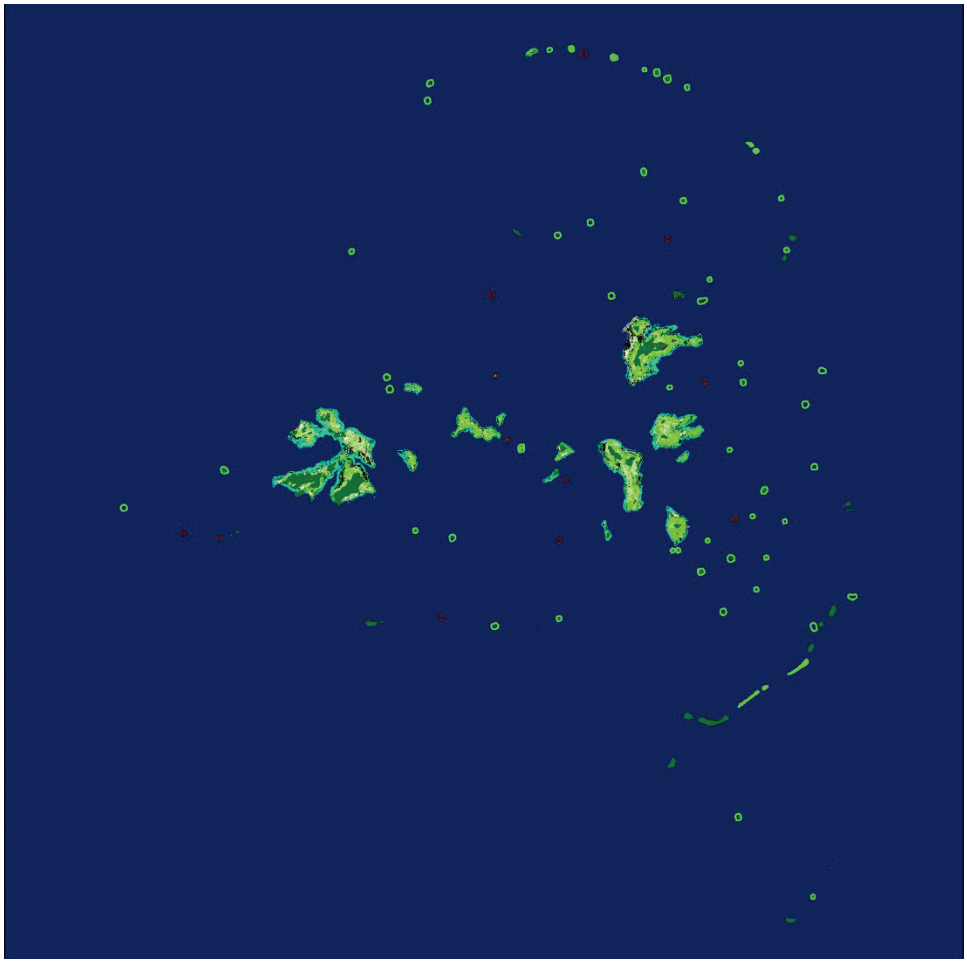
Chuuk Vegetation Map 2021-2023



Chuuk Lagoon, Federated States of Micronesia

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March 2024

Map 1. Cover Image Vegetation and land cover mapped on Chuuk Lagoon Islands, FSM, from 2021-2023 WorldView scenes and ancillary data. USDA Forest Service map.

Contents

Summary

Vegetation in Chuuk Lagoon Islands, Federated States of Micronesia (FSM) was mapped from satellite imagery and related data using a combination of computer modeling and visual interpretation. This map includes small islands in and around Chuuk Lagoon and nearby Neoch Atoll. 100 islands were mapped in the study area, 12 of them greater than 500 acres in area. Two thirds of forested islands are smaller than 100 acres. Islets smaller than 100 acres are shown in outline on the Cover Image. Forested area has decreased by 3000 acres since 2005, representing a loss of16%.

Class	Acres
agroforest	12,406
bare ground	1,236
forest	1,376
mangrove	2,573
other vegetated nonforest	4,627
urban built up	1,053
total	22,552

Table 1. 2023 Land cover class acreages

Data

In addition to the small format maps contained in this report, GIS data (updated March 2024) accompanying this report is available in Shapefile (SHP) format.

2023 Chuuk Vegetation Zipped ESRI Shapefile (SHP.ZIP) format associated with this report is available at https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd1169687.zip

This methods report can be downloaded here: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd1169688.pdf

This map updates the Forest Service 2008 map (Liu) which was based on 2004-2005 Quickbird II satellite imagery composites. Like this effort, the methods included image segmentation

using eCognition. Classification methods were less automated in the earlier effort and were assisted by in situ confirmation of the more detailed land use and land cover classes. The vegetation data is here
https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_045210.zip

Additional vegetation maps of Pacific islands are available on the R5 SPF Pacific Island Vegetation Mapping (PIVM) web page
https://www.fs.usda.gov/detailfull/r5/forest-grasslandhealth/?cid=fsbdev3_046690

Data Sources

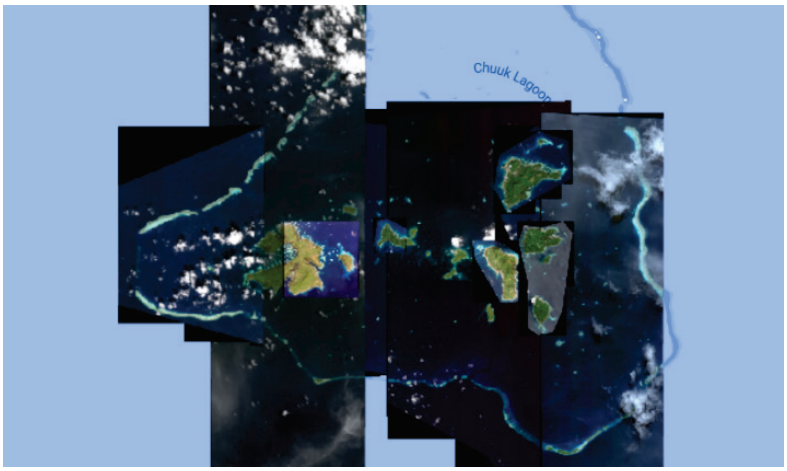


Figure 1. WorldView-2 and WorldView-3 scenes used

Scene Code	% Coverage	Date	Islands	Sensor	Maxar Image ID
ChuE1N	34	2022-01-19	Weno, islets	WV-2	10300100CD32BB00
ChuW0	24	2023-08-03	Tol, islets	WV-3	1040010088BB0600
ChuE0	19	2023-04-21	Fefan, Uoma, Udot	WV-2	10300100E510F500
ChuW	16	2022-01-19	Polle	WV-2	10300100CD32BB00
VIVID	14	2018 - 2021	islets	any	(RGBN Composite)
ChuW2021	12	2021-02-06	Tol, Fanapanges	WV-2	10300100B524E500
ChuFefan	11	2021-11-04	Fefan	WV-2	10300100C82E9A00
ChuE2S	9	2023-04-23	islets	WV-3	104001008577C300
ChuUdotW	7	2023-02-28	Udot	WV-2	10300100E39A1800
ChuE3	6	2022-07-20	Etten, Tonowas, Uman	WV-2	10300100D7178B00
ChuC0	5	2022-07-20	Fanapanges, Parem	WV-2	10300100D7188000
ChuWeno	5	2021-01-23	Weno	WV-2	10300100AFAEE700
ChuWreef	4	2022-11-30	islets	WV-2	10300100DE0AE200
ChuC00	2	2023-08-03	Oan, Unup	WV-3	10400100892A8900

