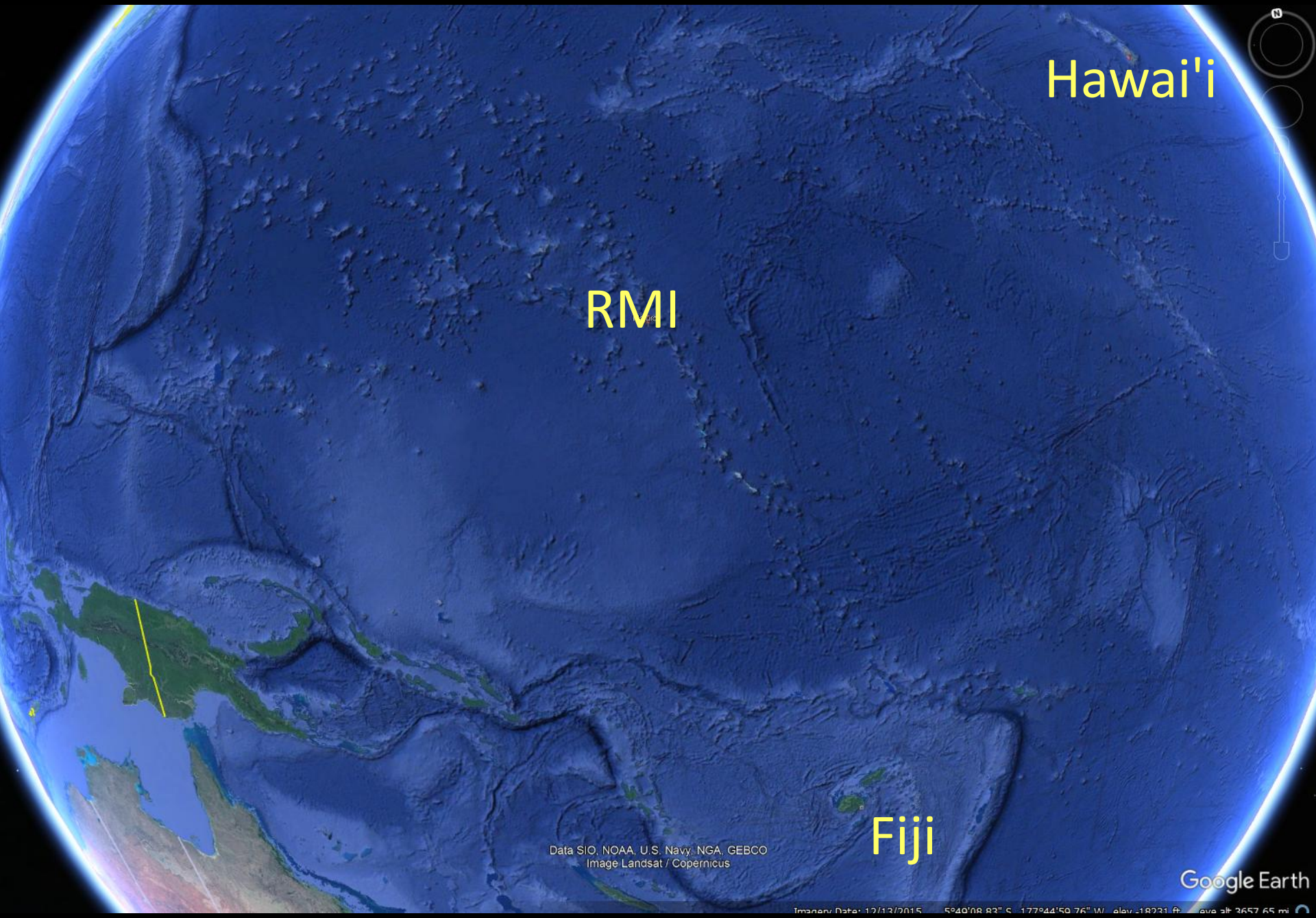


Herbicide Ballistic Technology demonstration



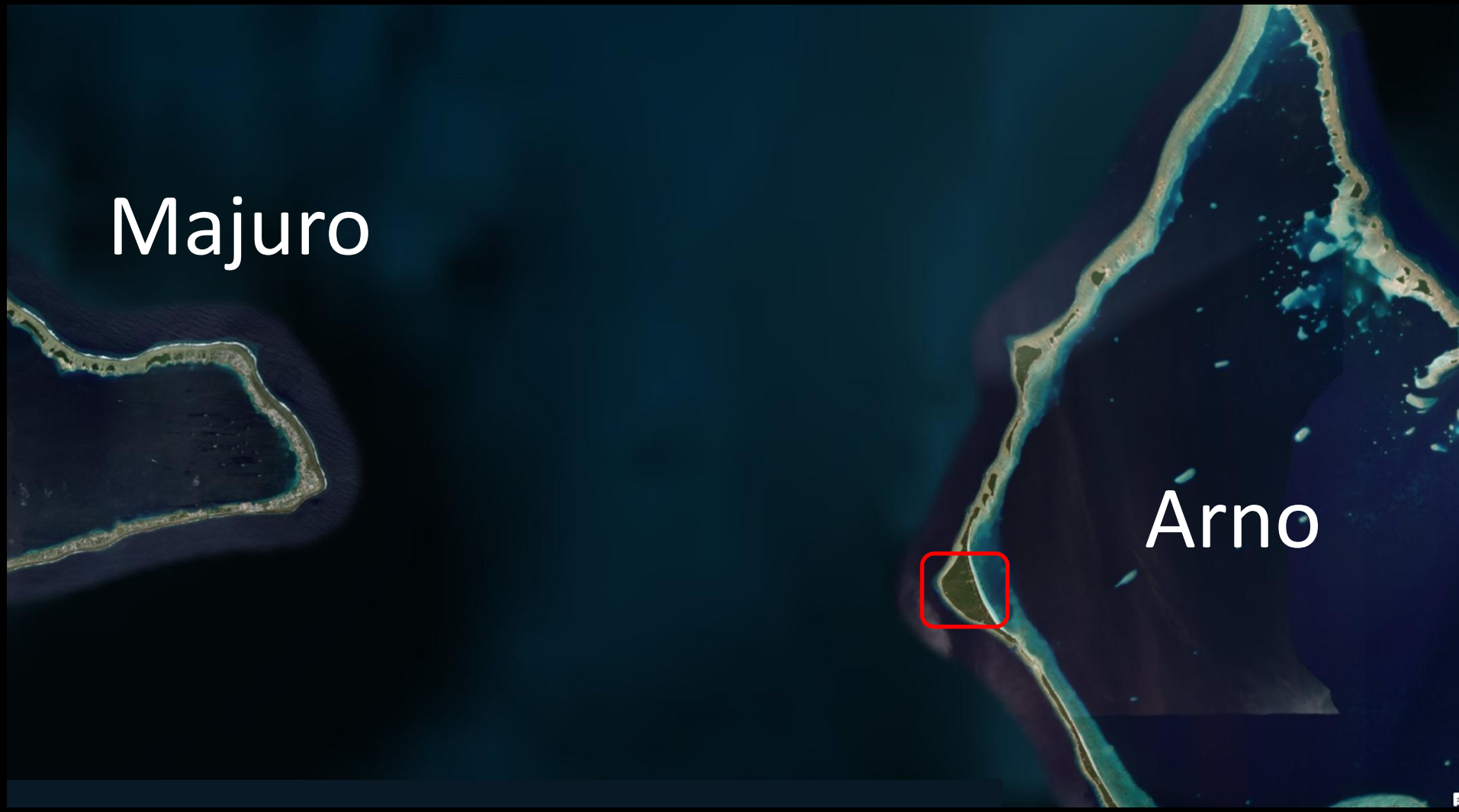
(Rodriguez et al., 2022)

Figure 4. (**A**) Gimbal marker system with major components labeled. (**B**) HBT-UAS in flight.

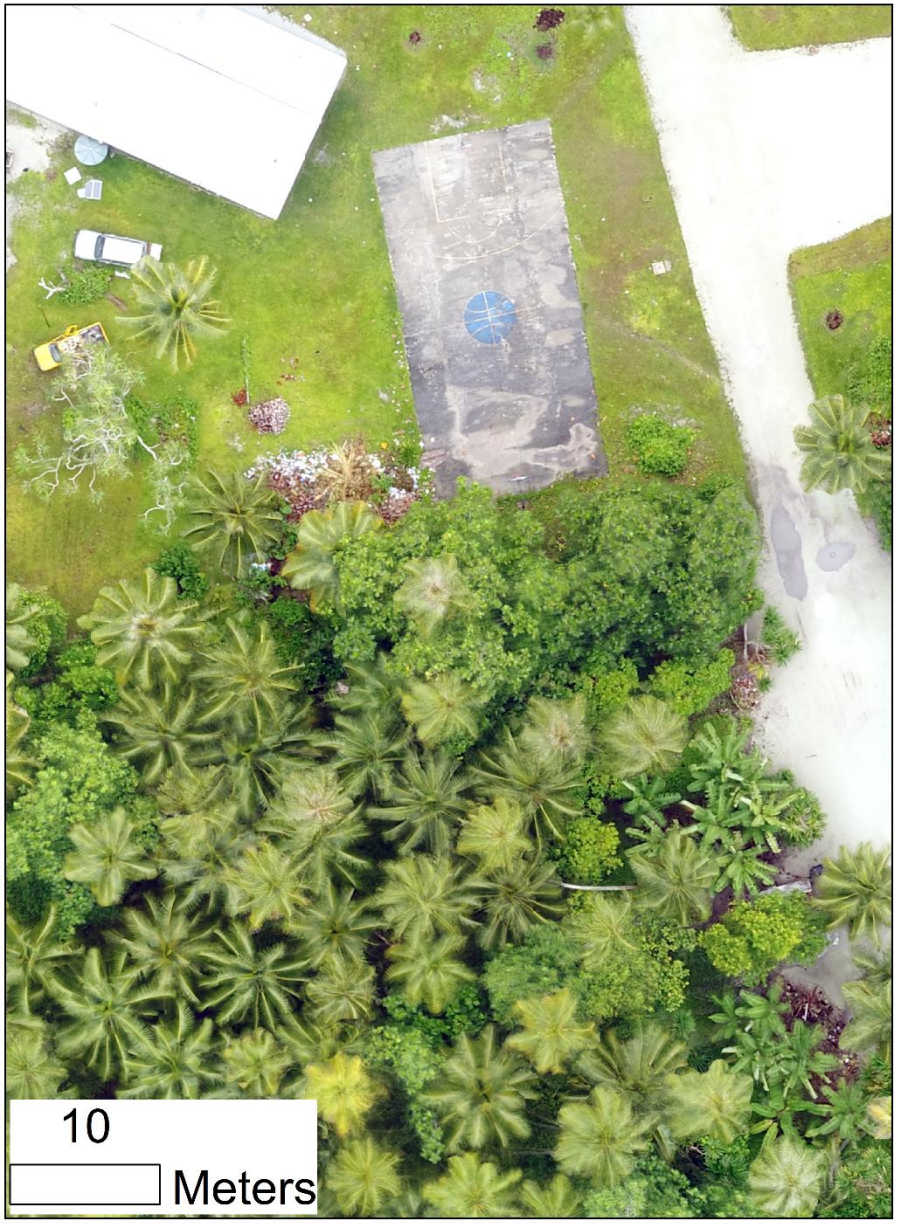

Hawai'i
RMI
Fiji
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Google Earth

