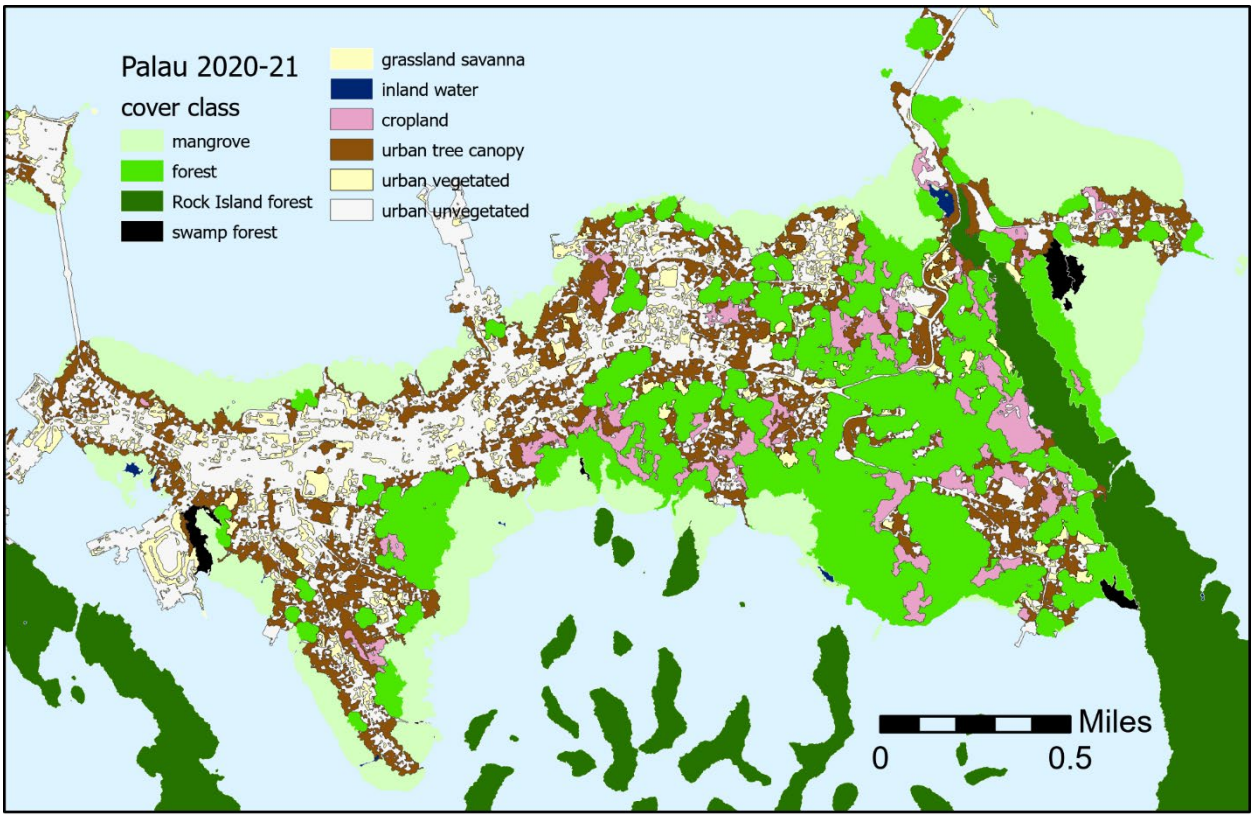
Palau Vegetation Map 2020-21

Koror State and Rock Islands

Micha Salomon – State and Private Forestry, Region 5 – USDA Forest Service

April 2022



Map 1. Cover Image Vegetation and land cover mapped in Koror State, including the Rock Islands, from 2020-21 WorldView scenes and ancillary data. USDA Forest Service map by Micha Salomon

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Contents

Palau Vegetation Map 2020-21 i
Map 1. Cover Image i
Summary 1
Table 1: 2020-21 land cover classes and acreages mapped 1
Data Sources 2
Methods 4
Figure 1. eCognition Segmentation parameters and inputs 5
Figure 2. Canny edge analysis on WV2-panchromatic in Google Earth Engine 6
Figure 3. Segmentation of Imagery into Vegetation Patches 7
Results 8
Table 2. 2020-21 Land Cover Data 8
References 16
Acknowledgements 17
Appendix A: Class Descriptions and Crosswalk to other Palau Land Cover Classifications 17

Summary

Vegetation in Koror State, Republic of Palau was mapped from satellite imagery and related data using a combination of computer modeling and visual interpretation. Three satellite images collected in 2020 and 2021 were classified into vegetation and land cover types.

Class	Acres
mangrove	410
forest	818
Rock Island forest	12,406
swamp forest	14
grassland savanna	9
inland water	334
cropland	159
urban tree canopy	327
urban vegetated	153
urban unvegetated	580
Total	**15,210**