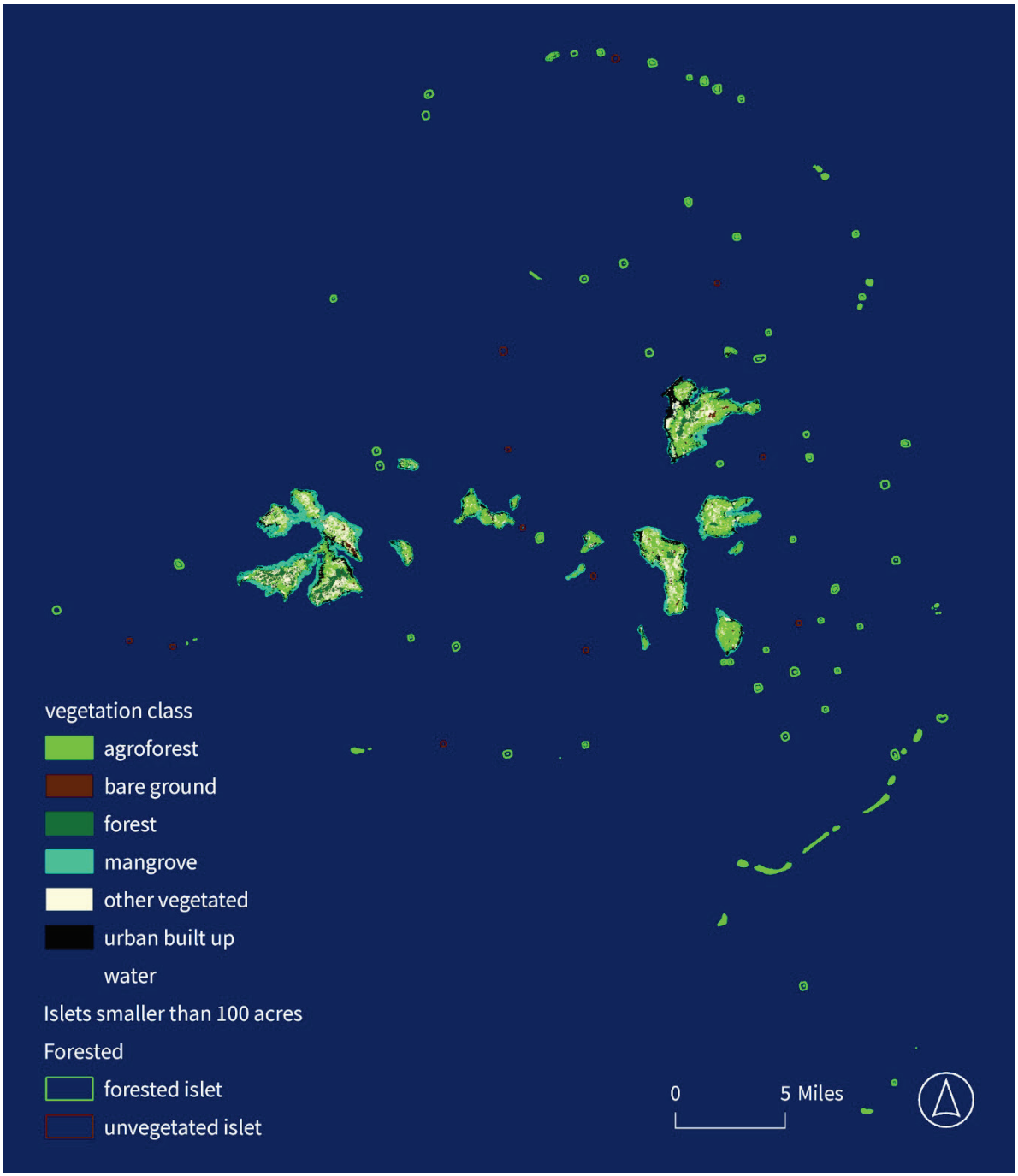
Table 2. Image Sources

- Primary Imagery: 13 WorldView-2 (WV-2) and WorldView-3 (WV-3) scenes from 2021-2023. Eight band (1.9m/1.2m) + panchromatic (0.5/0.3m) (Table 2). The imagery was acquired from Maxar's Digital Globe under the U.S. Government's Enhanced View Program
- Additional Imagery for filling gaps: Maxar Vivid FSM 2021
    - WorldView Four band composite (0.5m), multiple acquisition dates 2018-2021. Public license. Served via Natural Resources Conservation Service (NRCS) (accessed 27 November 2023) https://nrcsgeoservices.sc.egov.usda.gov/arcgis/rest/services/ortho_imagery
- Additional Imagery to aid automated classification: Sentinel-2 bands from two adjacent same day scenes from 2 February 2023 were incorporated the classified data
    - Code snippet from GEE script

```
var S2_Chu =
ee.Image('COPERNICUS/S2_SR_HARMONIZED/20230202T002421_20230
202T002418_T56NLP');
var S2_ChuS =
ee.Image('COPERNICUS/S2_SR_HARMONIZED/20230202T002421_20230
202T002418_T56NLN');
```

- Elevation Models: from 2018 VRICON 50cm photogrammetrically derived DSM and modeled DTM datasets. Covers most of the central islands
- Existing vegetation and substrate classifications and maps
    - Vegetation: Liu et al. 2008 (Central islands), Falanruw et al. 1987

The mapped area covers Chuuk Lagoon Islands, FSM, and the small islands lying within its reef. Land cover classes were adapted from Liu (2008), Falanruw et al. (1987). Classes include forest, agroforest, mangrove, urban built up, fern savanna, other vegetated (nonforest), water, secondary vegetation, wetland, and bare ground. Table 2 describes the classes, and lists land cover types from the other studies included in the scheme. This mapping effort uses hybrid methods that balanced a few considerations including classification accuracy, spatial detail and user needs.