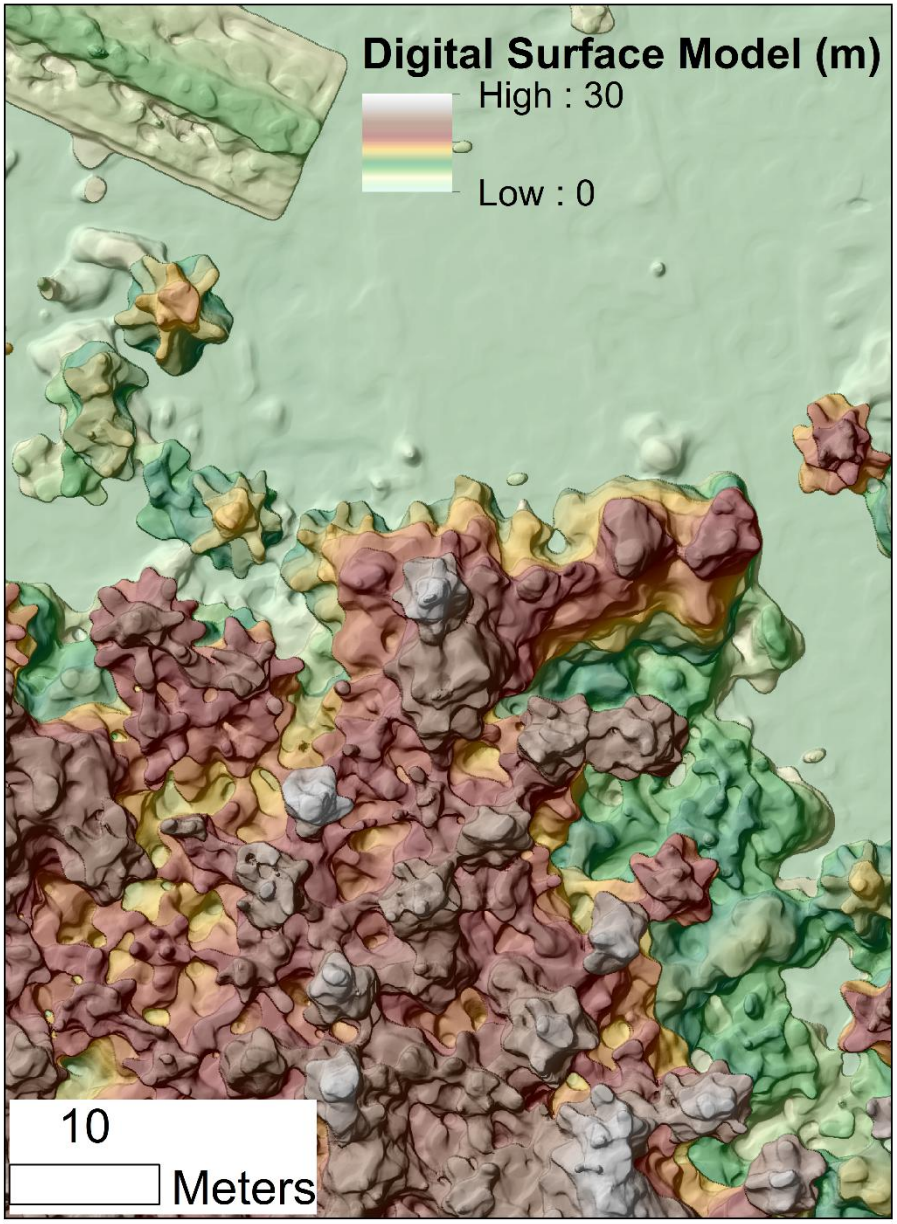
Coconut census, forest health assessment & capacity-building

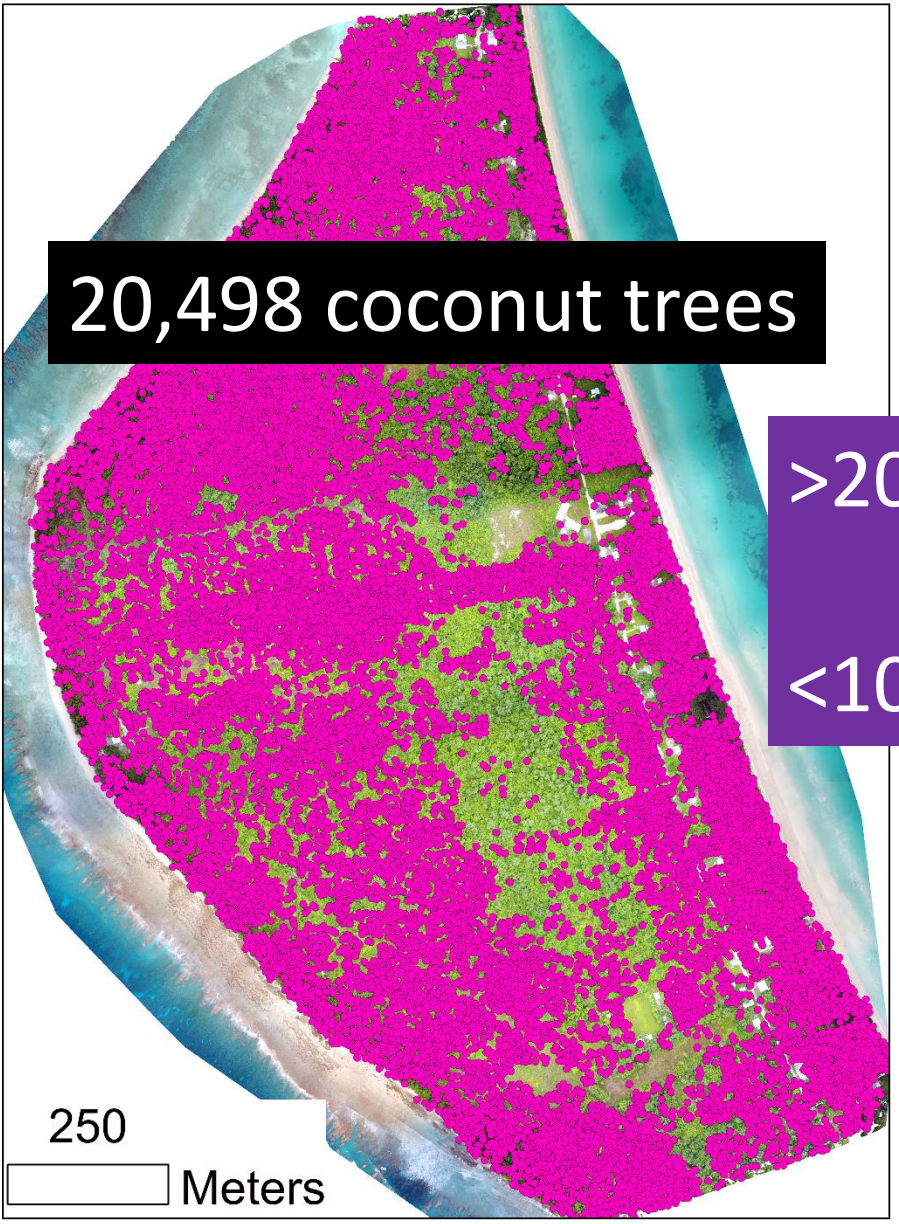
- Provide data on coconut plantation resources useful for agroforest management plans for RMI communities and atolls
- Develop and institutionalize RMI data collection and analysis
- Develop techniques to detect coconut health and pest conditions


Majuro
Arno


10
Kilometers
0.5
Kilometers


10
Meters

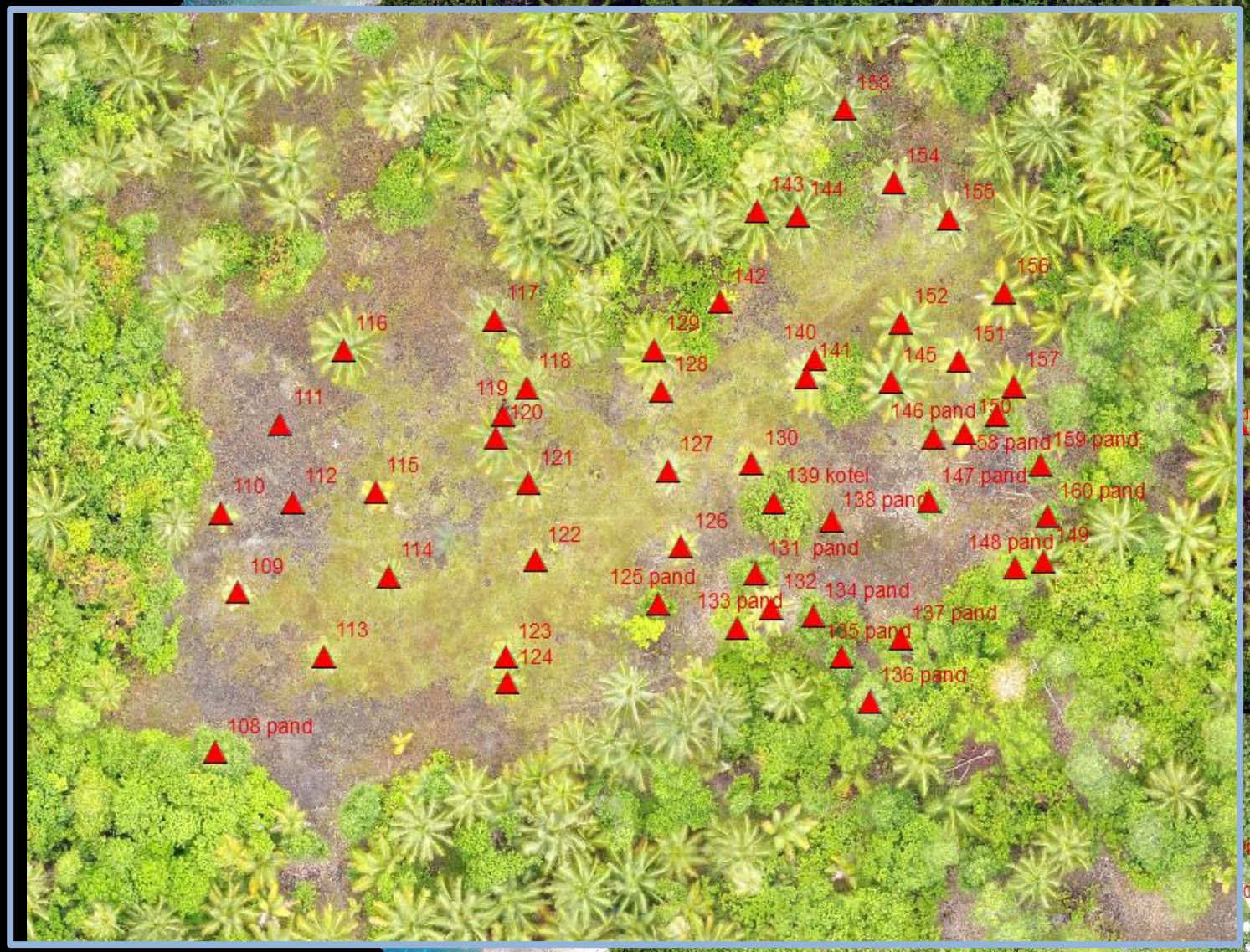

Digital Surface Model (m)
High : 30
Low : 0
10
Meters

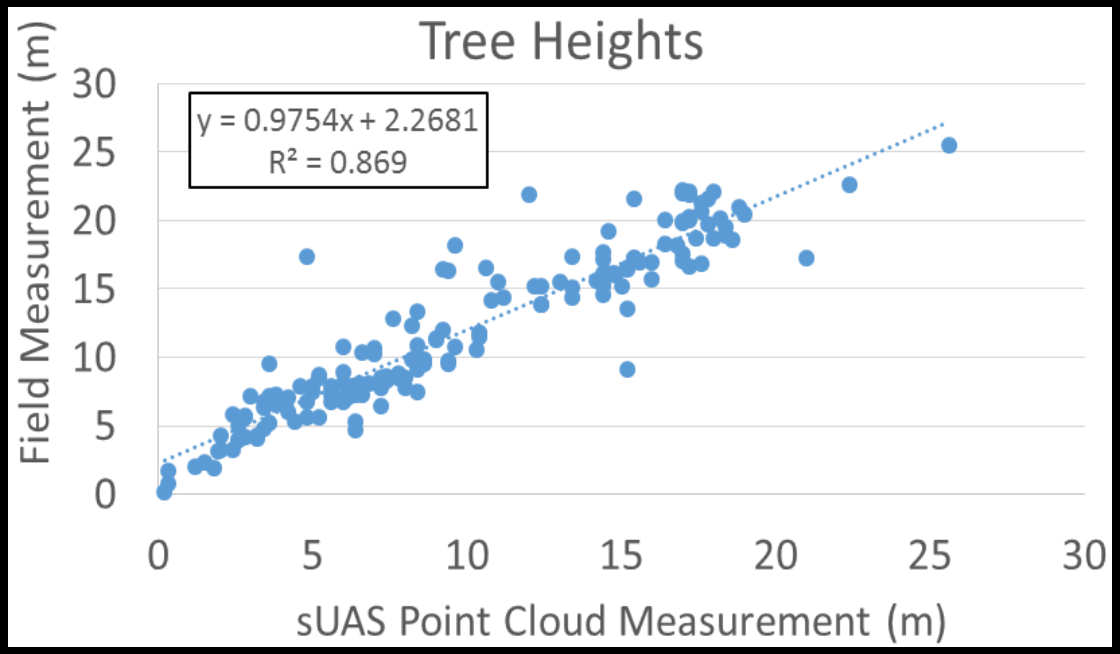


>20 hours by human analyst

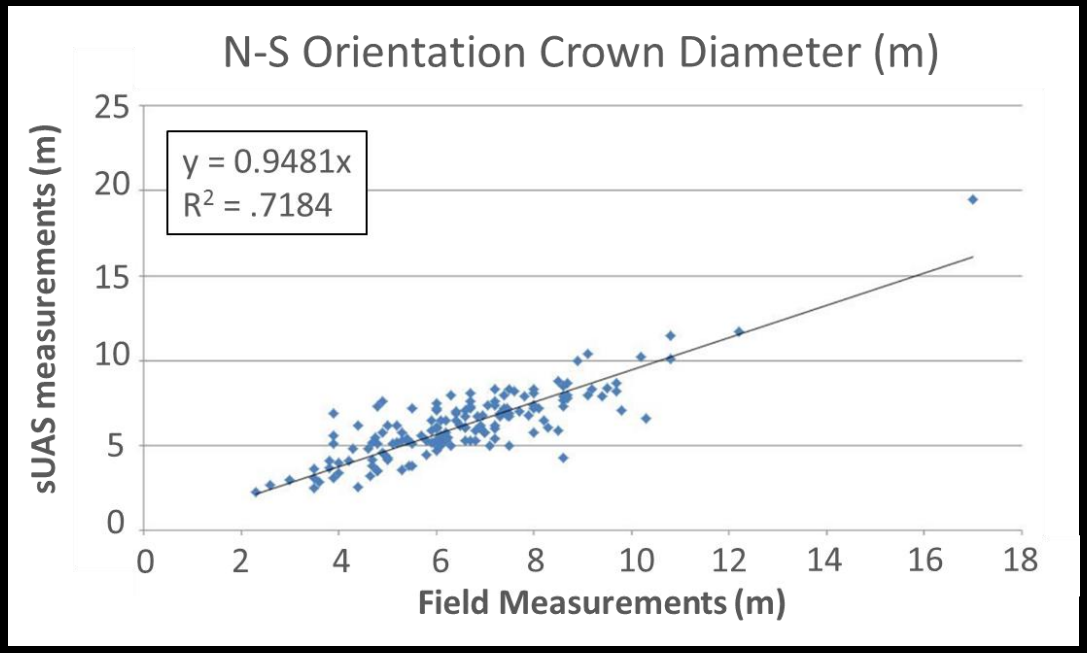
<10 minutes by CNN detector

Field Sampling Sites




Tree Heights
y = 0.9754x + 2.2681
R² = 0.869
Field Measurement (m)
sUAS Point Cloud Measurement (m)
0
5
10
15
20
25
30