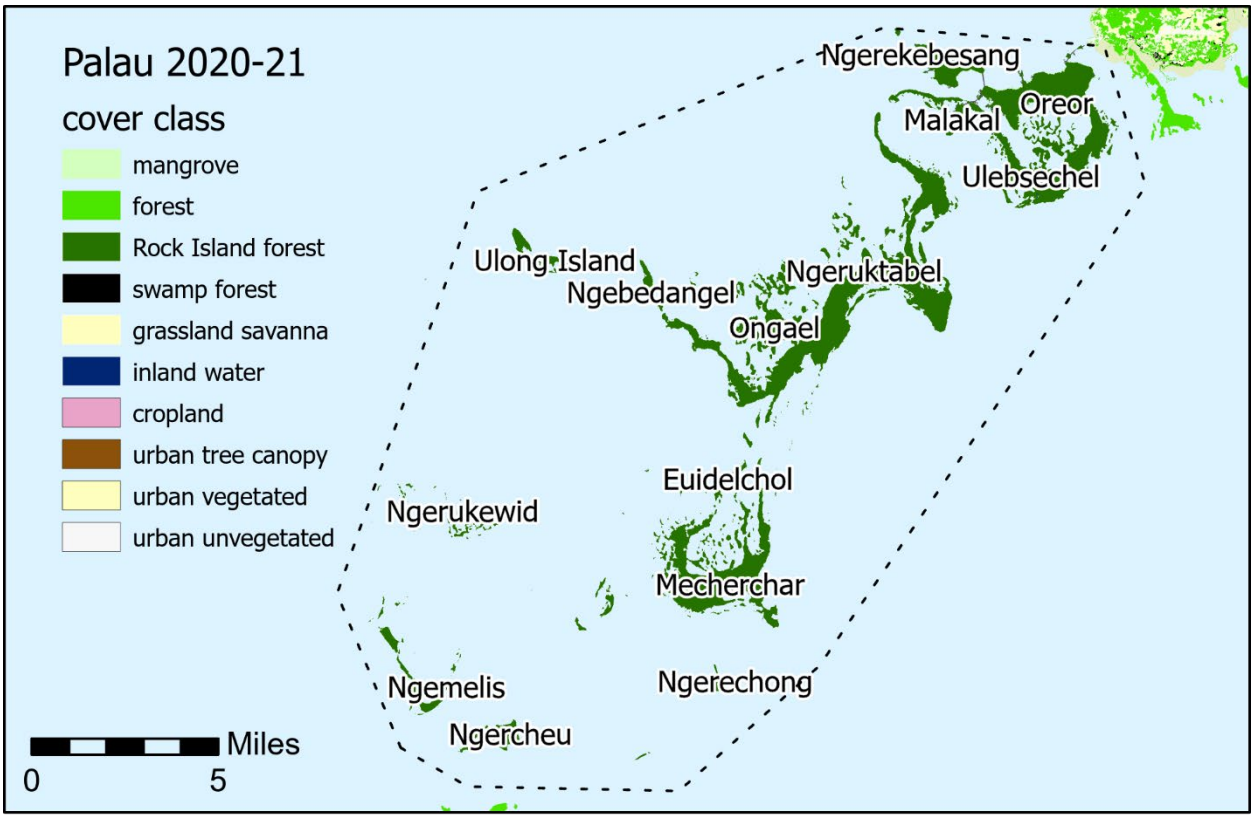
Table 1: 2020-21 land cover classes and acreages mapped

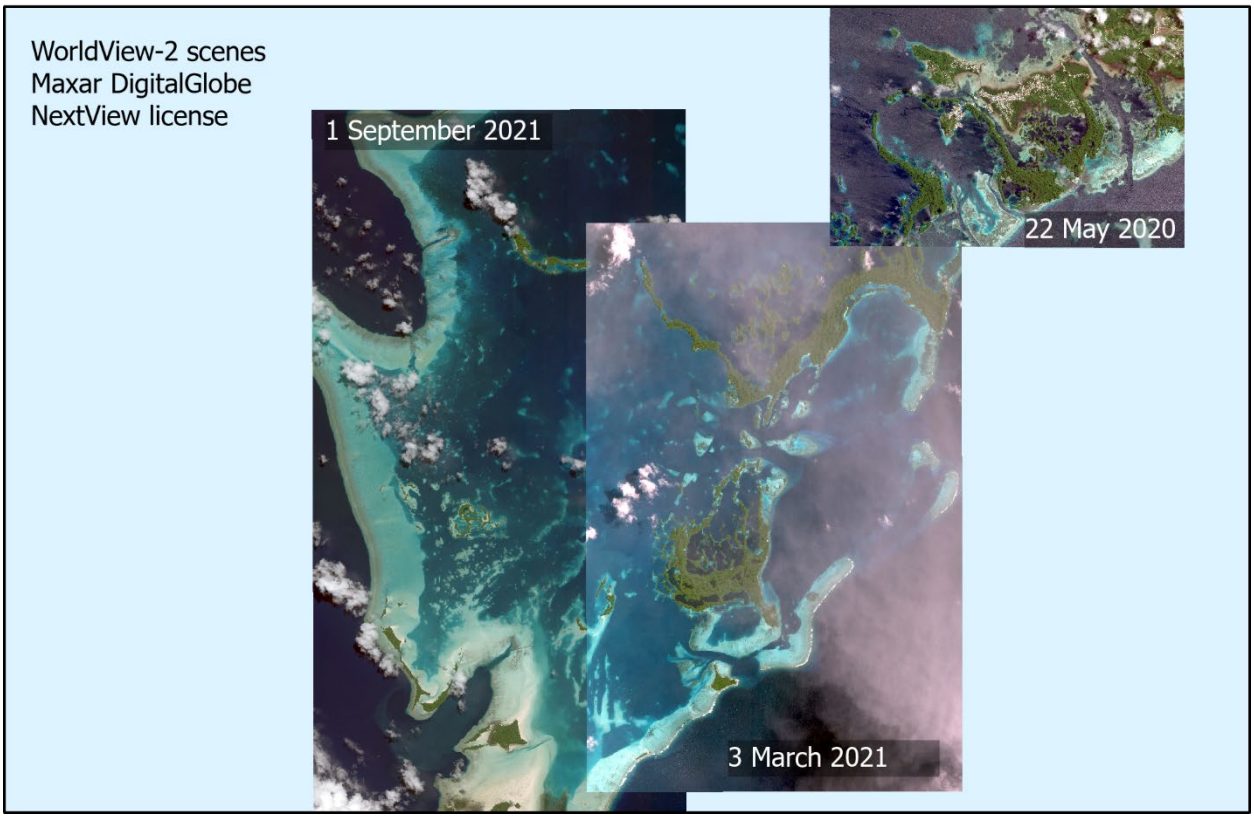
This mapping effort supplements Greenberg 2020 in updating Liu 2006.