Map 2. Chuuk Lagoon Islands Vegetation and land cover

Class	Description	Includes
agroforest	cultivated forests, silviculture including palm plantations. Local knowledge could further refine.	Forests intersecting or within 50m of mapped agroforest in historical sources, tree gardens, coconut stands. Islets with visible coconut stands.
bare ground	unvegetated areas	Beach, barren land
forest	tall upper canopy with woody vegetation excluding mangroves and agroforest	Upland Forest, Upland Broadleaf Forest, Atoll/Beach Forest, Palm forest,
mangrove	tidal forested wetlands	
other vegetated nonforest	vegetated landcover excluding forest	Grassland, Savanna, Cropland, Urban Cultivated, brush, low Pandanus, large Taro patches, vines including Merremia.
urban built up	unvegetated, paved, compacted or impervious	Developed/Disturbed
water	near shore and inland open water	Water, intertidal mud and sand flats, eelgrass beds

Table 3. 2023 land cover classes description

Methods

Overview

1. Review existing vegetation maps, identify current classification priorities
2. Via G-EGD, Obtain recent WorldView scenes, cloud free as possible
3. Data preparation and Preliminary Classification
    a. Refine analysis area of map (aoi)
        i. a buffered spatial extent of all terrestrial areas, mangrove zones, and vegetated barrier islets within study area
    b. Collect recent inventory of satellite imagery at Maxar Discovery site , obtain subsets of 8band + panchromatic via G-EGD as needed (Table 2)
    c. Upload assets to Google Earth Engine (GEE) workspace
    d. Scripted raster stack creation in GEE
    e. Collect image training samples in ArcPro
    f. Use training samples to train random forest classifier
    g. Classification of raster stack
    h. Review interim classification and interim accuracy assessment
    i. Iterate: repeat and refine steps a-g above
    j. Export stack of preliminary classifications and additional bands
4. Segment and vectorize stack in eCognition
    a. use preliminary class as major factor
    b. Export classified image objects as classified polygons
5. Synthesize single Vegetation layer in ESRI Arc Pro 3.1
6. Map Revision 1: Targeted QA of uncommon types and systemic error
7. Reclassify selected forest polygons as agroforest
8. Apply 50m^2 and 250m^2 minimum mapping units some mapped classes
9. Internal and Partner review of Draft map GIS, Methods and Results document
10. Address review recommendations and apply corrections
11. Publish revised map and report

Classification priorities

Throughout the mapping process, several considerations guided the development of the classification scheme. One consideration was finding the clearest and most recent imagery available. The need to produce a draft map with high spatial resolution was also important, as was a map with good classification accuracy overall, and with good accuracy by vegetation class. Another goal was to develop a mapping process that was more automated than previous efforts, and that could be applicable to other Pacific islands.

Capturing unvegetated forest areas was an additional key priority, with attention given both during preliminary model iteration, as well as draft review and editing. This can assist in identifying candidate sites for reforestation in cleared areas.

Refine and reduce mapped area

Mapped area includes all terrestrial sites within Chuuk Lagoon. To identify these sites, a Sentinel-2 based 36 month composite 'SCL' classification was used to omit water and clouds but include land with a spatial buffer. A second pass was made over Chuuk Lagoon using 2021 VIVID to identify all vegetated and unvegetated islets. These buffered masks are used to include all land and mangroves, and to also remove most water except for a buffer around the shore. This refined mask is useful in several later steps that use 'by island'. This mask is further broken into 'by scene' based on which Source imagery is used for each part of the stack.

Source imagery

Obtaining timely imagery with limited cloud cover and haziness over Chuuk Lagoon Islands continues to pose a challenge. Thirteen WV2 scenes with relatively limited cloud cover from 2021 to 2023 were identified and acquired under the NextView license. Scenes were obtained in multiple formats, including 8 band and panchromatic for analysis and classification, and in pansharpened format to aid visual interpretation and classification of image samples. CIDR 'best available imagery' DAR data requests were happily fulfilled for imagery collection in August of 2023 (Table 2), allowing for an updated map. Scripting the composite of images, allowed for easy updating of the image stack on Google Earth Engine soon after new imagery became available.

A 2021 VIVID composite was also used for interpretation, and for filling in classification gaps in 2023 imagery due to cloud cover and/or haze.

Uploading assets

In addition to subsets of the WV scenes listed in Table 2m, other uploaded assets include

- DSM
- DTM
- small subsets of 4 band VIVID
- polygons by scene
- sample classification points

Raster stack creation

A script was developed in Google Earth Engine to compile the stacks, train, run and test a classifier, display various results, and finally to export preliminary classifications for vectorization and further refinement in eCognition and ArcPro.

Two separate stacks are referred to in this process, an analysis stack and an export stack. Both are based on the 8-band multispectral, with additional elements from the supplementary data sources. Bands were normalized to 8-bit values with the 'ee.Image.visualize()' function in Google Earth Engine. Band and image specific parameters were used for normalization.

The analysis stack includes these bands:

1. Green
2. Blue
3. Red edge
4. Yellow
5. NDVI = (NIR-Red)/(NIR + Red)
6. NDWI = (NIR-Green)/(NIR + Green)
7. Digamma of Blue band
8. Texture band. glcm inverse distance moment (idm) derived from WV panchromatic
9. Elevation value. Derived from VRICON 2018 DTM
10. Near-Tidal Elevations ~30m and less. Derived from VRICON 2018 DTM (DTM < 30m)
11. CHM 'canopy height model'. Derived from VRICON 2018 (DSM – DTM)
12. 'MVI' index derived from Sentinel-2. MVI = (NIR - Green)/(SWIR - Green)
13. 'ndNSW1' index derived from Sentinel-2. = (NIR – SWIR1 / NIR + SWIR1)

The first 8 bands are derived from WV-2 or 3 (Table 2). The remainder are derived from the elevation models and Sentinel-2. Indices using the SWIR band can be useful for identifying mangroves MVI from Tran et al. (2023) is illustrated in Figure 3. To include this predictor, the last two bands are derived from harmonized Sentinel-2 scenes. They incorporate shortwave infrared band 11 (SWIR1), near infrared band 8 (NIR) and Green band 3.