Nikon Forestry Pro II


N-S Orientation Crown Diameter (m)
y = 0.9481x
R² = .7184
sUAS measurements (m)
Field Measurements (m)
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25

Site	Area (m^2)	# of Trees Counted in Field	Trees per Ha	# of Trees Detected from sUAS data (% of Field Count)
1	4276	70	164	70 (100%)
2	645	17	264	11 (65%)
3	277	20	722	9 (45%)
4	5000	53	106	53 (100%)
5	535	42	785	18 (43%)

Expanding the project…

- Produce spatial and summary data of coconut tree locations (counts) and heights for additional atolls:

- Mejit
- Aur (2 sites): Aur and Tobal
- Ebon atoll: Eneko Ion, Ebon, and Toka
- Likiep (3 sites): Likiep, Melang, Jebal
- Majuro
- Kwajelin- Bikej

- Establish protocols and assess potential to detect forest health conditions (senility, drought stress, disease, insect damage, etc.)

Capacity Building to institutionalize RMI data collection and analysis

MICS

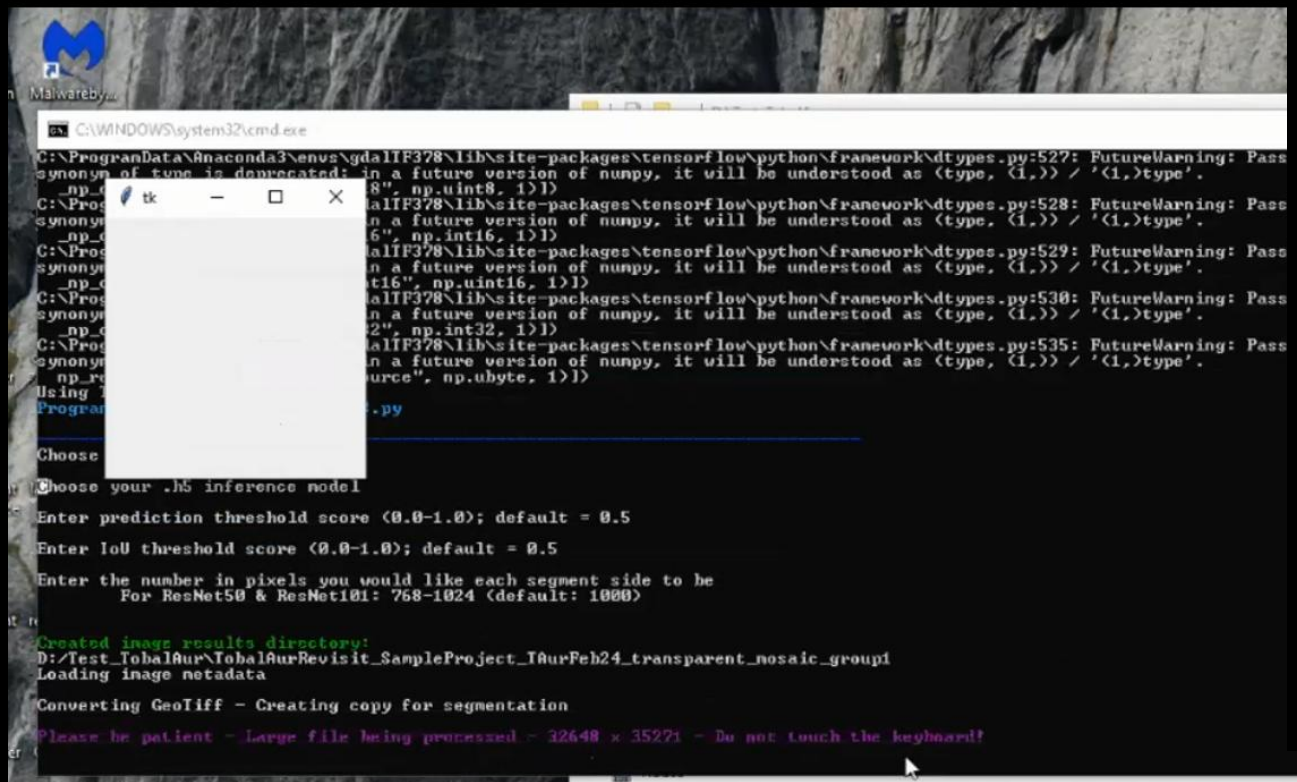
Marshall Islands Conservation Society

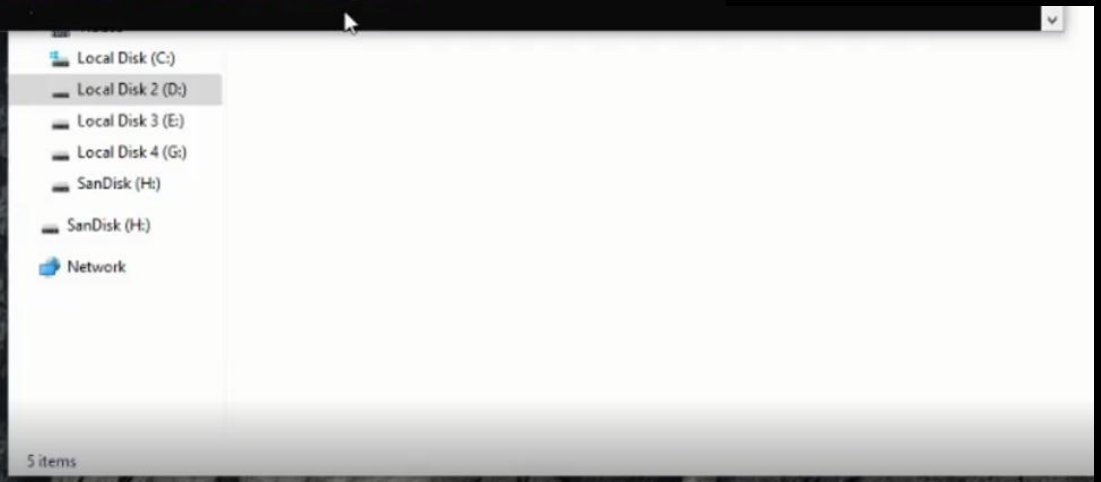

Mejit
Likiep Atoll
Bigej
Aur Atoll
Majūro
Arno Atoll
Ebon Atoll
REDMI NOTE 8
AI QUAD CAMERA


ECKŌUN

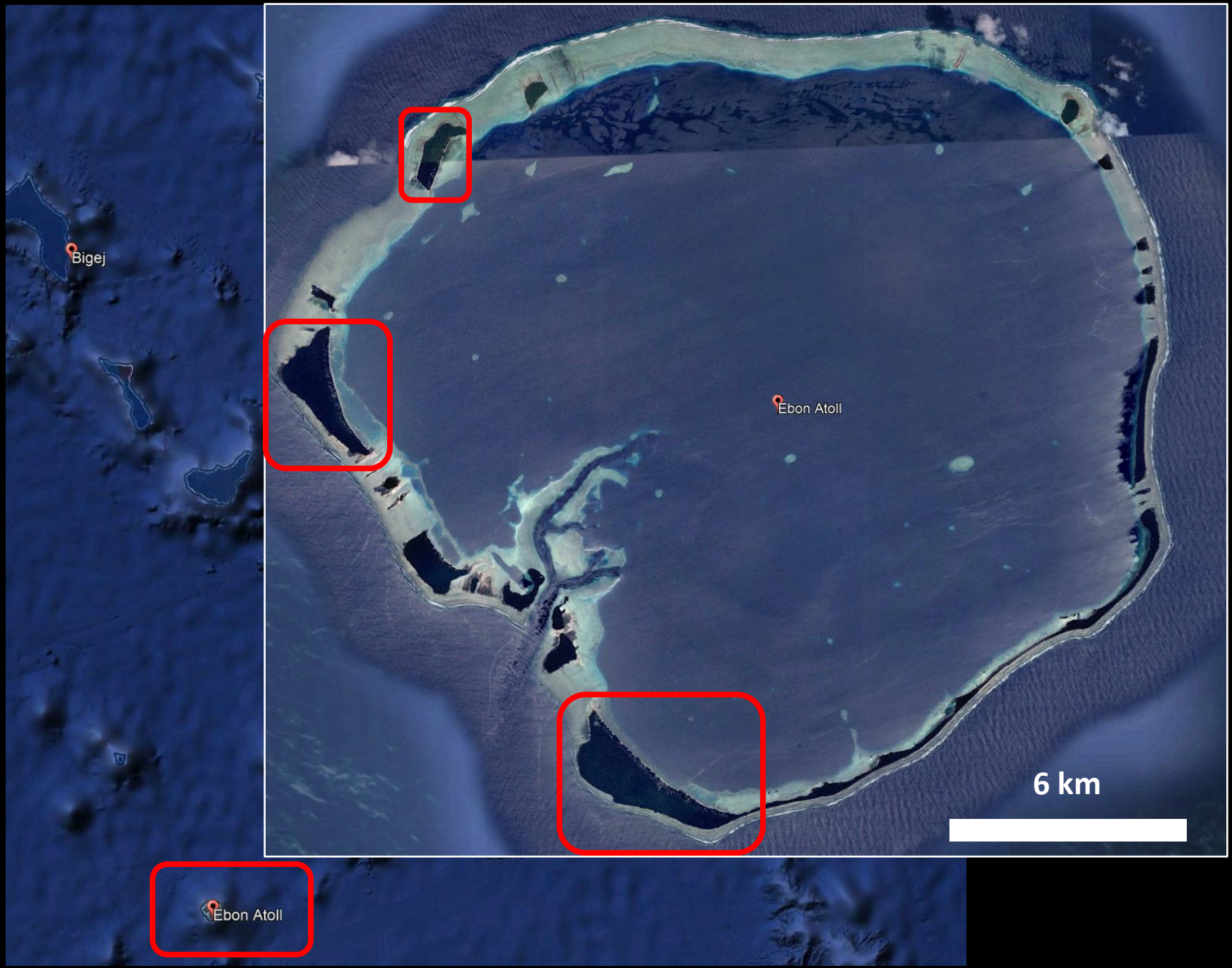
0:03:01

0:53:17





CS_training_2022_05_31_Geocoords_Ortho


Bigej
Ebon Atoll
Ebon Atoll
6 km

Coconut Tree Inventory: Enekoion Island (Ebon Atoll)