GIS data accompanying this report is available at https://www.fs.usda.gov/detailfull/r5/forest-grasslandhealth/?cid=fsbdev3_046690

Data Sources

- Satellite Imagery: 3 WorldView-2 (WV2) scenes from 2020-21. 8 band (1.9m) + panchromatic (0.5m). The imagery was acquired from Maxar's DigitalGlobe under the U.S. Government's EnhancedView Program
    - 22 May 2020 – Koror City, Malakal, Ngerekbesang, nearby Rock Islands
    - 3 March 2021 - Rock Islands including Ngeruktabel and Mecherchar
    - 1 September 2021 – Rock Islands including Carp Island, Ngerukewed
- Ancillary imagery: Maxar Vivid Palau 2021
    - WorldView composite, multiple acquisition dates 2015-2021. Public license. Served via NRCS (accessed 7 Feb 2022) https://nrcsgeoservices.sc.egov.usda.gov/arcgis/rest/services/ortho_imagery
- Elevation from Vricon
    - DSM, DTM 50cm horizontal resolution, variable vertical precision. Unpublished
- Existing vegetation and substrate classifications and maps
    - Vegetation: Forest Action Plan (Republic of Palau 2021), Greenberg 2020, Liu et al. 2006, Cole et al. 1987
    - Substrate: NOAA 2007, NRCS SSURGO





Map 2. Area Mapped and Source Imagery

Methods

The mapped area covers Koror State in Republic Palau including the iconic Rock Islands extending southwest. Land cover classes were adapted from Liu (2006), Cole et al. (1987), and the 2021 Palau Forest Action Plan (SWARS). Final land cover classes include mangrove, forest, Rock Island forest, swamp forest, grassland savanna, inland water, cropland, urban tree canopy, urban vegetated, and urban unvegetated. Absolute minimum mapping unit (MMU) for all classes was set at 32 m^2 , equivalent to 9 pixels in WV2 8 band. The small MMU includes all but the smallest nearshore mangrove stands, and captures in detail urban vegetation and cultivated areas near Koror City.

Three WV2 scenes with limited cloud cover were identified and acquired under the NextView license. NDVI and NDWI, spectral indices that highlight vegetation and water, were generated from the 8-band imagery and rescaled to 8-bit values for segmentation in eCognition Developer 10.1. A 50 cm Vricon digital surface (DSM) and terrain (DTM) model and derived nDEM (DSM-DTM), a coarse canopy height model, were scaled similarly into 'relative elevation' rasters and used in segmentation.

Threshold classifications on WV2 bands and the indices and ancillary rasters mentioned above, including NDWI, NDVI to separate unvegetated from vegetated landcover. For two of the three WV2 images and about half of the third, this was largely sufficient to classify most of the Rock Islands into 'Rock Island forest' and 'inland water'. Since this mapping effort is focused on mapping terrestrial vegetation, 'priority' is given to classifying the tallest canopy cover, rather than what is underneath, whether that might be a road, a tidal channel or understory vegetatation. Around Koror City, on the islands of Oreor, Ngerekbesang and Malakal the complexity of the landscape required further differentiation.

Multiple steps were taken to further classify vegetation on the islands nearest Koror City, including image segmentation, random forest classification, vectorization, rule-based classification of intensive land uses, review and revision, especially in areas of cloud cover.

ECognition's 'multiresolution segmentation' algorithm was used to segment only the vegetated portion (defined in the previous step) of the 22 May 2022 WV2 image.

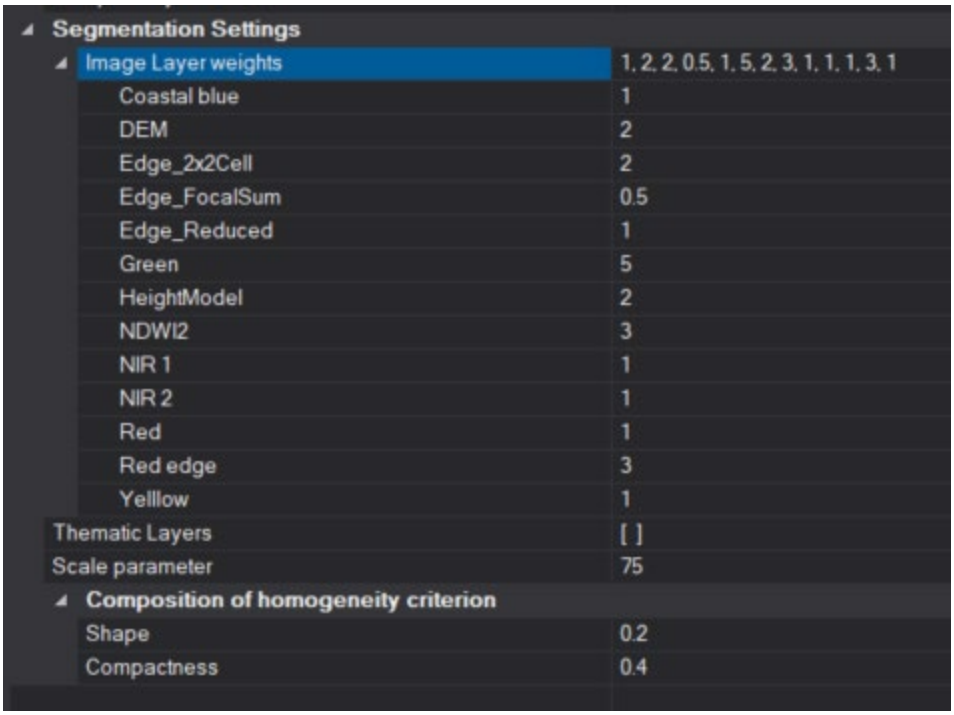


Figure 1. eCognition Segmentation parameters and inputs

To help differentiate between tree canopy and grassland/cropland vegetation and to incorporate the higher spatial resolution of the panchromatic band (0.5m) relative to the visible/IR 8 band product (1.9m) , a Canny edge analysis was conducted on the panchromatic band in Google Earth Engine. Three derivatives of the edge raster were used in the segmentation model to help separate vegetation types.

```
// Perform Canny edge detection and display the result.
var canny = ee.Algorithms.CannyEdgeDetector({
  image: image, threshold: 100, sigma: 0.2
});
Map.addLayer(canny, {}, 'canny');

/*var reduced = canny.reduceResolution({
```