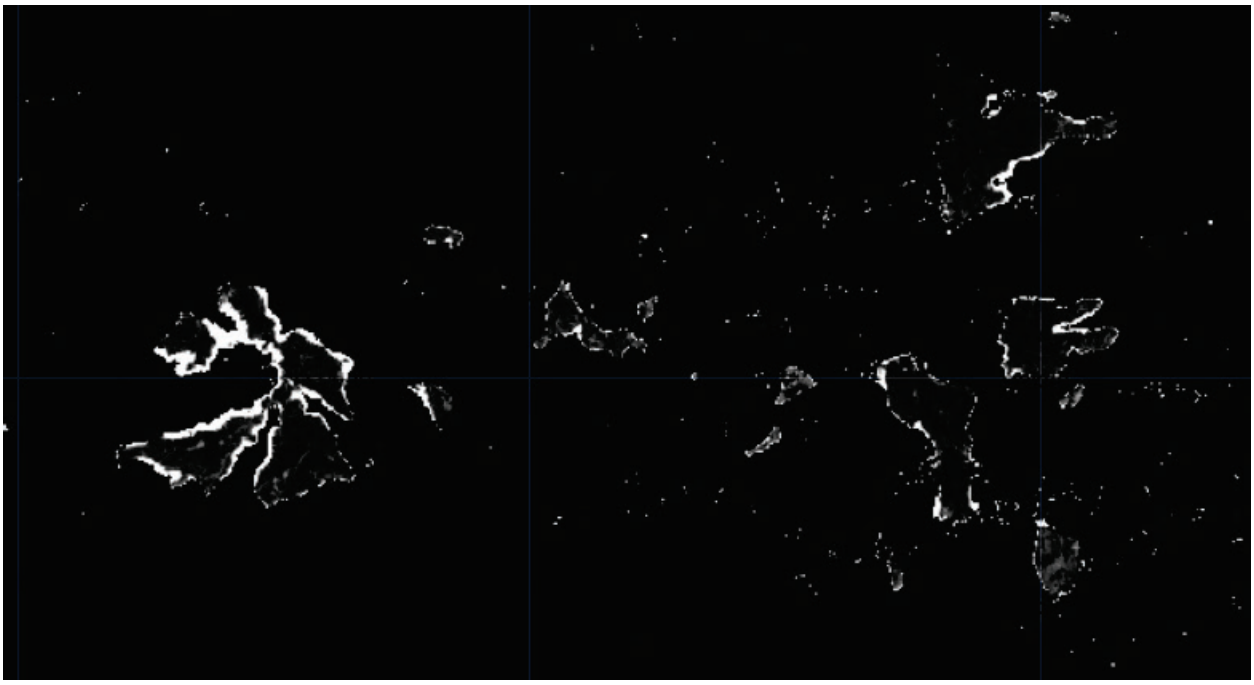
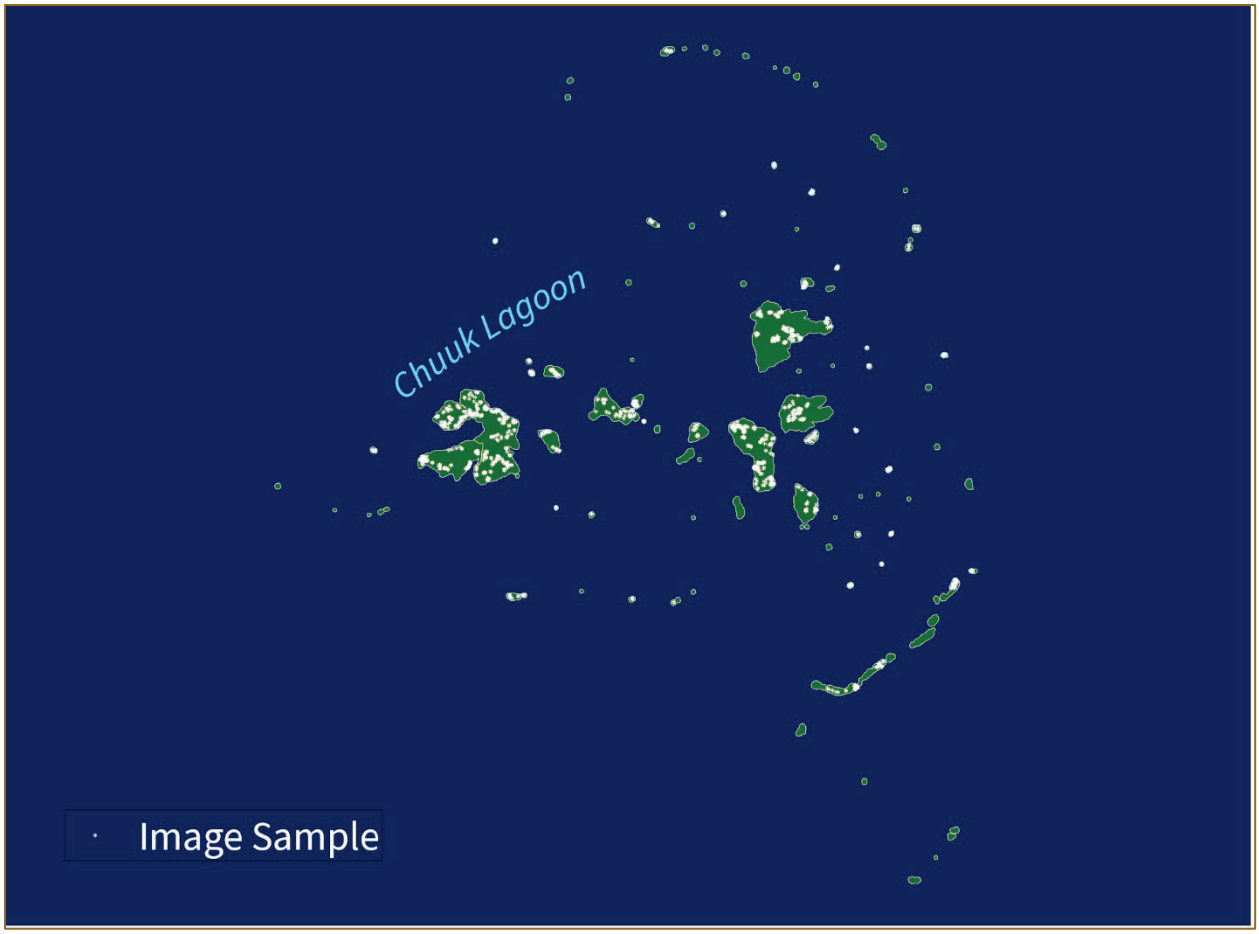


Figure 2. MVI from Sentinel-2 displayed in Google Earth Engine

Image sampling

Collection of training sample data was conducted in ArcPro. Over several iterations, about one thousand image samples were collected from land cover classes listed in Table 3.



Map 3. Image sample locations

Classification

In Google Earth Engine, a random forest classifier was trained with 80% of the image sample data, and with a random 20% held in reserve for testing. Target accuracy for this preliminary classification model was 80%. An alternate classification was created that did not use the 2018 elevation data. This was used to identify bias introduced by the useful, but older elevation models.

Review interim classification and iterate

After checking the accuracy, qualitative checks over the mapped area were conducted. Developing the script was an iterative process. This scripted model can be adapted for other Pacific Islands. It is also updatable with new imagery for Chuuk.