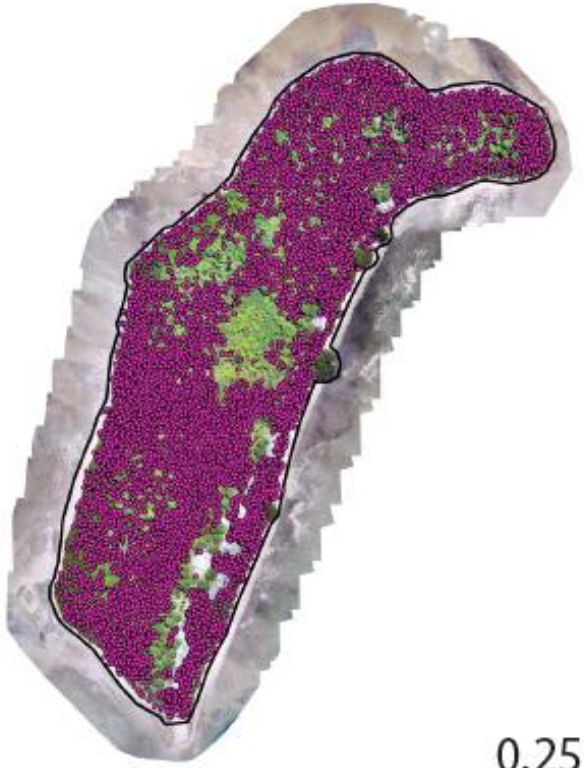
Mapped Area
82 acres

Number of Images Collected
1,860

Image Pixel Resolution
0.89 in

Number of Coconut Trees Identified

6,529

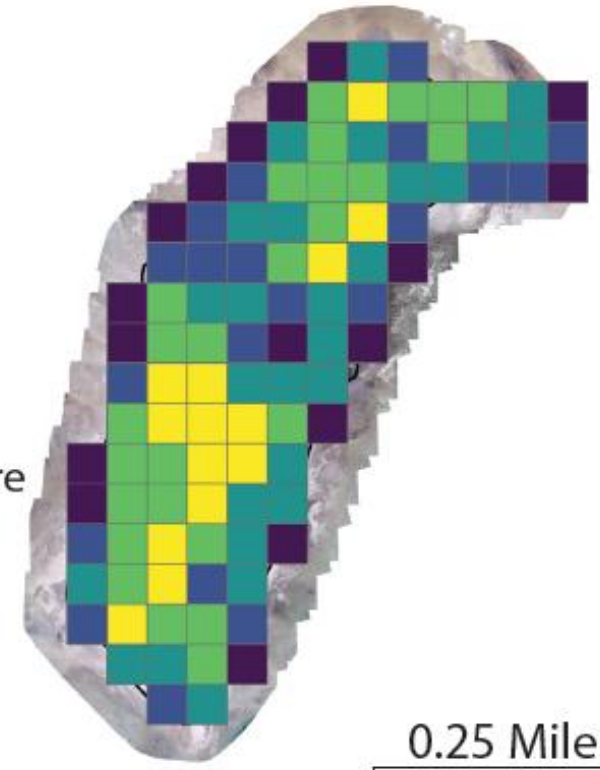


Coconut Tree

0.25 Mile

Average Tree Density

62±34/acre



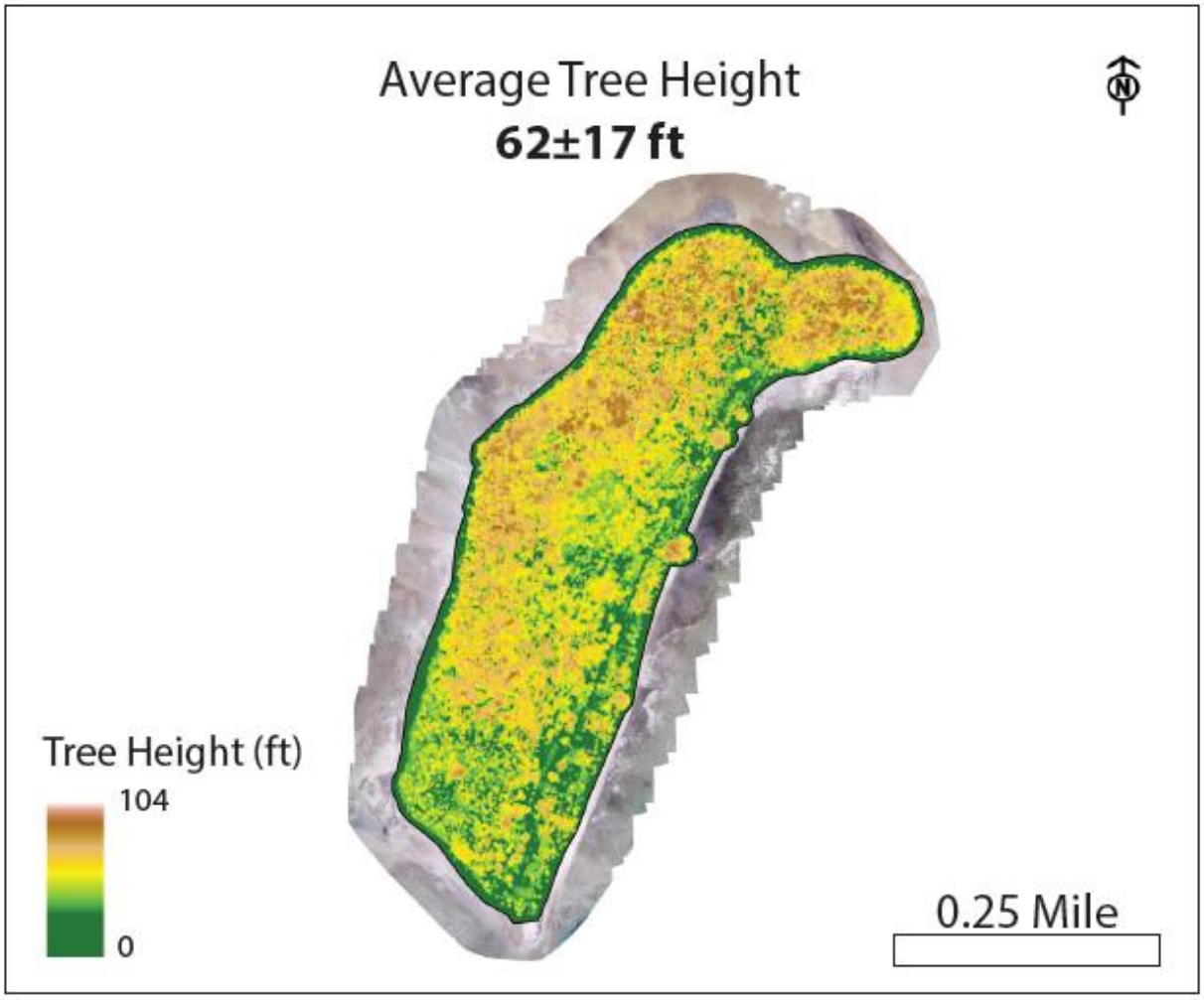
Trees per Acre

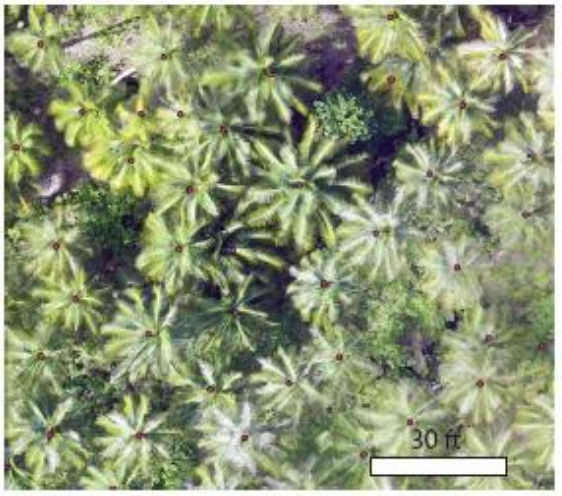
- ≥100
- 75-100
- 50-75
- 25-50
- 1-25

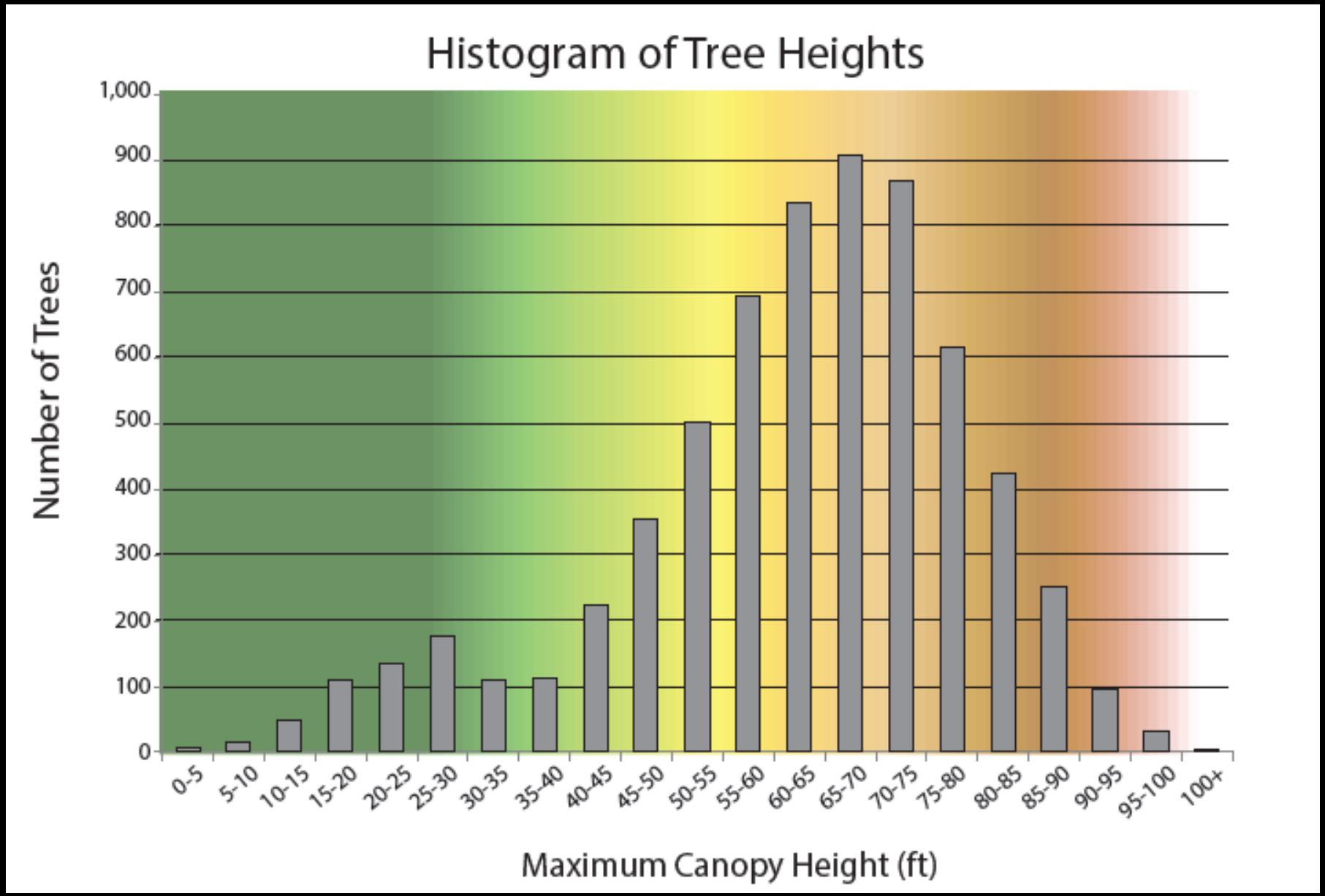
each cell = 1 acre

0.25 Mile

Coconut Tree Inventory: Enekoion Island (Ebon Atoll)






Histogram of Tree Heights
Number of Trees
1,000
900
800
700
600
500
400
300
200
100
0
0-5
5-10
10-15
15-20
20-25
25-30
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
95-100
100+
Maximum Canopy Height (ft)

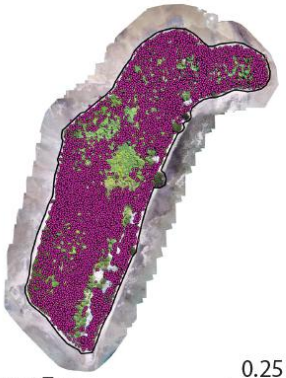
Coconut Tree Inventory: Enekoion Island (Ebon Atoll)

Mapped Area
82 acres

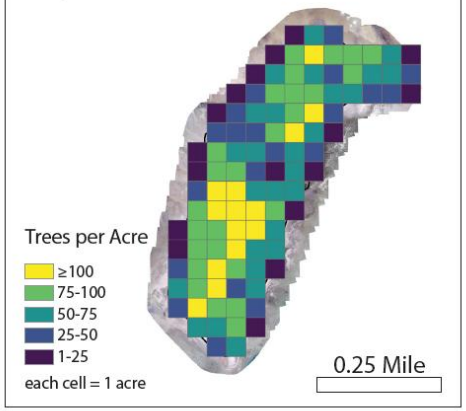
Number of Images Collected
1,860

Image Pixel Resolution
0.89 in

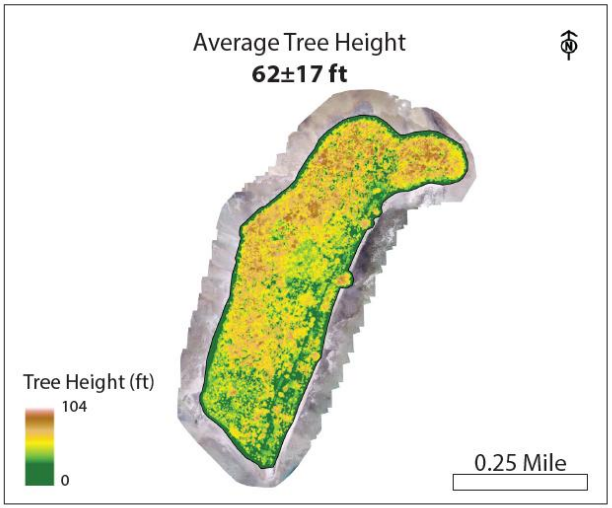
Number of Coconut Trees Identified
6,529