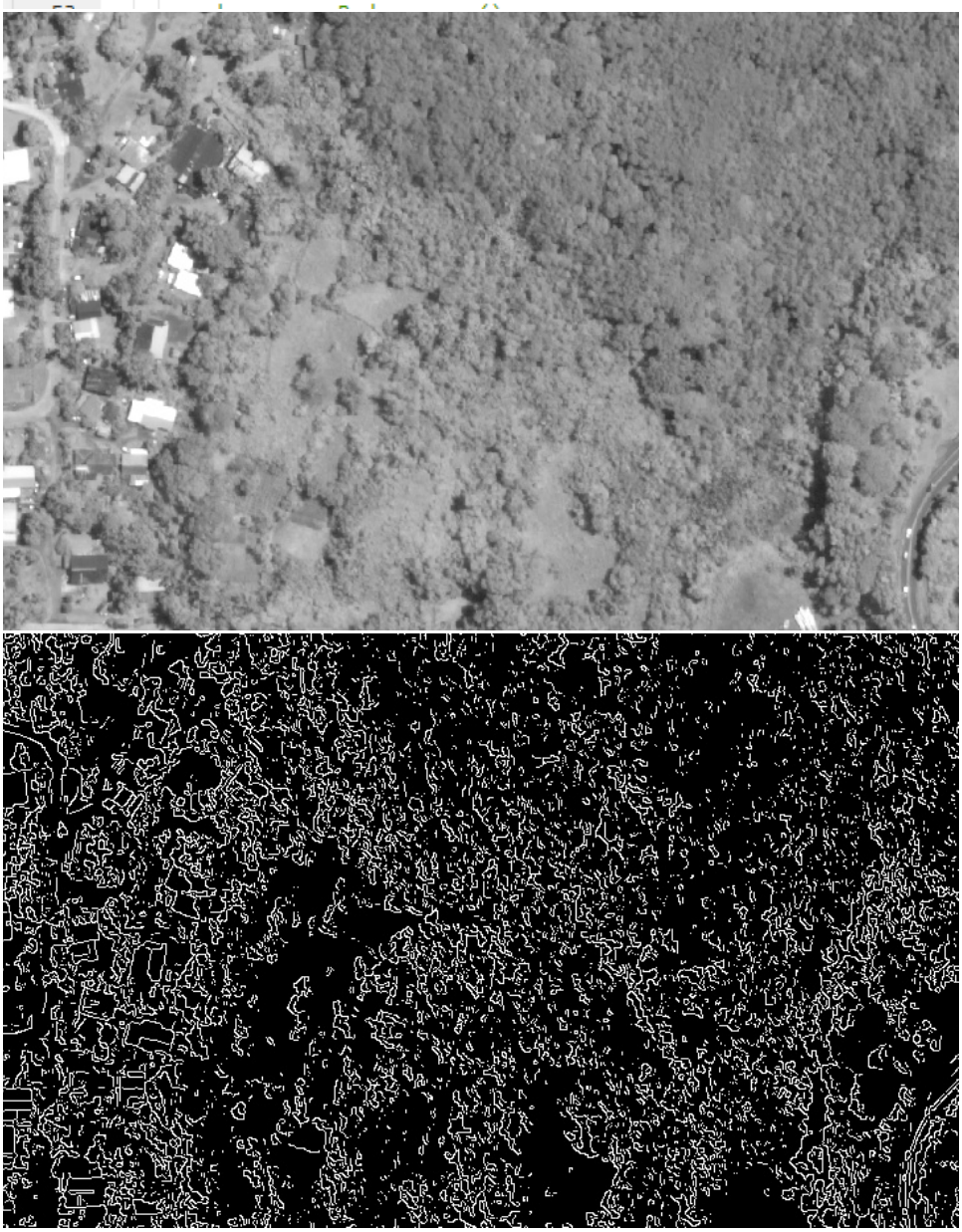


Figure 2. Canny edge analysis on WV2-panchromatic in Google Earth Engine

Figure 3. Segmentation of Imagery into Vegetation Patches

A training sample set (n=180) was created from the image segments. The training set was classified from image interpretation and verification of uncommon land cover types from Cole's 1984 map, SSURGO and other ancillary sources. No examples of 'marsh' landcover were identified, and very few 'swamp forest' examples were found. ECognition's 'Random Trees' image object classifier was used to assign a preliminary classification to each of the segments. Image object statistics used by the classifier include the per object mean of each band including Green, NIR1, NIR 2, Red edge, Yellow, the Canny edge derivatives, and the elevation derivatives. The preliminarily classed image objects were exported as polygon vectors (file GDB) for further workup in ArcPro.

Polygons corresponding to cloudy and hazy portions of the images were examined and corrected by redrawing polygon boundaries, some with reference to Maxar VIVID (4 band WV2 composite) imagery from a similar time frame. A smoothing function was applied to the polygons to improve cartographic representation. On Oreor, Malakal and Ngerekbesang islands, some 'forest' was reclassified to 'urban canopy'. Also, all 'grassland savanna' was reclassified to 'cropland' or 'urban vegetated' according to rules outlined in Appendix A. In order to remain classified as 'forest' near Koror City, polygons must be at least 0.5 acre and be wider than 100m across. The polygons were reviewed for accuracy by regional and subject

matter experts and then published at
https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/[LINK].zip

Results

Classification methods captured terrestrial vegetation at a large spatial scale (<2m) including a high level of detection of vegetation within an urban 'envelope'. The vast majority (82%) of the mapped area is covered by Rock Island forest, covering most of >500 mapped Island. The remaining diversity of land cover types, especially including 'mangrove', 'forest', 'cropland' and 'urban _' classes are concentrated on more populated islands with volcanic geology and substrate: Oreor, Malakal and Ngerekbesang. Features labeled 'urban' in the vicinity of settlement represent a much more fragmented landscape. The 'Feature Median Acreage' shows that non-urban features are about 10 to 100 times larger than urban features.

Class	Acres	% mapped	N (polygon count)	Feature Median Acreage
mangrove	410	2.7	66	0.3
forest	818	5.4	60	2.1
Rock Island forest	12,406	81.6	509	1.0
swamp forest	14	0.1	6	1.3
grassland savanna	9	0.1	5	1.0
inland water	334	2.2	108	0.5
cropland	159	1.0	62	1.6
urban tree canopy	327	2.2	597	0.06
urban vegetated	153	1.0	994	0.03
urban unvegetated	580	3.8	1,332	0.03
Total	**15,210**		**3,736**	