When image segments in the composite were updated, so were image sample points. With additional samples being collected as newer imagery was integrated into the scripted model.

Export stacks

The exported stack contains the 8 WorldView bands, the glcm derived bands and preliminary and alternate classification rasters. The alternate classification does not use the VRICON DEM for training the model. Four separate raster stacks were exported at 1.24m resolution for import into eCognition.

Vectorization and segmentation in eCognition

While preliminary classification was implemented in Google Earth Engine, refinement and vectorization was done in eCognition Developer 10.2 using the classified raster, an alternate classification generated without the elevation derived bands, and additional bands in the exported stack.

eCognition was used differently in the Chuuk mapping effort than in previous FSM mapping efforts. In Chuuk, the preliminary classification is pixel-based via Google Earth Engine scripts. Earlier efforts in Yap and Pohnpei (Salomon 2023, 2022) used eCognition more extensively for classification. For Chuuk, eCognition is used for vectorization and further segmentation within vegetated areas.

Multi-threshold segmentation by class was performed on the classified raster stacks that were exported from Google Earth Engine. Vegetated objects were further segmented using multi-resolution segmentation applied to other bands in the export stack. This was to allow for easier refinement in final mapping corrections and the classification of agroforest. The results were vectorized and exported as shapefiles with preliminary land cover classification applied.

Synthesis and revision of vegetation map

A single vegetation map layer was synthesized using classified shapefiles from the previous steps in eCognition. In ArcMap, the two spatially overlapping datasets were combined into a single vegetation map without overlaps. Additional systematic rule-, size- and location-based edits were performed on the draft vegetation map in preparation for delivery. Very small polygons of all classes that were less than 25 m^2, excepting small mangrove islands were eliminated by merging with adjacent larger polygons. Larger minimum mapping units of 250 square meters were used for secondary vegetation and other nonforest vegetation. Land cover polygons were dissolved by class into single part polygons to reduce the number of output features.

Reclassify selected forest polygons as agroforest

Forest polygons from the synthesis layer were reclassified as agroforest if they spatially intersected or were within 50m of agroforest classes in the 1987 or 2008 USDA Forest Service vegetation maps. GIS data from these earlier efforts was spatially shifted to better align with the current mapping effort.

Review, Revision and Publication

Internal review was conducted. Comments were solicited on the draft report and vegetation map. The draft was shared partners including foresters in Micronesia and Chuuk State, as well as regional and subject matter experts within the USDA Forest Service and academia. Internal map accuracy assessments were also conducted. Further revisions were. Final changes were made to the vegetation map and document based on review comments and internal accuracy assessments. The final accuracy assessment of the vegetation map is shown on Table 4.

Accuracy Assessment

Final accuracy assessment will be conducted on the final layer after review comments are incorporated. Assessment based on image interpretation estimate 73% overall accuracy.

Reference (Test Samples)	Agro/ forest	mangrove	other veg.	bare ground	urb built	water	total correct	total	% User Acc.
Map Class									
Agro/forest	210	4	23	1	6	2		246	85
mangrove	4	48	1	0	0	3		56	85
other vegetation	45	5	62	1	1	1		115	53
bare ground	3	0	11	9	0	0		23	39
urban built up	10	0	4	3	17	0		34	50
water	1	3	0	0	0	9		13	69
total	273	60	101	14	24	15	355	487	
% Producer's accuracy	77	80	61	64	71	60			73

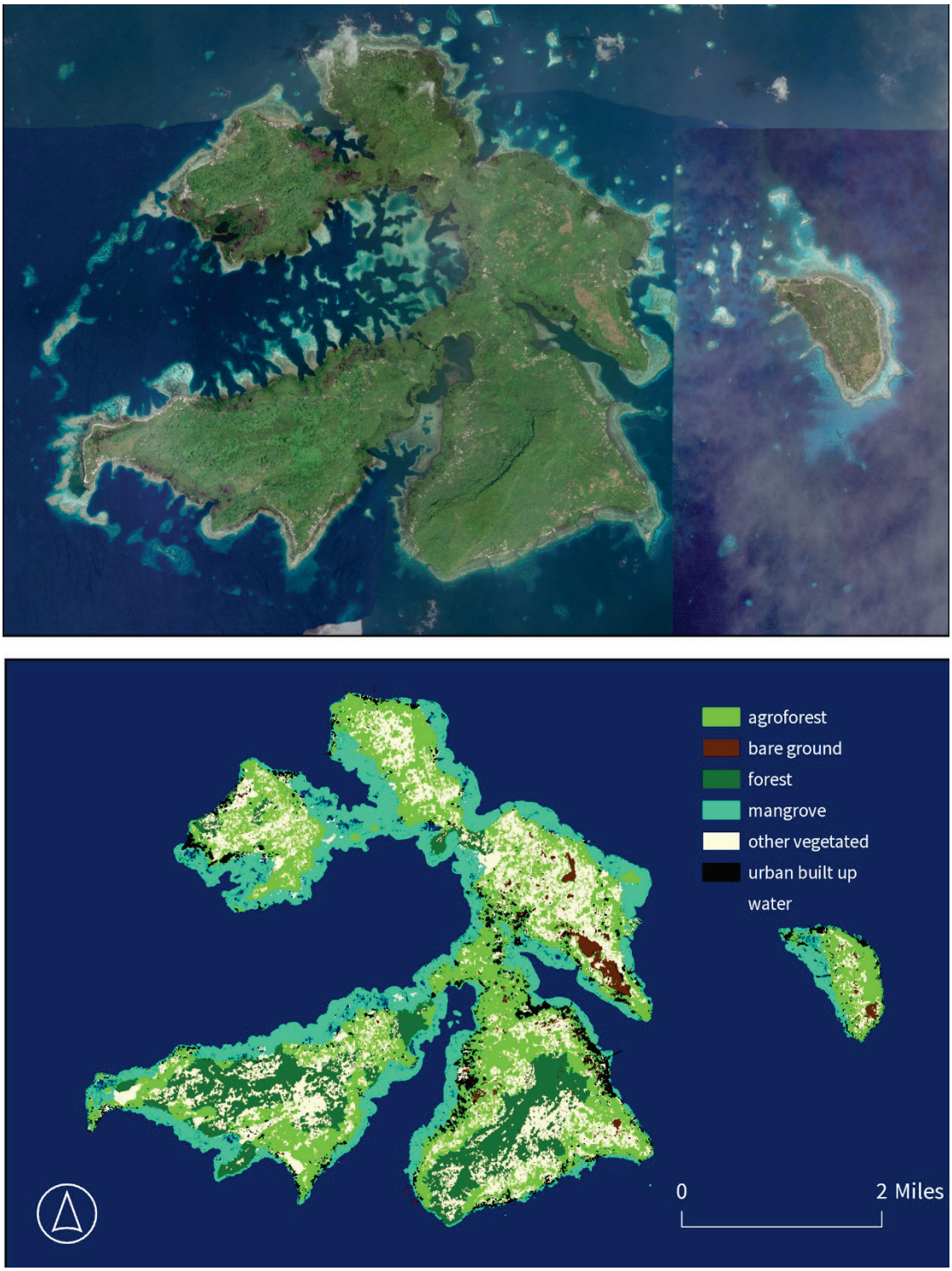
Table 4. Accuracy assessment and confusion matrix