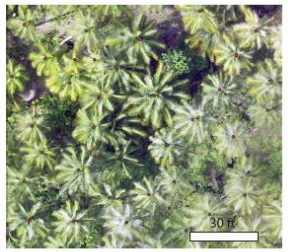


Average Tree Density
62±34/acre

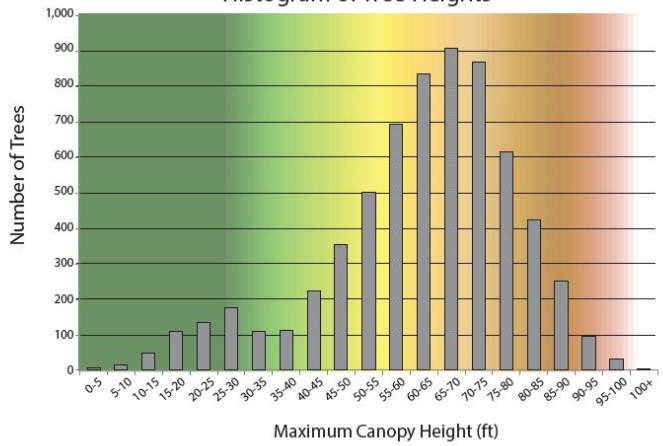


Coconut Tree Inventory: Enekoion Island (Ebon Atoll)





Histogram of Tree Heights



Translating these into Marshallese…

Coconut Tree Inventory: Jebal Island (Likiep Atoll)

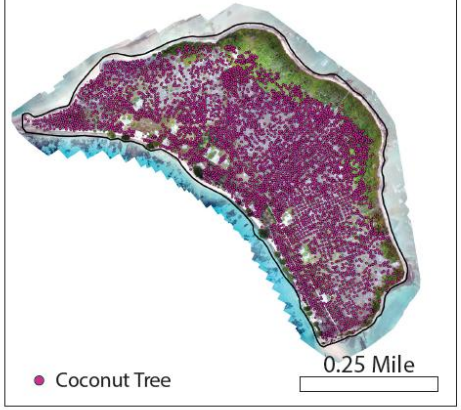
Mapped Area
110 acres

Number of Images Collected
1,901

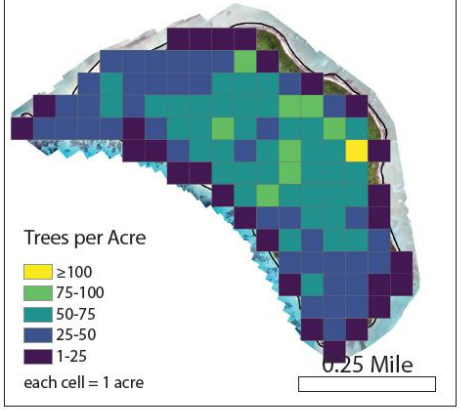
Image Pixel Resolution
0.89 in


Close-up example of a photo used to create mosaic

Number of Coconut Trees Identified
4,983

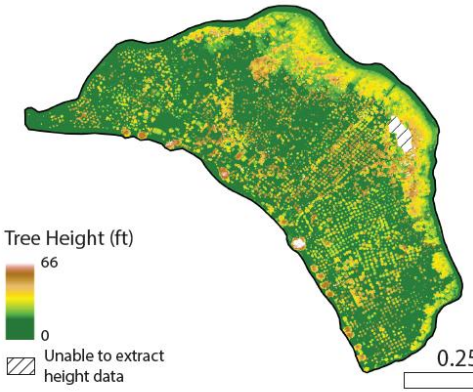


Average Tree Density
43±25/acre

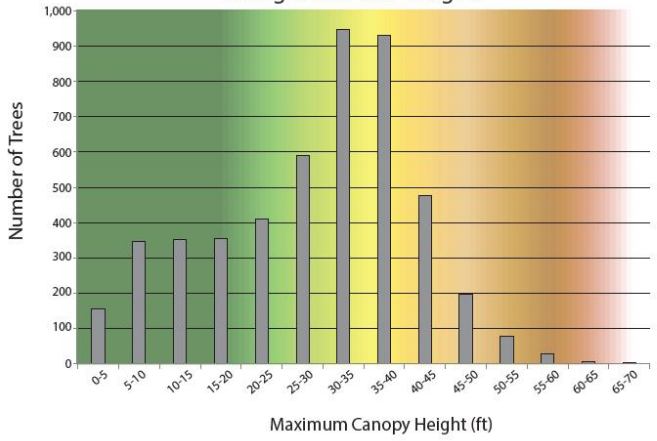


Coconut Tree Inventory: Jebal Island (Likiep Atoll)

Average Tree Height
29±12 ft

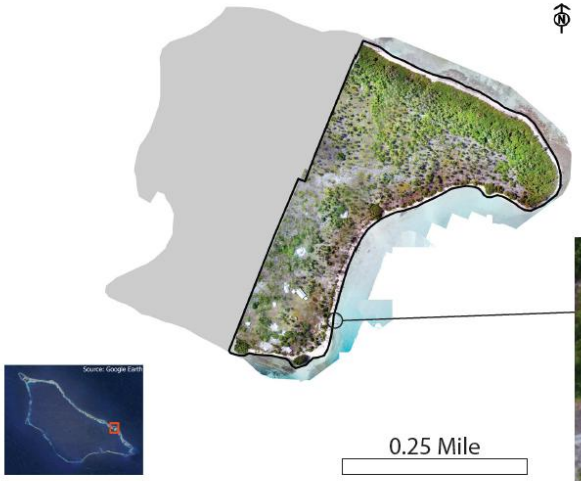


Histogram of Tree Heights



SDAV UH HILO · University of Hawai'i Hilo
Prepared by the UH Hilo Spatial Data Analysis and Visualization (SDAV) Lab
Contact: Dr. Ryan Perroy (rperroy@hawaii.edu)
Funded by the Forest Stewardship Program, USDA Forest Service
This institution is an equal opprtunity provider
MICS Marshall Islands Conservation Society

Coconut Tree Inventory: Melang Island (Likiep Atoll)



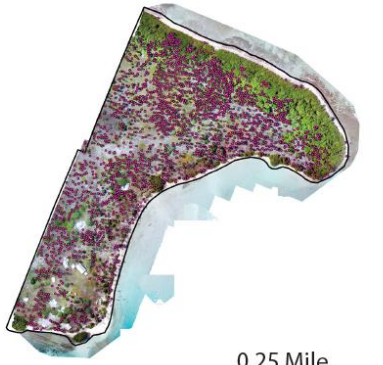
Mapped Area
48 acres

Number of Images Collected
1,019

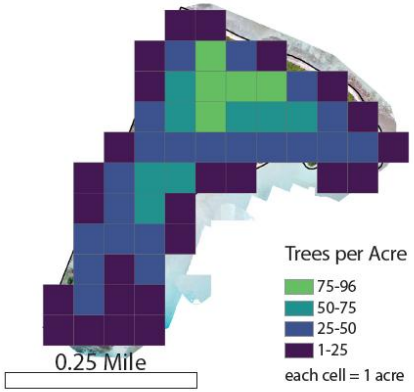
Image Pixel Resolution
0.89 in


Close-up example of a photo used to create mosaic

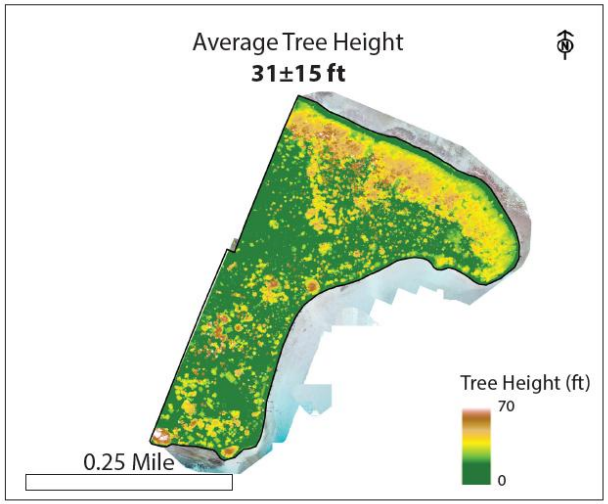
Number of Coconut Trees Identified
2,023



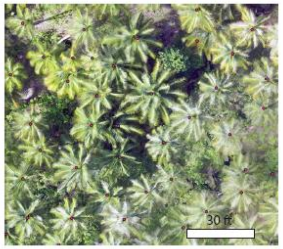
Average Tree Density
34±25/acre



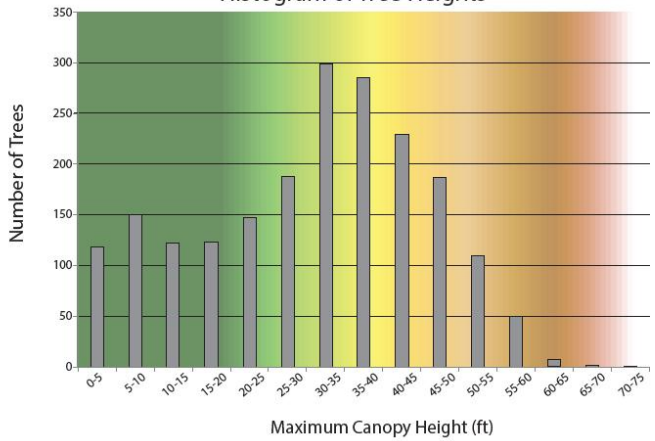
Coconut Tree Inventory: Melang Island (Likiep Atoll)




Close-up of tree heights



Histogram of Tree Heights



SDAV UH HILO · University of Hawai'i Hilo
Prepared by the UH Hilo Spatial Data Analysis and Visualization (SDAV) Lab
Contact: Dr. Ryan Perroy (rperroy@hawaii.edu)
Funded by the Forest Stewardship Program, USDA Forest Service
This institution is an equal opprtunity provider
MICS Marshall Islands Conservation Society

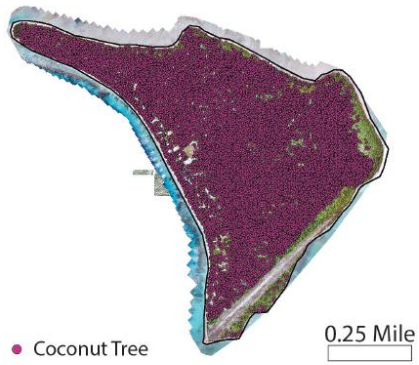
Coconut Tree Inventory: Tobal Island (Aur Atoll)

Mapped Area
346 acres

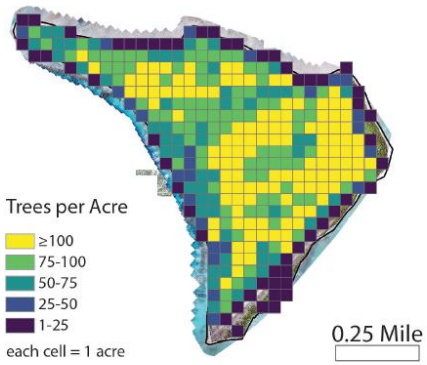
Number of Images Collected
6,703

Image Pixel Resolution
0.89 in

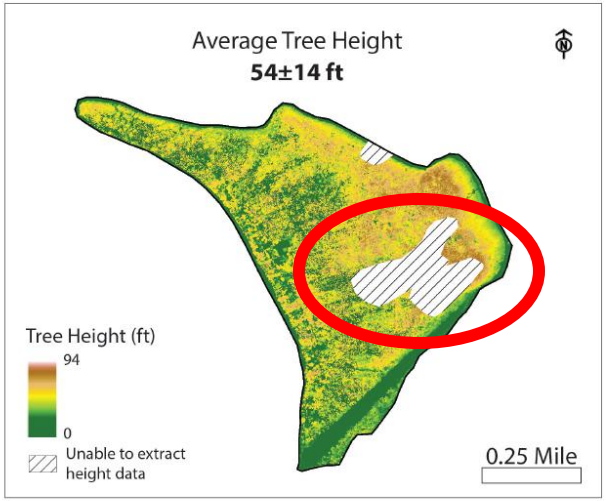
Number of Coconut Trees Identified
27,915