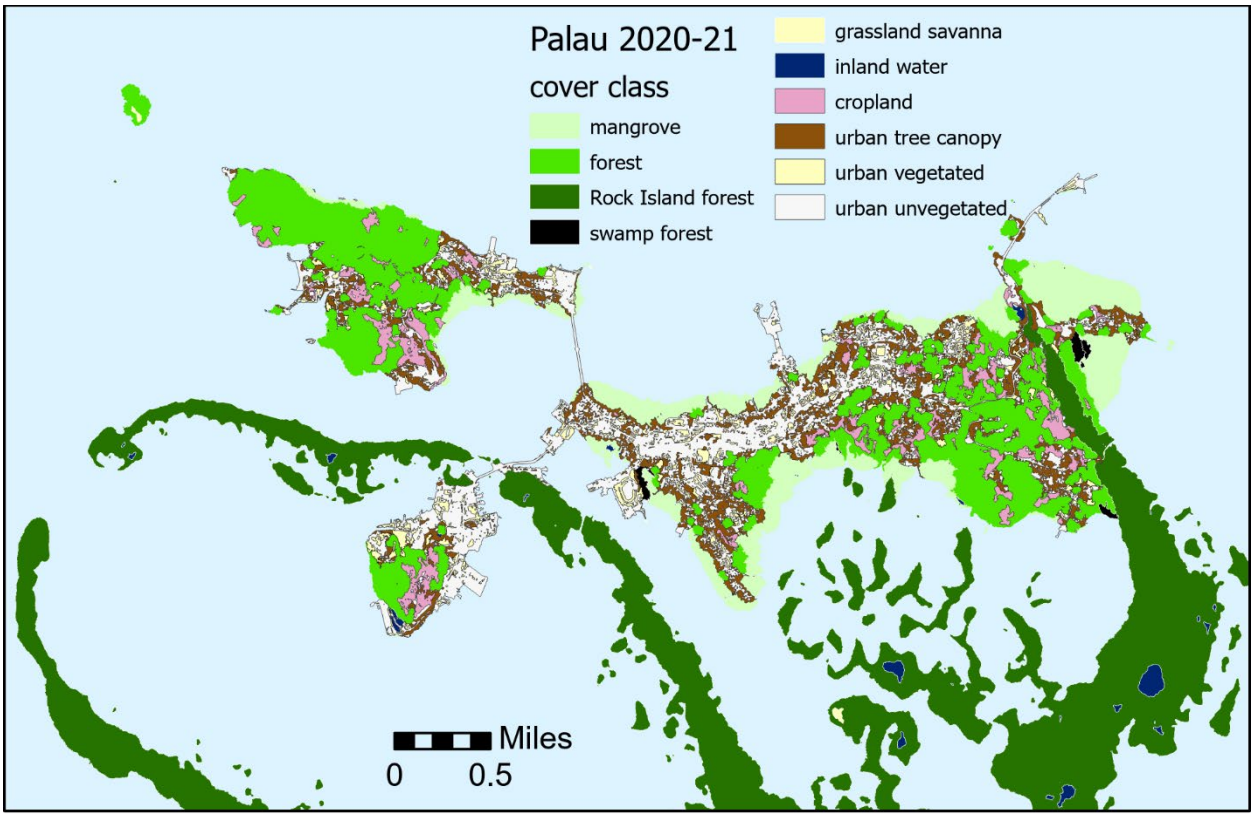
Table 2. 2020-21 Land Cover Data

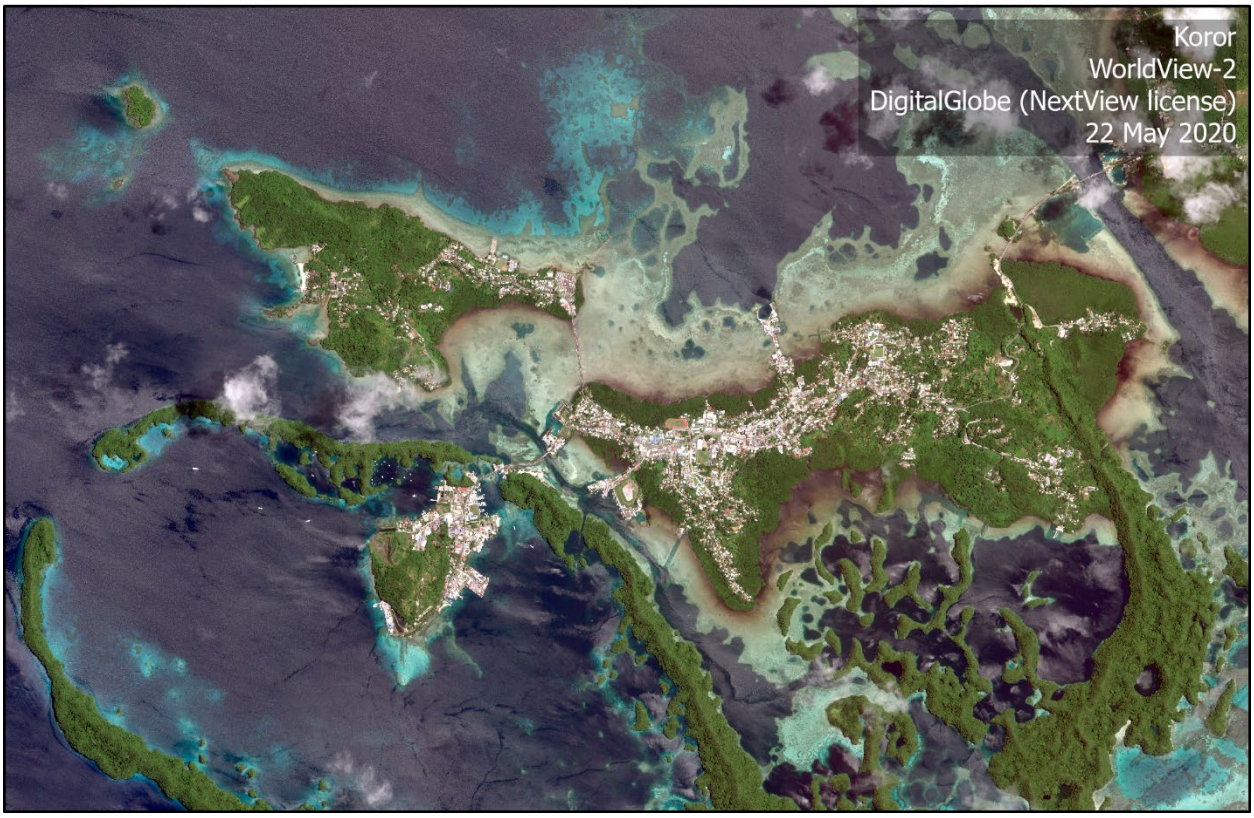
The mapped area is 92% forested, which includes all classes of tree canopy: mangrove, forest, Rock Island forest, swamp forest, and urban tree canopy. 94% of the study area is vegetated, when cropland, grassland savanna, and urban vegetated are added to the forested land cover classes listed previously. When all three urban classes are combined, the urban envelope takes up 7 % of the mapped area.