Results

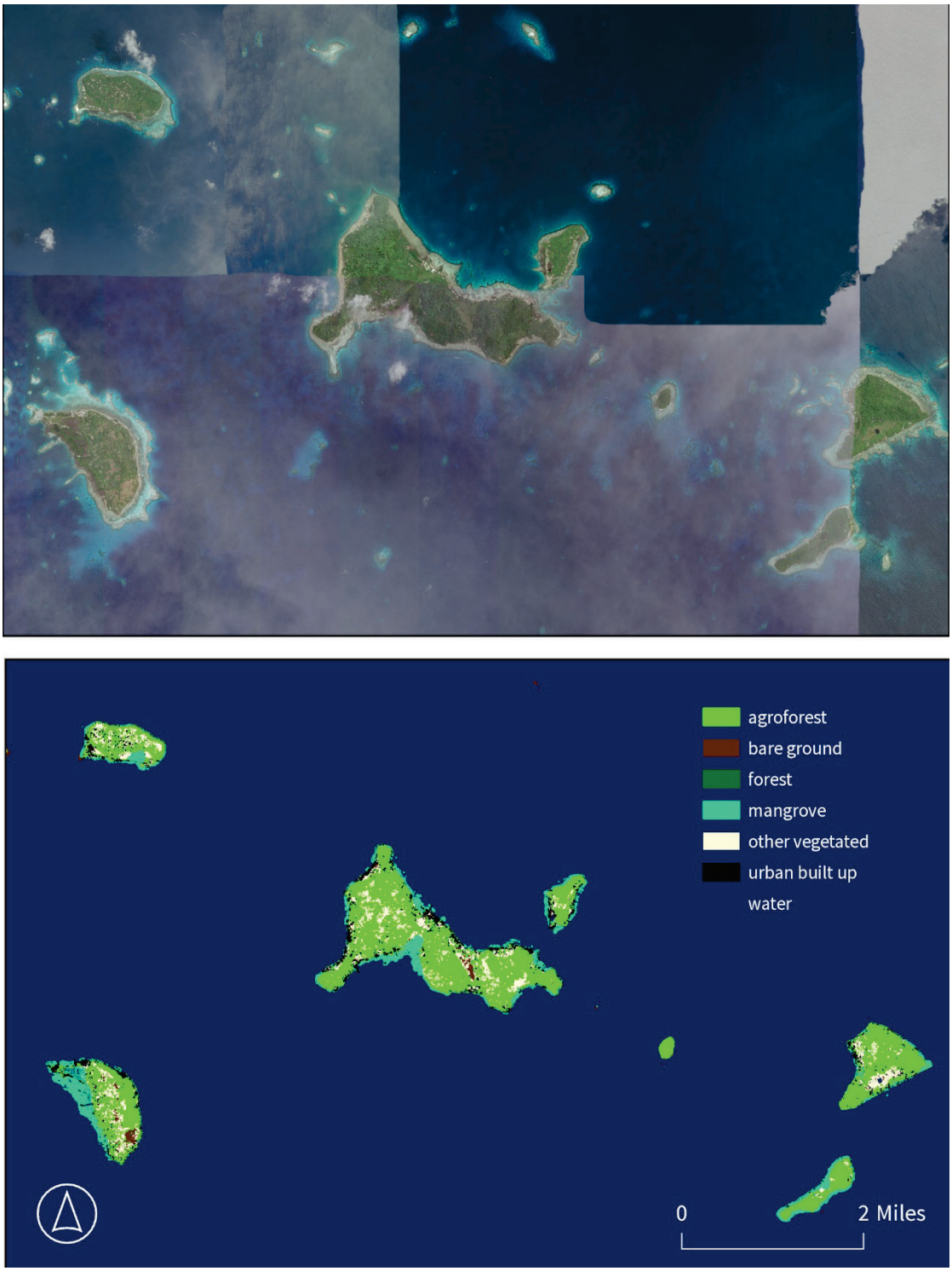
Acreages of each land cover class were calculated (Table 1). Including mangroves, the islands of Chuuk Lagoon, totaling 22,552 acres, are 73% forested and 93% vegetated. Maps on the following pages show several views of the dataset in comparison with contemporary imagery (VIVID 2023). Small islets represent an additional 1,000 forested acres that were not mapped in prior efforts.

Table 6 compares the classification between this vegetation map and two historical vegetation maps. The Falanruw et al. 1987 mapping effort used manual mapping methods at a smaller scale, combined with botanical expertise, aerial photo interpretation, and extensive field confirmation. Previous mapping efforts conducted by Liu were based on 2003-2005 satellite imagery.