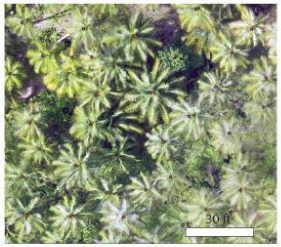


Average Tree Density
79±40/acre

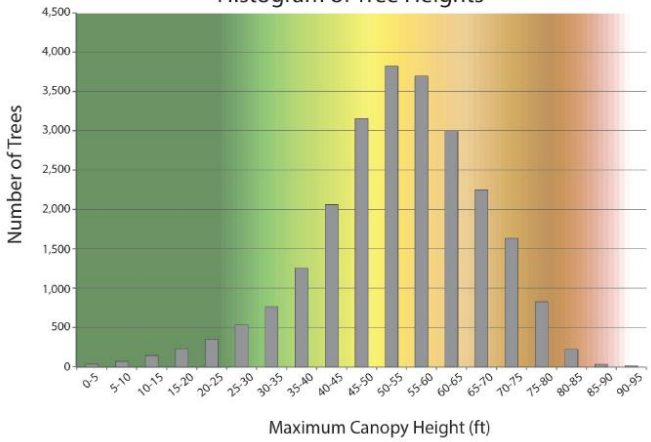


Coconut Tree Inventory: Tobal Island (Aur Atoll)