Class	Acres	Percent of Total
Total Urban	1,060	7.0%
Total Forested (incl. urban tree)	13,975	91.9%
Total Vegetated	14,297	94.0%

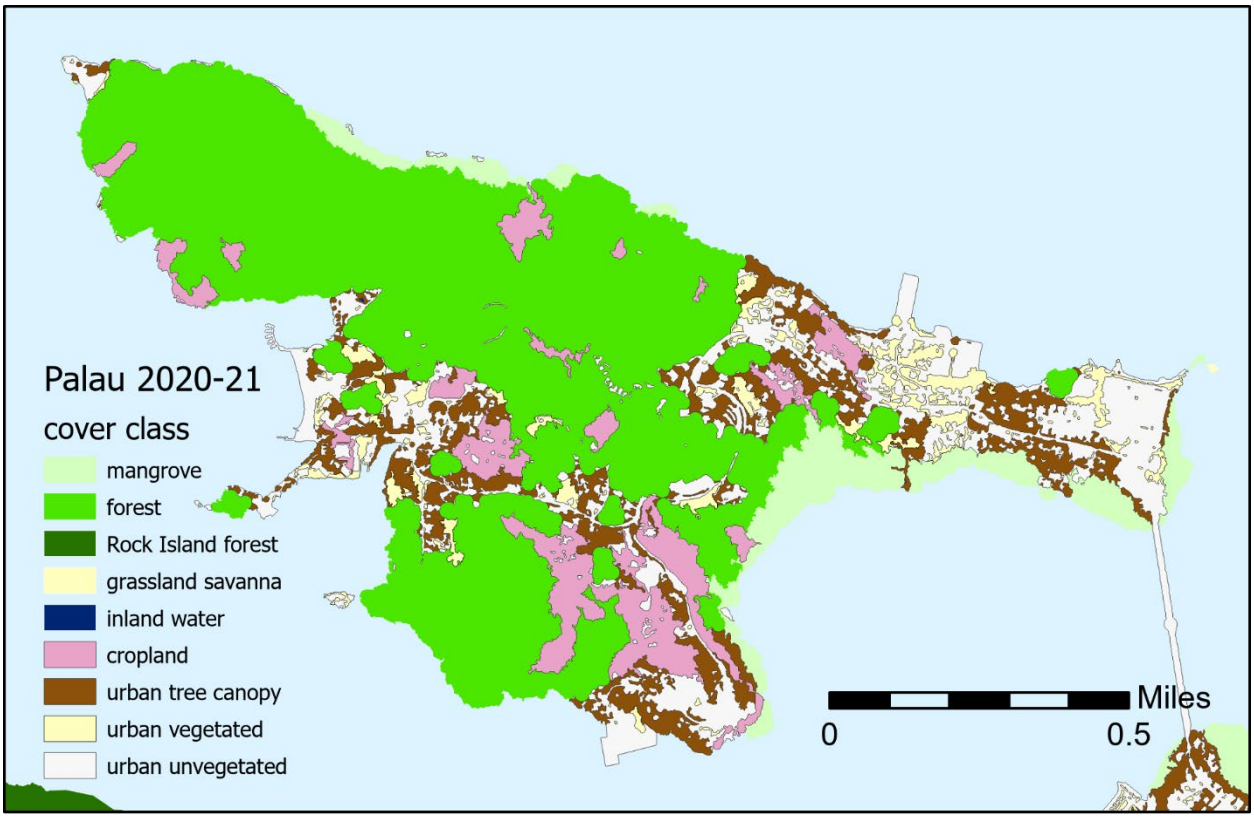
Table 3. 2020-21 Area of Vegetated, Forested, Urban land cover

Maps on the following pages show several views of the dataset in comparison with the WV2 source imagery.