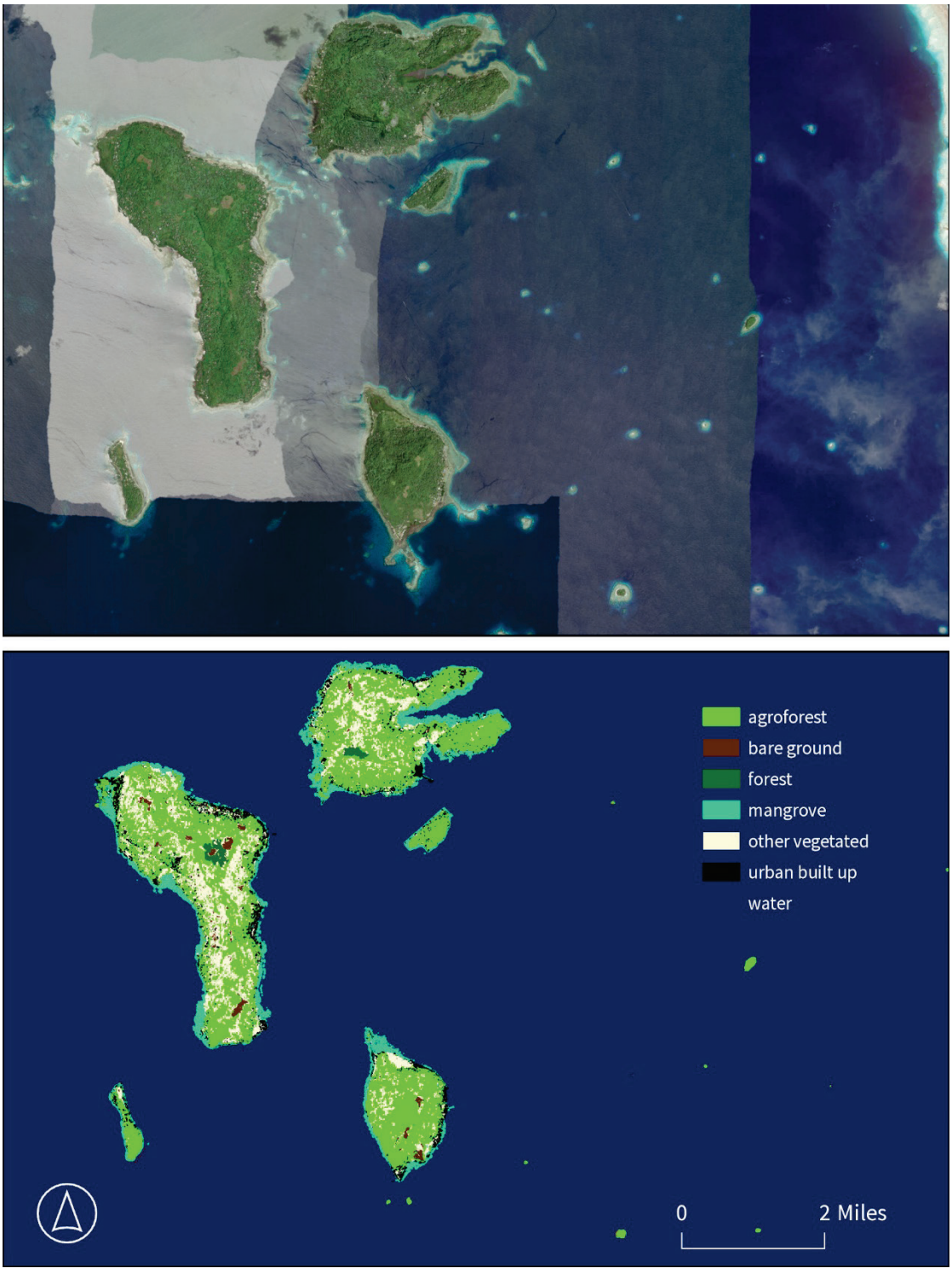
Table 7 compares the central islands in overlapping areas from Liu 2008. Comparison indicates a decrease of almost 3000 forested acres or 16% in the last two decades. Forested areas include agroforest, upland forest, and mangrove. About 2/3 of the change is to from forest to nonforest (other) vegetation.



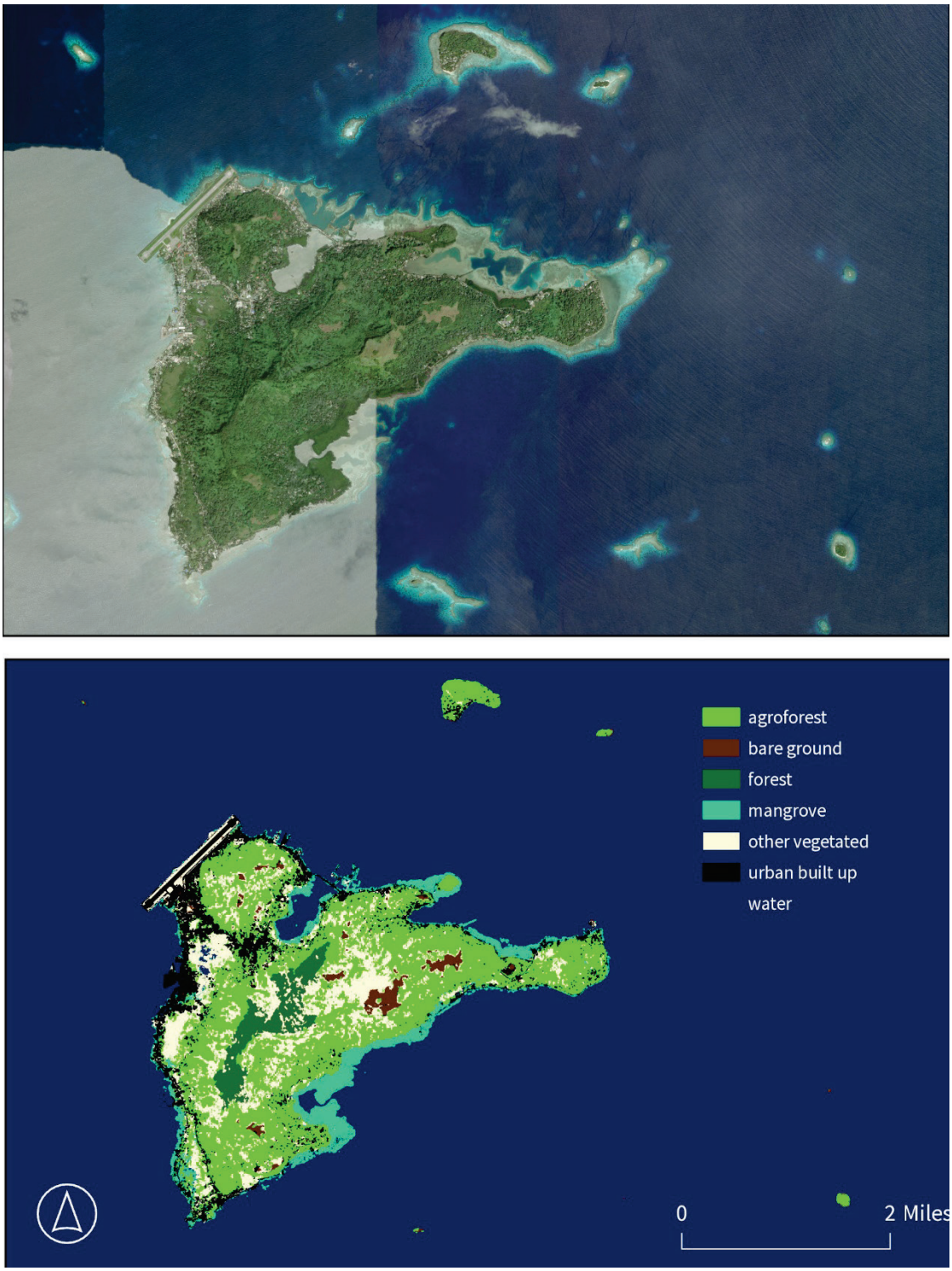
Map 4. Faichuuk: Tol, Polle, Wonei, Paata, Fanapanges