Histogram of Tree Heights



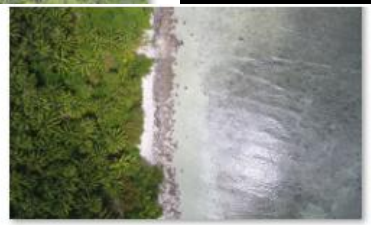
DJI_0296_F1Sec1

DJI_0299_F1Sec1

DJI_0302_F1Sec1

DJI_0167_F1Sec1

DJI_0168_F1Sec1



DJI_0169_F1Sec1

DJI_0170_F1Sec1

DJI_0171_F1Sec1

DJI_0172_F1Sec1

DJI_0173_F1Sec1

DJI_0174_F1Sec1

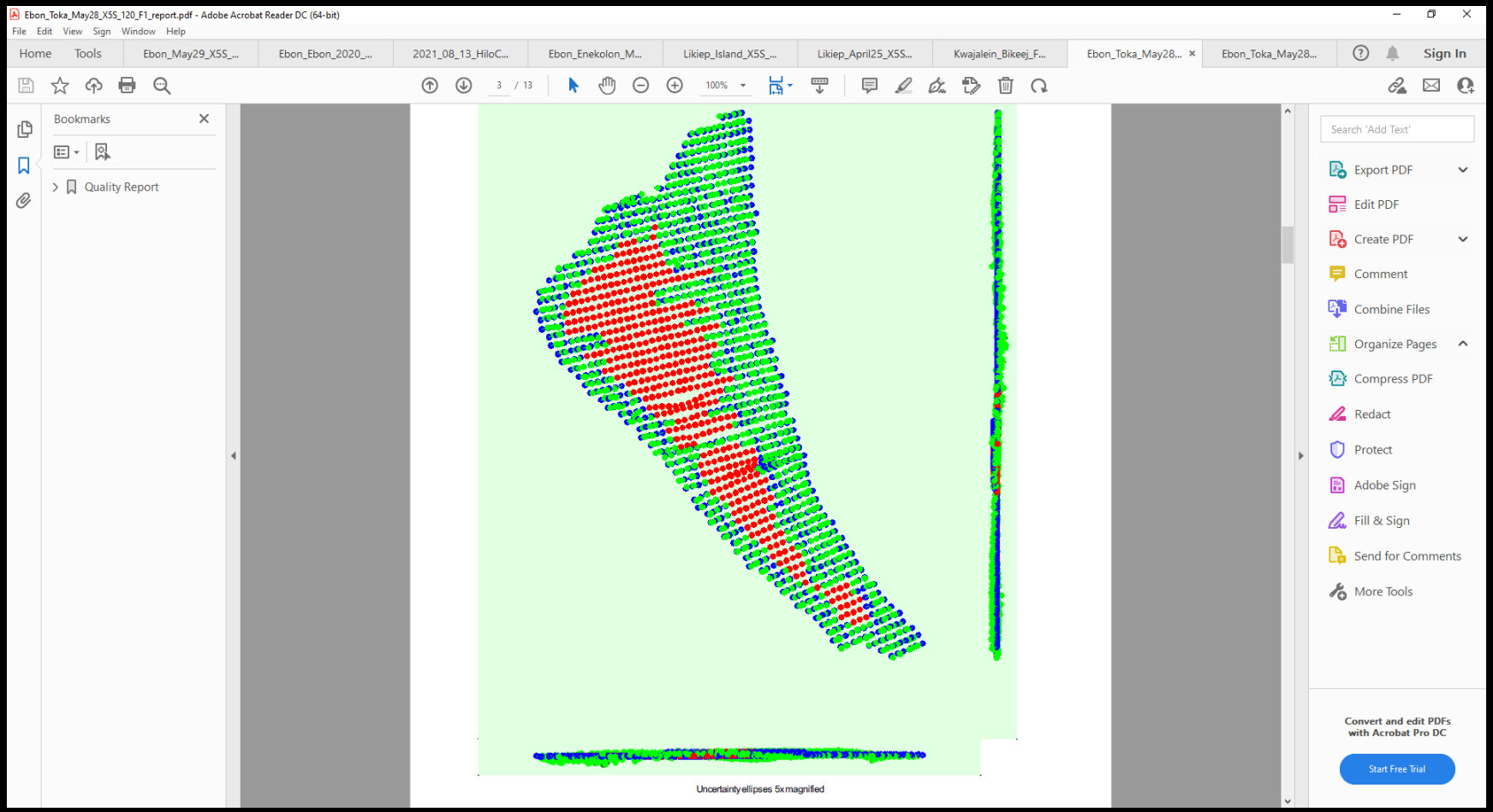
DJI_0175_F1Sec1

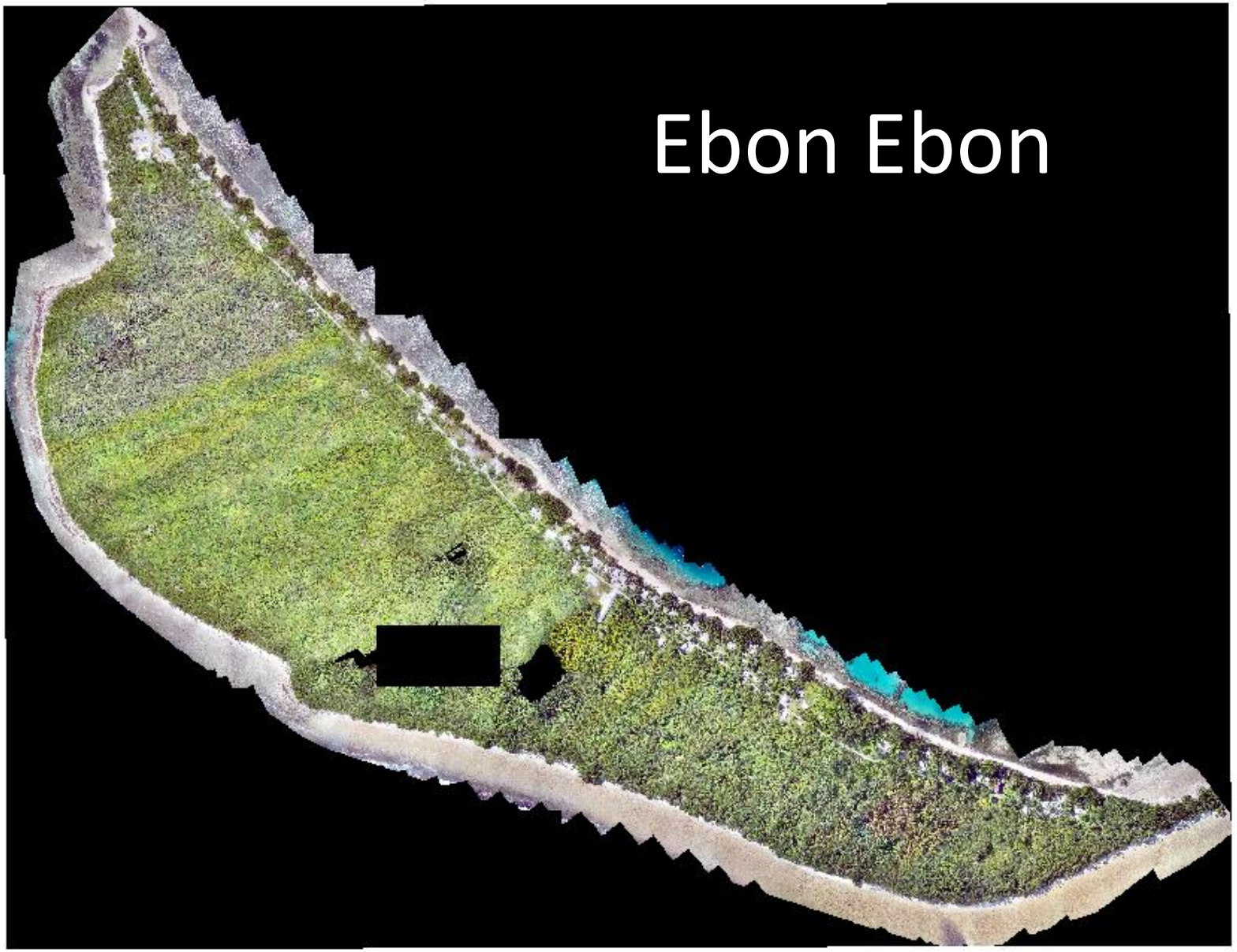
DJI_0176_F1Sec1

DJI_0177_F1Sec1

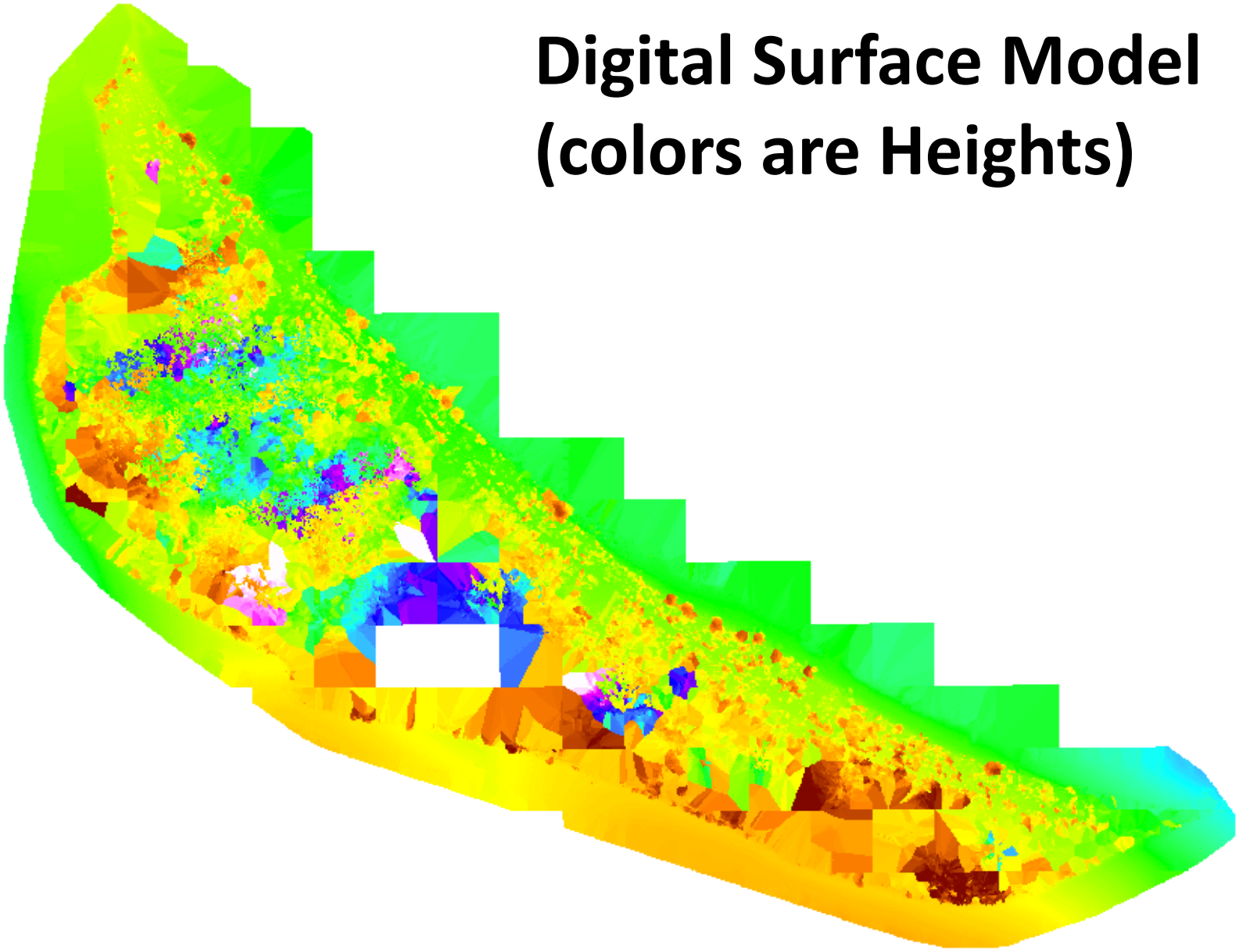
DJI_0178_F1Sec1

Ebon Toka
108 ha

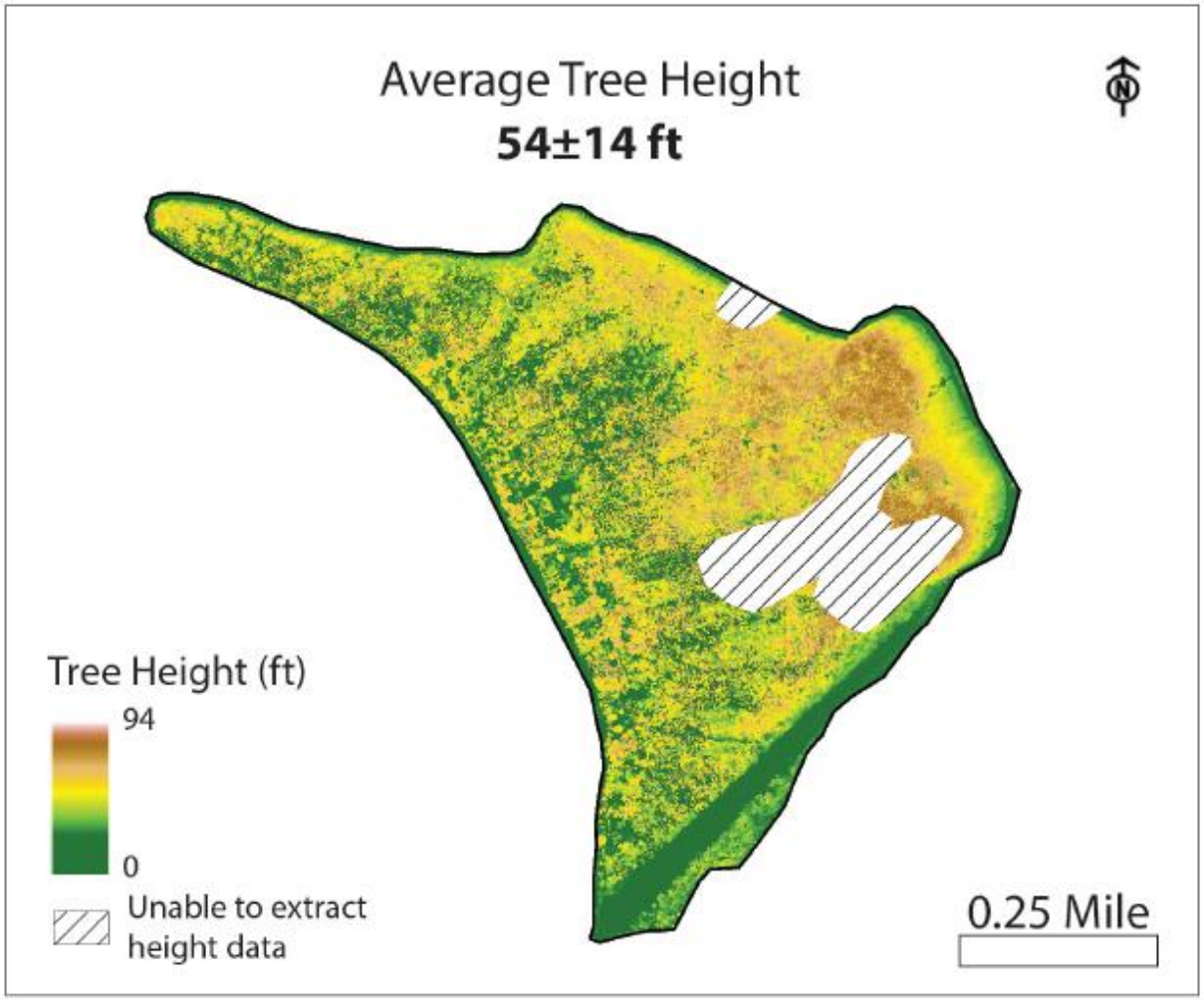


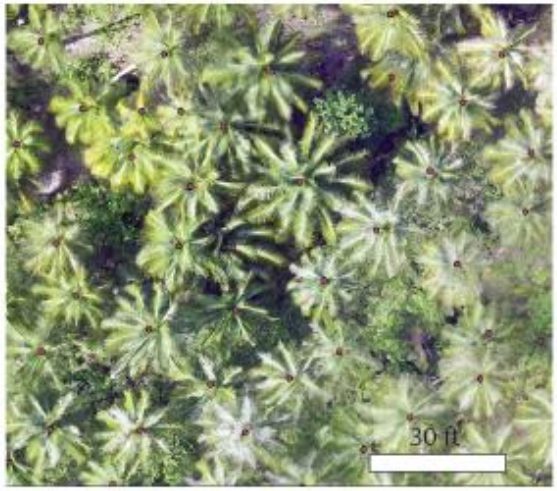

Ebon Ebon

Digital Surface Model (colors are Heights)



Coconut Tree Inventory: Tobal Island (Aur Atoll)



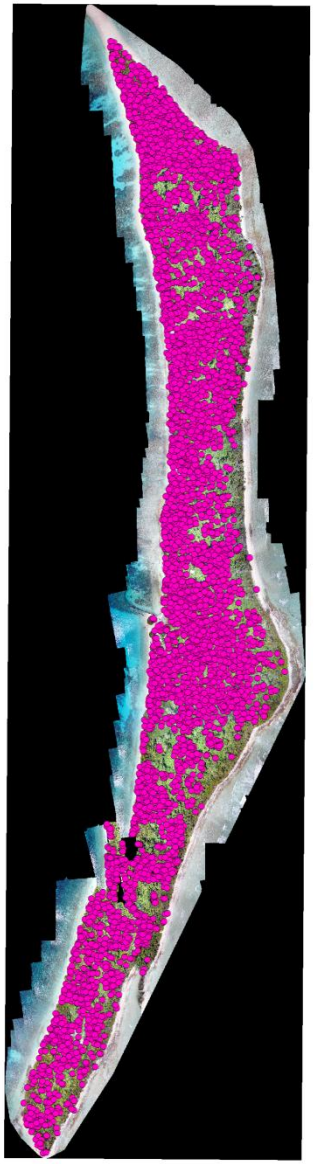


Coconut census, forest health assessment & capacity-building

- Provide data on coconut plantation resources useful for agroforest management plans for RMI communities and atolls
- Develop and institutionalize RMI data collection and analysis
- Develop techniques to detect coconut health and pest conditions


Mejit
Likiep Atoll
Bigej
Aur Atoll
Majuro
Arno Atoll
Ebon Atoll

Bikiej



~5,400 coconut trees

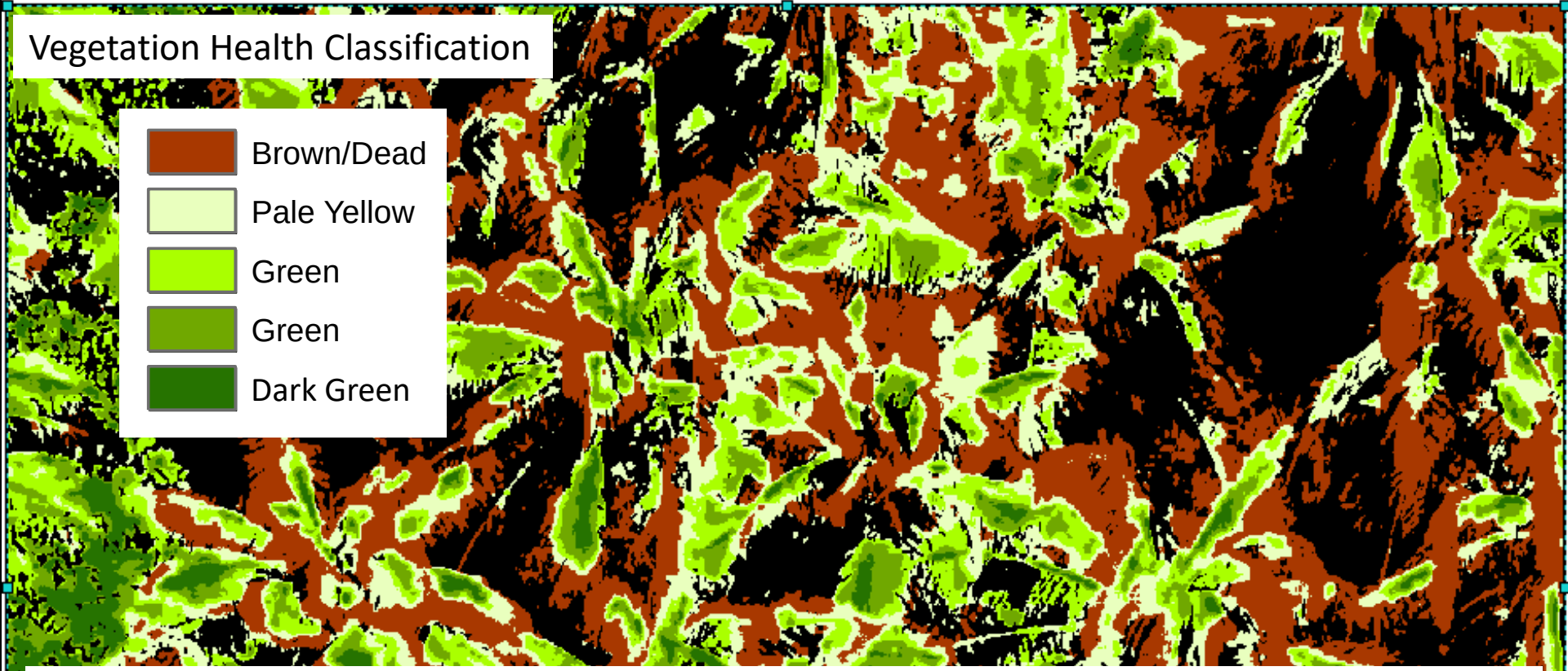


Table 1. Vegetation Indices (VIs) included in the study. *Perroy et al. 2020*

Data Source	Index	Formula	Reference
Spectroradiometer	NDVI	$(R_{800} - R_{670}) / (R_{800} + R_{670})$	[34,35]
	PRI	$(R_{570} - R_{531}) / (R_{570} + R_{531})$	[36]
	MSI	R_{1600} / R_{820}	[37]
	CAI	$0.5 * (R_{2015} + R_{2195}) - R_{2106}$	[38]
RGB Camera	ExG-ExR	$(2 * g - r - b) - (1.4 * r - g)$	[39]
	VCI	$g / (r + b)$	[40]

coconut rhino beetle (CRB) damage

Image from Oahu, HI
Mohsen Paryavi & Dan Jenkins
UH Manoa

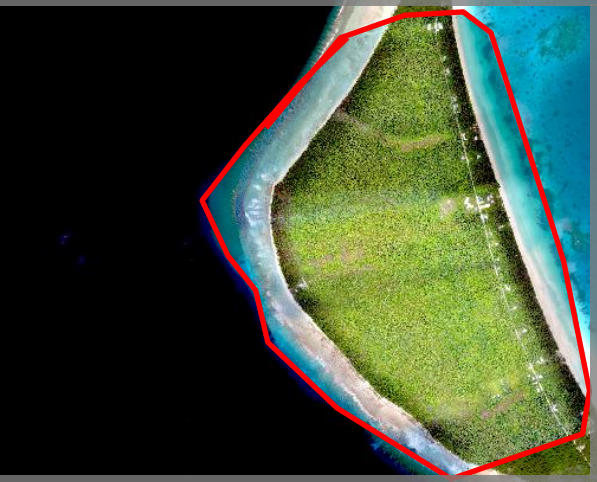
New Project!