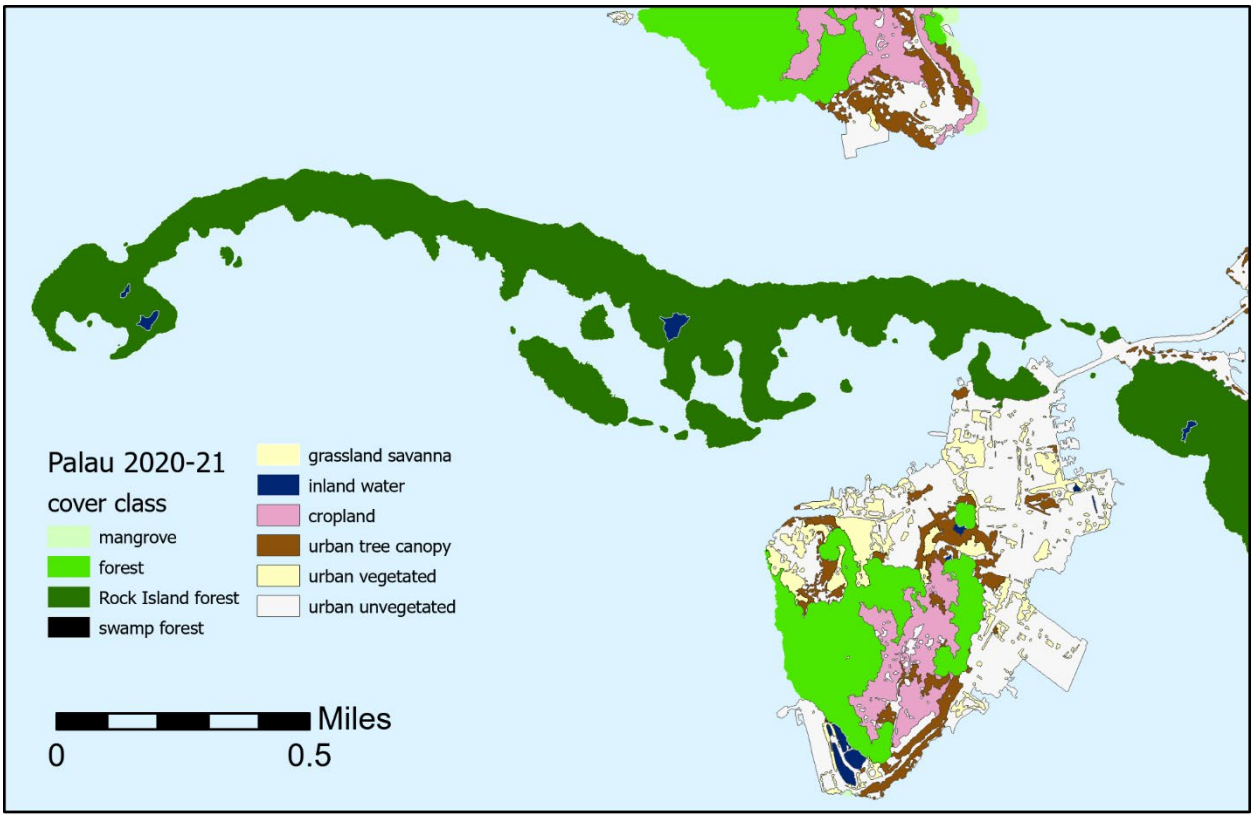




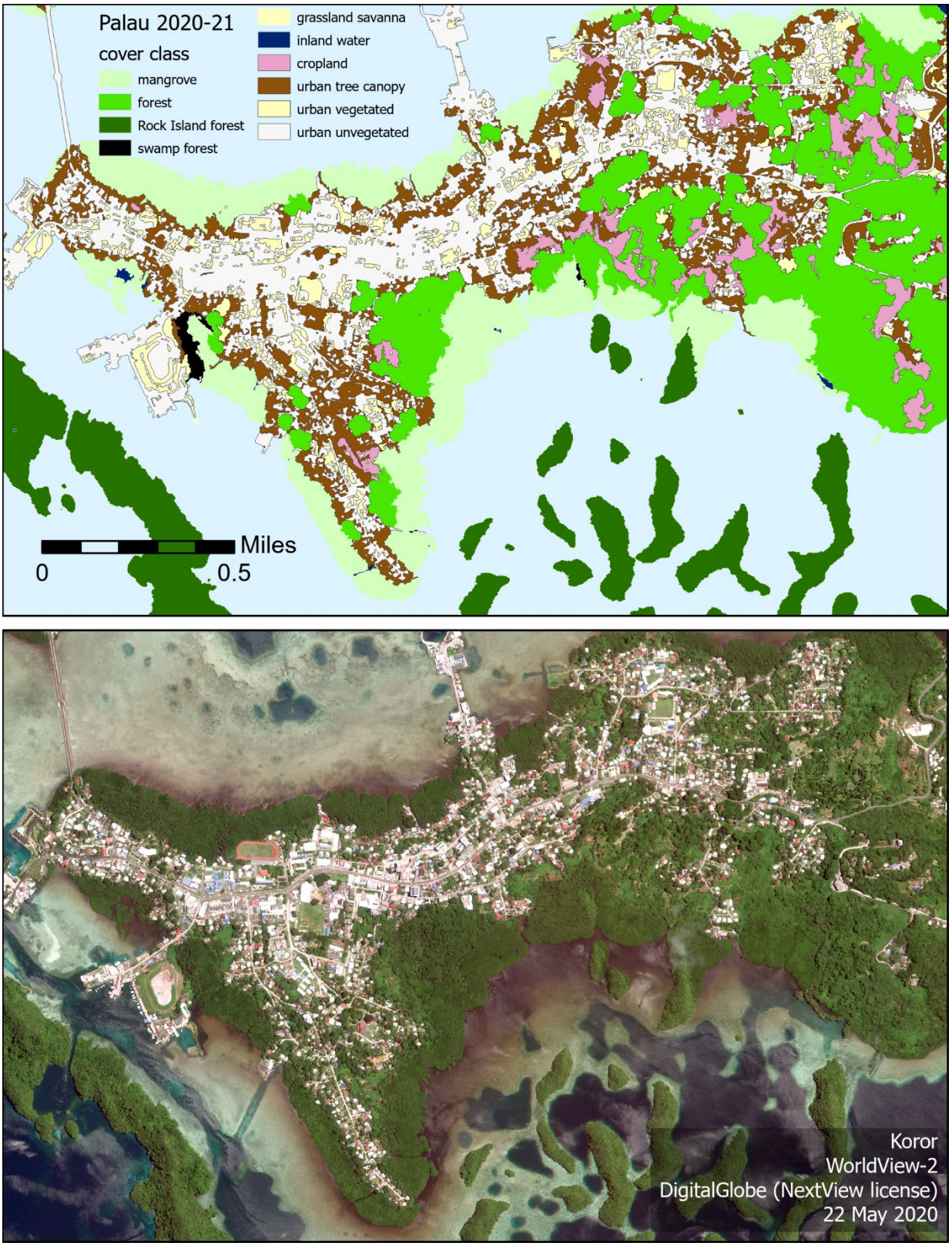
Map 3. Oreor, Ngerekbesang, Malakal and Nearby Rock Islands