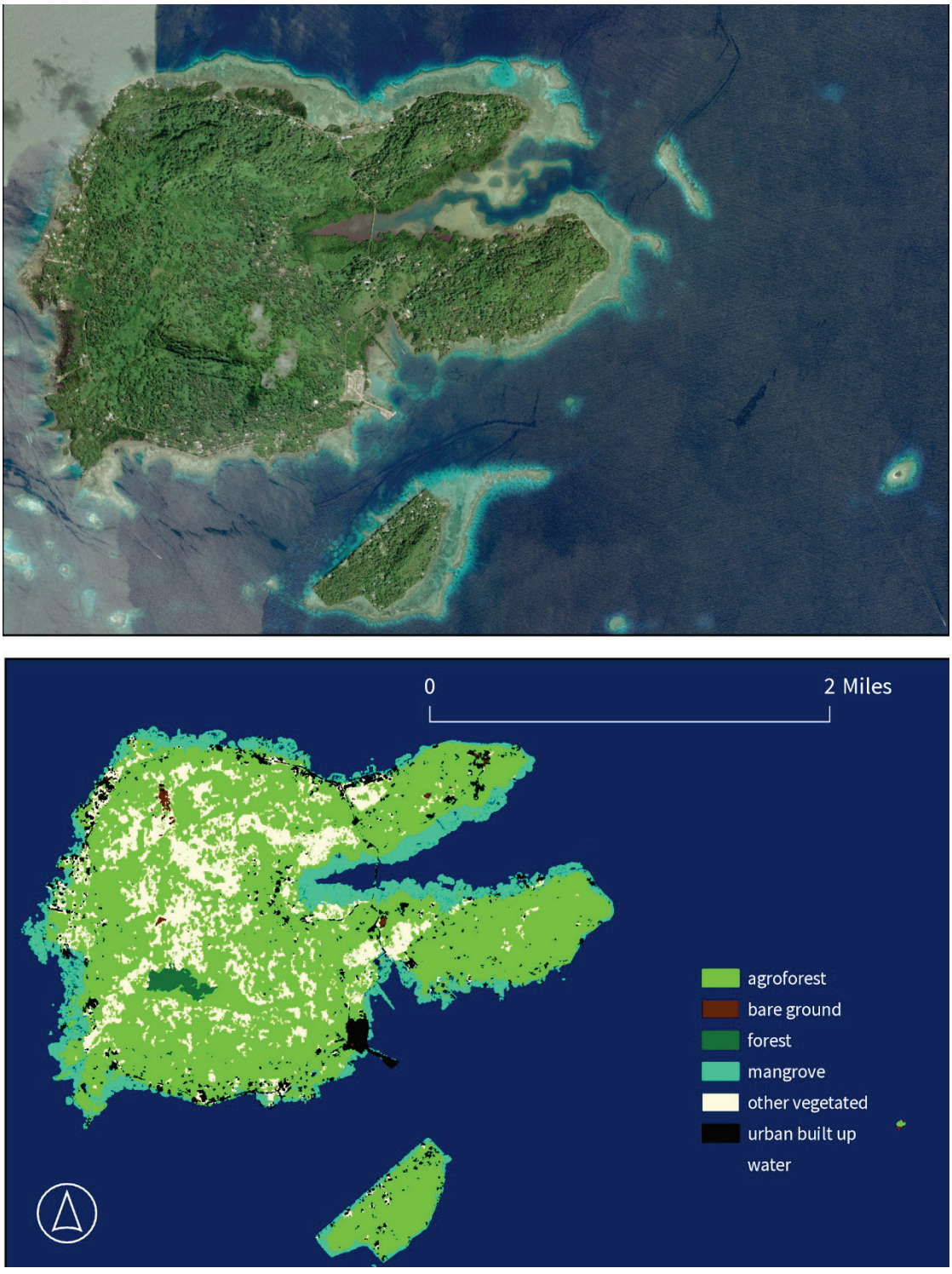
Map 5. Udot, Parem



Map 6. Fefan, Uman


agroforest
bare ground
forest
mangrove
other vegetated
urban built up
water
0
2 Miles

Map 7. Weno



Map 8. Tonowas, Etten

Salomon (2021-23)	Falanruw et al. (1970s – 1987)	Acres	Liu et al. (2004-5)	Acres	~1980	~2005	~2023
agroforest	Agroforest	5,393	Agroforest	5,384	5,393	5,384	5,858
forest	Upland Broadleaf Forest	1,597	Upland Forest	1,514	1,613	1,514	278
	Palm Forest	5					
	Atoll/Beach Forest	11					
mangrove	Mangrove Forest	713	Mangrove Forest	792	713	792	668
other Vegetation	Savanna/Grassland	443	Grassland or Savanna	296	1,434	1,639	2,194
	Secondary Vegetation	594	Secondary Vegetation	549			
	Freshwater Marsh	397	Marsh	411			
			Urban Cultivated	381			
			Cropland	2			
urban built up	Developed/Disturbed	513	Urban Builtup	553	513	553	638
bare ground	Rock Outcrop	5	Barren	18			218
	total	9,671		9,900			9,852

Table 5. Comparison with circa 1980 and 2005 acreages

The overlapping extents of the 1987 map with the later studies include only the largest islands in eastern Chuuk Lagoon: Weno, Fefan, Tonowas, and Etten.

Salomon (2021-23)	Liu et al. (2004-2005)	Acres	~2005	~2023
Agroforest	Agroforest	10,618	10,618	11,254
forest	Upland Forest	4,147	4,342	1,376
	Palm Forest	195		
mangrove	Mangrove Forest	3,181	3,181	2,573
Other Vegetation	Grassland or Savanna	685	2,682	4,623
	Urban Cultivated	528		
	Cropland	147		
	Secondary Vegetation	772		
	Marsh	550		
urban built up	Urban Builtup	774	774	1,043
bare ground	Barren	43	43	499
		21,640		21,369

Table 6. Comparison with 2004-5 acreages

The overlapping extents of the 2008 and 2024 maps include the largest islands near Chuuk lagoon. These islands are Weno, Fefan, Tonowas, Etten, Tol, Polle, Udot, Peniata, Uman, Nukaf, Fanapanges, Parem, Romonum, Siis, Unup, Eot, and Oan.

References

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Data https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd835201.zip

Liu, Z , 2008. Vegetation Map Data, Yap 2004-2005. USDA Forest Service Region 5, State and Private Forestry.

https://www.fs.usda.gov /Internet/FSE_DOCUMENTS/fsbdev3_045210.zip

Maxar (DigitalGlobe) satellites https://www.maxar.com/constellation

WorldView-2 and -3 single scenes. Refer to Table 2

Vivid 2021 and 2023 composites and metadata (accessed 12 December 2023)

- https://nrcsgeoservices.sc.egov.usda.gov/arcgis/rest/services/ortho_imagery/micronesia2021/ImageServer
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- https://nrcsgeoservices.sc.egov.usda.gov/arcgis/rest/services/ortho_imagery/micronesia_vivid_2023_30cm/ImageServer

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