Increasing Agroforestry Inventory and Monitoring Capacity and Climate Change Resilience across the Pacific through High-resolution Imagery and Artificial Intelligence

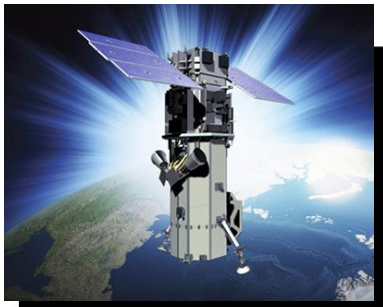
- Federated States of Micronesia
- Republic of the Marshall Islands

Worldview-2, 5/25/2018, 47.2 cm

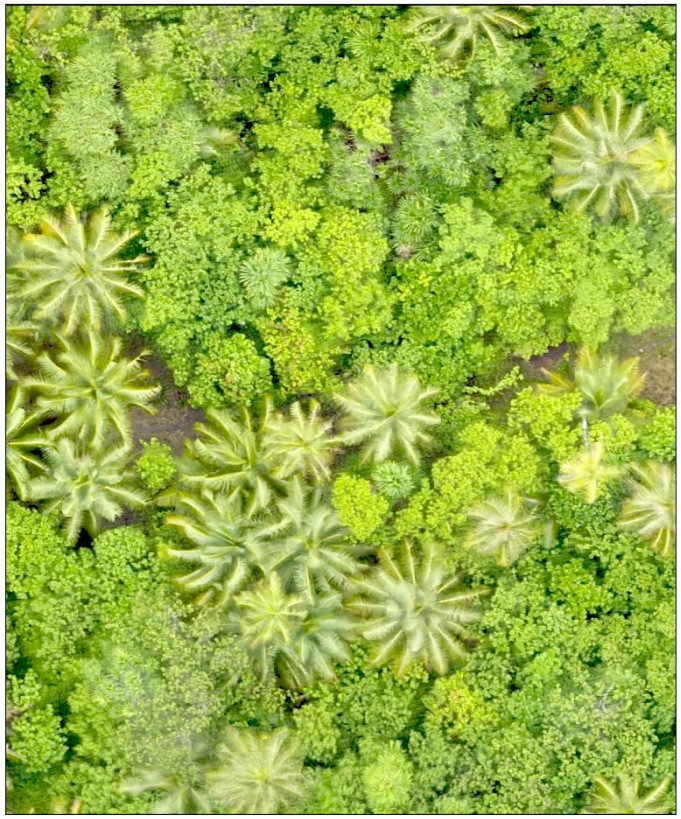
DJI X5S camera
5/23-30/2018
4 cm

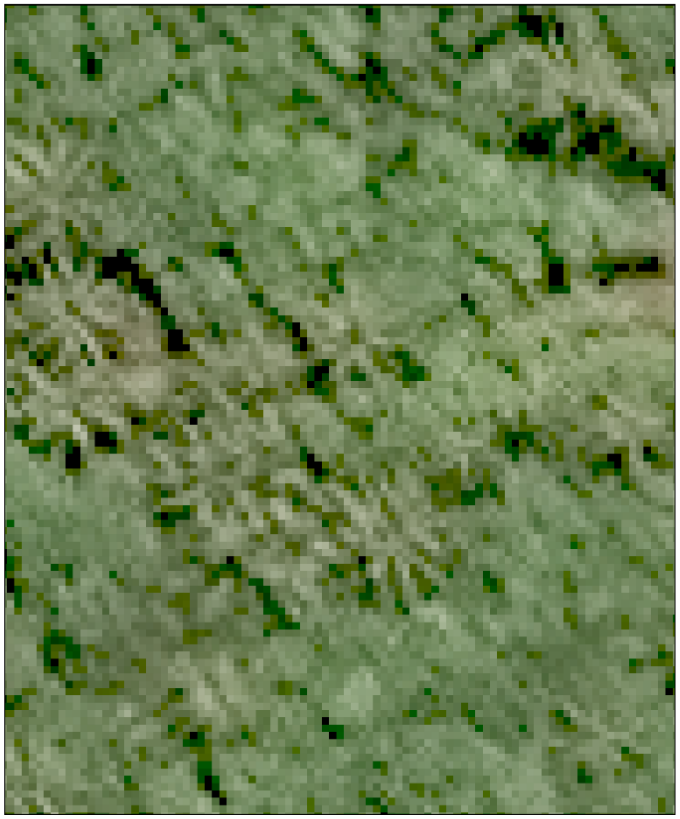


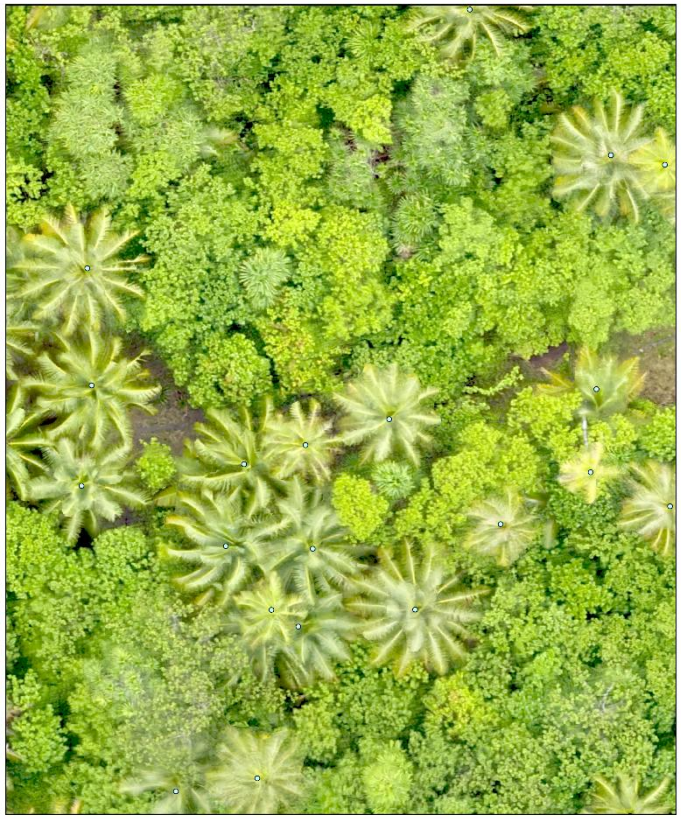
0.5
Kilometers



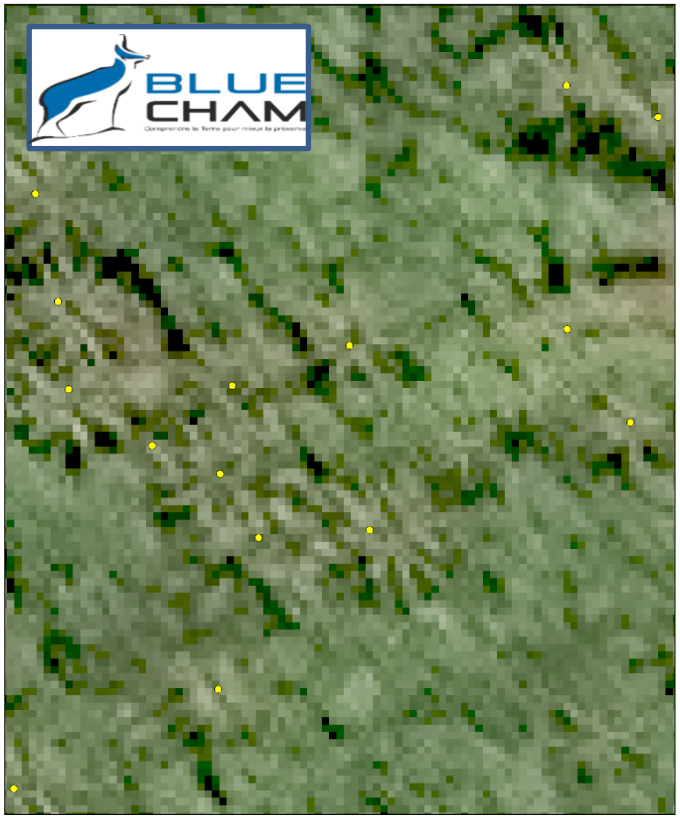
0.5
Kilometers


0.01
Kilometers


0.01
Kilometers

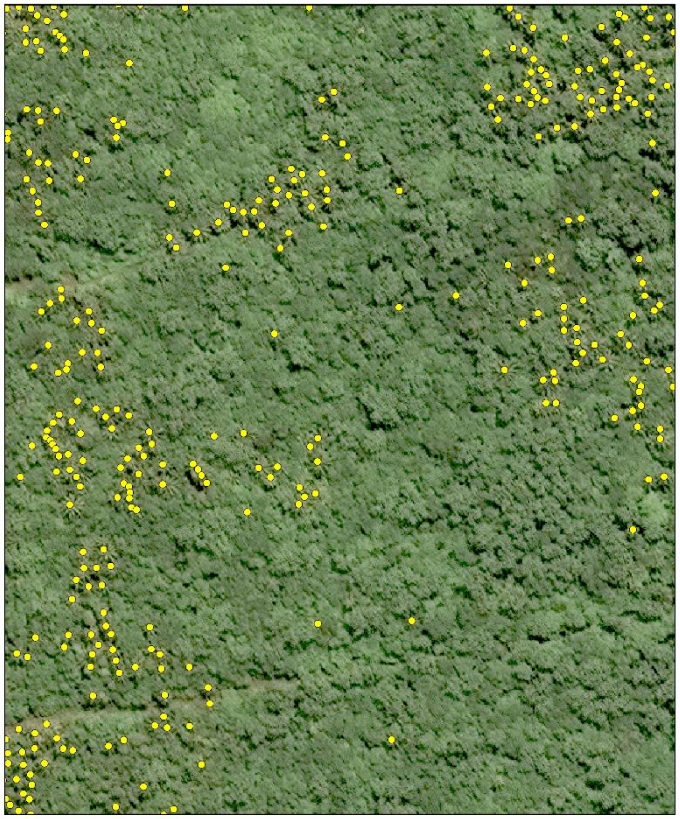


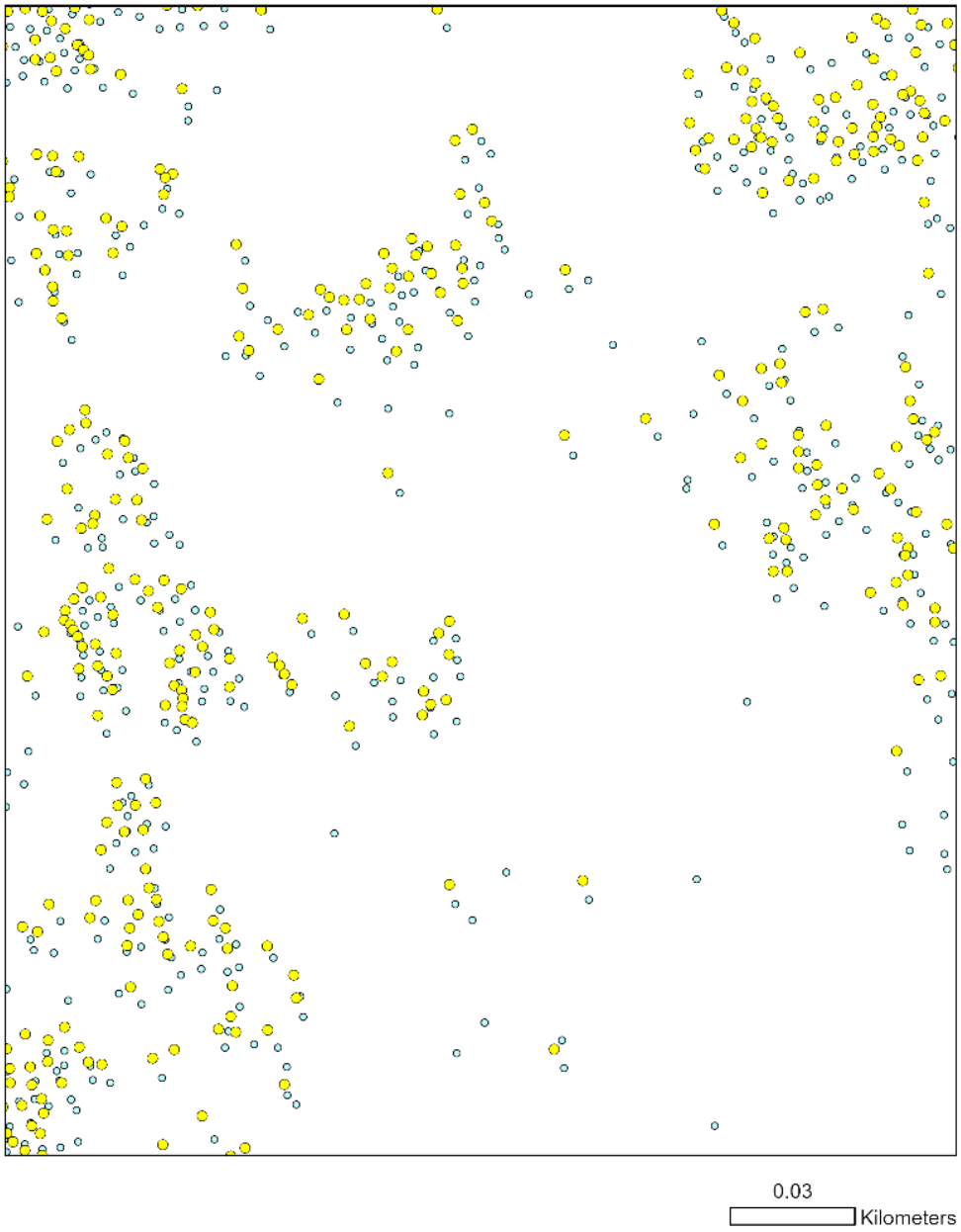
0.01
Kilometers



0.01
Kilometers


0.03
Kilometers


0.03
Kilometers



20,498
(drone)
vs.
17,322
(WV3)

~85% of the drone estimate

rperroy@hawaii.edu
juddson@atollconservation.org