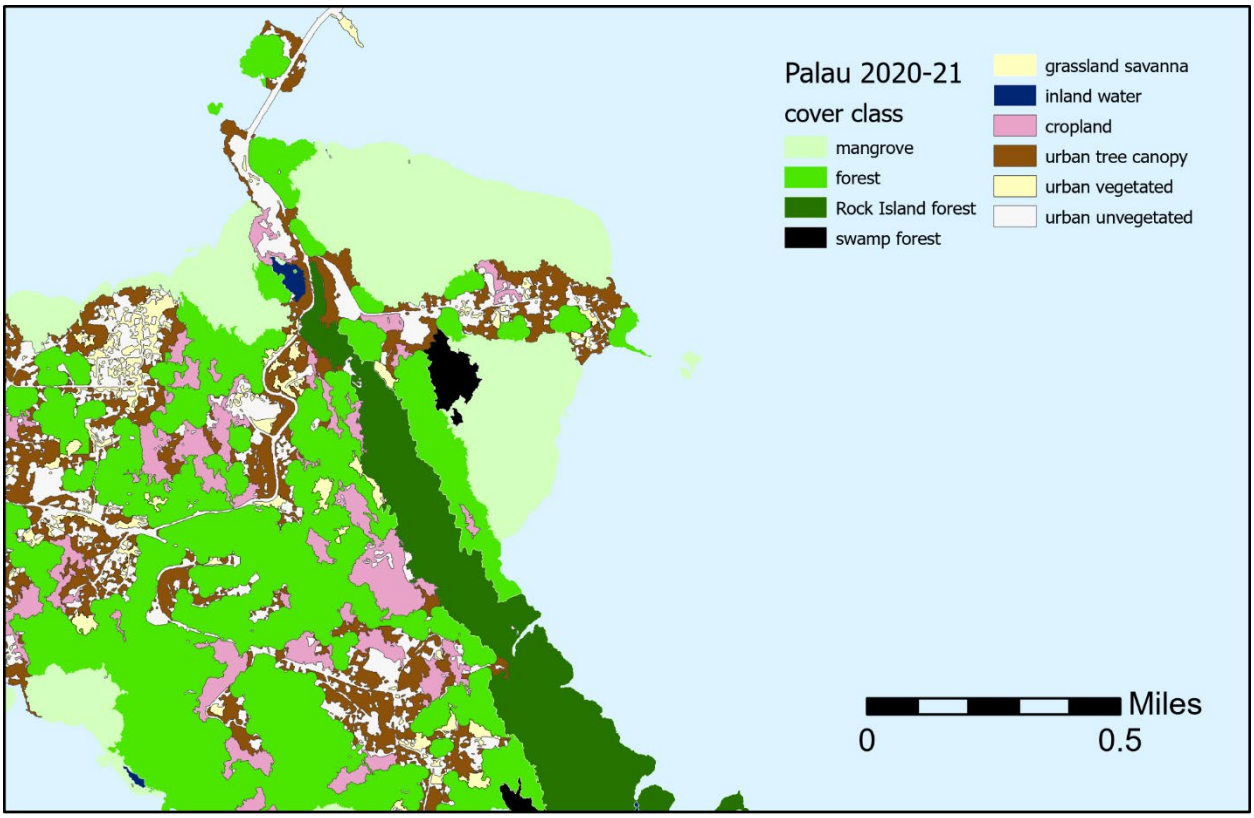
Map 4. Ngerekbesang



Map 5. Malakal



Map 6. Koror City – Oreor west



Map 7. Koror City – Oreor east

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- 2021 September 1 https://api.discover.digitalglobe.com/show?id=10300100C589AB00
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Acknowledgements

Kathleen Friday, Richard MacKenzie, Miranda Hutten (USDA Forest Service), assisted in landscape interpretation. David Greenberg, Aaron Kamoske, Kain Kutz, Lila Leatherman, Wendy Goetz, Indigo Catton provided valuable advice on mapping methods.

Appendix A: Class Descriptions and Crosswalk to other Palau Land Cover Classifications

Class (2022)	Description and Notes	INCLUDES >>>	Palau Plan-SWARS 2021	Greenberg 2020	Liu 2006*	Cole 1987*
					* Excludes classes found on Babeldaob only	
forest	Oreor/Koror, Ngerekbesang, Malakal only. Indicates Tree canopy not differentiated into another class. Minimum mapping unit (MMU) 1 acre excepting small island islands. Forest that highly fragmented due to urban/impervious land cover (e.g. <100m wide or << 1 acre) is reclassified to 'urban canopy'		Volcanic OR Volcanic steep slope palm OR Agroforest OR Casaurina OR Coconut Plantation OR Mahogany plantation	Forest	Upland Forest	Upland Forest OR Palm Forest OR Plantation Forest
Rock Island forest	Apparently undisturbed Limestone forest occurring on Palau's Rock Islands.		Limestone forest	Forest (small strand present SE Babeldaob)	Rock Island Forest	Rock Island Forest

	Location-based classification for most small and medium sized islands south and southwest of Koror. See NRCS SSURGO for rough (~1:24,000 scale) extent of Limestone substrate 'Peleliu-Chelbacheb' complex					
swamp forest	Oreor/Koror, Ngerekbesang, Malakal only. Forested Palustrine (non-tidal) wetlands. Only a handful of examples documented by Cole in NE Koror. Several modeled stands were reclassed to mangrove		Freshwater swamp forest	NONE	NONE	Swamp Forest
urban tree canopy	Oreor/Koror, Ngerekbesang, Malakal only. vegetated and initially classified as forest but highly fragmented by settlement patterns, Must be adjacent to urban unvegetated. Less than 1 acre or highly fragmented		Urban forest	Forest or NA	NONE	NONE

	by urban/impervious.					
mangrove	Forested estuarine wetlands. Rich Mackenzie: Mature dwarf mangroves exist on Palau so minimum Canopy Height should not be used exclude mangrove		Mangrove forest	Mangroves	Mangrove Forest	Mangrove
grassland savanna	Outside of Oreor/Koror, Ngerekbesang, Malakal only. Most was reclassified to 'cropland' or 'urban vegetated' depending on size and adjacency to urban unvegetated.		Savanna/Grassland/Herbaceous	Grassland/savanna	Grassland and Savannah	Secondary vegetation (?) Grassland or Savanna
urban vegetated	Oreor/Koror, Ngerekbesang, Malakal only. Initially classified as grassland savanna, AND adjacent to 'urban unvegetated'. Usually >>1 acre.		NONE	Grassland/savanna or NA		
cropland	Oreor/Koror, Ngerekbesang, Malakal only. Land cover is 'grassland savanna', MMU about 500 m^2 (0.12 acre) but mostly 1-2 acres. Mostly adjacent to forest			Grassland/savanna or NA	Agriculture Land	Cropland

	rather than ‘urban unvegetated’					
[marsh]	none detected in study area		Nonforest Marsh	Marsh	none in area	Marsh
urban unvegetated	Oreor/Koror, Ngerekbesang, Malakal only. Includes unvegetated non-water land areas. Paved and unpaved roads, rooftops, barren ground.		NONE	Built-Up	Urban OR Barren	Barren land OR Urban land
inland water	Ponds and inland lagoons. Includes narrow estuarine inlets with apparent continuous tree canopy		NA	Water	Water	Water
[coastal water]	unclassified/negative space in deliverable GIS. Refer to NOAA 2007 for marine + estuarine subtidal vegetation and substrates		NA	Water	NONE	NONE