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Vegetation Mapping of American Samoa

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AUTHORS

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PHOTO CREDITS

All photos, unless otherwise stated, were taken by Neil Gurr, American Samoa Community College Division of Community and Natural Resources.

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ABSTRACT

Liu, Zhanfeng; Gurr, Neil E.; Schmaedick, Mark A.; Whistler, W. Arthur; and Fischer, Lisa. (2011). Vegetation Mapping of American Samoa. General Technical Report. (R5-TP-033). Vallejo, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 19 pages.

A map of vegetation and general land cover for the islands of Tutuila, Aunu'u, Ofu, Olosega, and Ta'u in American Samoa was created based on high resolution QuickBird satellite imagery supported by field observations. Map accuracy was assessed using field data collected at sites selected by stratified random sampling. A primary reference label was assigned to each sample as the class that best represented the land cover on the ground. For sites that were difficult to classify, a secondary reference label was also assigned as the next best match. Estimated overall thematic accuracy was 89% with a Kappa value of 0.86 when agreement was defined as a match between the map class and either the primary or secondary reference class label. When agreement was defined as a match between the map class and primary reference label only, overall accuracy was 81% and the Kappa value declined to 0.75. Accuracies for individual classes were 80-100%, with the exception of Secondary Scrub and Agriculture, which were not reliably distinguished from each other in the map. Results showed the American Samoa islands mapped in this project were mostly covered by forest but dominated by disturbed vegetation types. Rhus Secondary Forest was the most abundant vegetation type, covering approximately 37% of the land area, followed by Secondary Scrub and Agriculture with a combined coverage of 27%. This updated map provides relatively detailed information about the current status of American Samoa's vegetation, which is important for land managers and other local decision-makers as well as researchers and the general public.

Keywords: American Samoa, vegetation mapping, remote sensing, accuracy assessment.

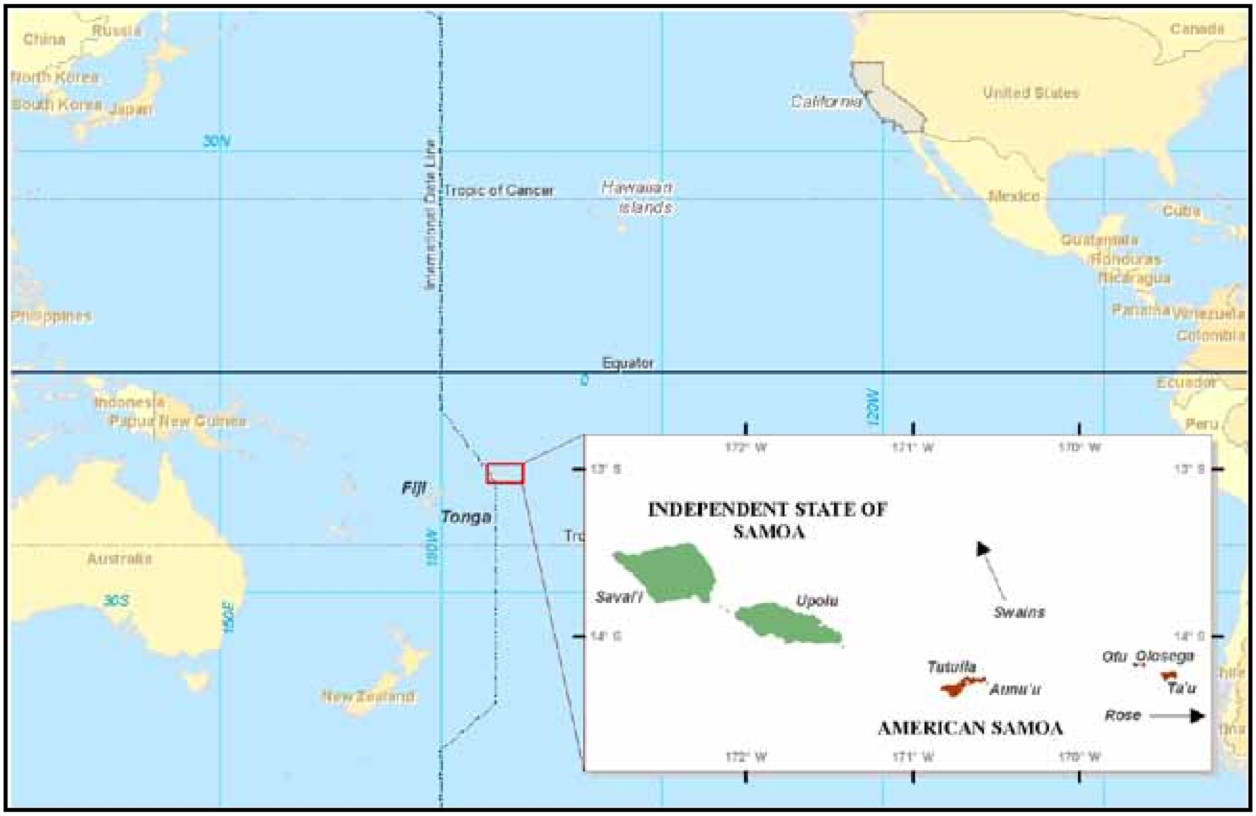


Figure 1. Location of the American Samoa islands.

INTRODUCTION

American Samoa is an unincorporated territory of the United States located in the South Pacific Ocean about 2,300 miles (3,700 km) southwest of Hawaii. With a total land area of 76.2 square miles (197 sq km), the territory consists of seven islands: two remote atolls (Rose and Swains), and five high volcanic islands (Tutuila, Aunu'u, Ofu, Olosega, and Ta'u) (Nakamura 1984). All the high islands and Swains are inhabited. The total population in 2000 was 57,291, with 97.5% residing on the largest island, Tutuila. Aunu'u is a small island located just off the eastern shore of Tutuila. Ofu, Olosega, and Ta'u Islands comprise the Manu'a Group, and are located approximately 62 miles (100 km) east of Tutuila. Ofu and Olosega are joined by a short road bridge. Approximately 90% of the territory's resident population is Samoan, and most land is held and managed within the traditional family communal system (Nakamura 1984, U.S. Census Bureau 2004, American Samoa Department of Commerce 2006).

American Samoa's climate is warm, wet, and humid (Figure 2). Annual precipitation averages about 118 inches (300 cm). Rainfall is abundant throughout the year but varies seasonally and with elevation and aspect. October through May tends to be the relatively wetter season. Temperature changes little from month to month, with daily averages between 75°F (23.9°C) and 85°F (29.5°C).

The topography of American Samoa is steep and rugged. About half of the land area exceeds 70 percent slope (Nakamura, 1984). The highest point is Mt. Lata on the second largest island of Ta'u, reaching 3,169 feet (966 m). Mt. Matafao (2,142 feet/653 m) is the highest peak on the largest island, Tutuila. The high islands of the Samoan Archipelago were formed from volcanic flows rising from a mid-ocean volcanic hot spot over which the Pacific Plate has been moving in a west-northwesterly direction (Keating, 1992). The soils of American Samoa include well-drained, shallow to deep soils in the rugged mountains; poorly- to well-drained sandy or clayey soils in the valleys and coastal areas; and well-drained, shallow soils in the flatter areas of Tafuna and Leone (Nakamura, 1984).

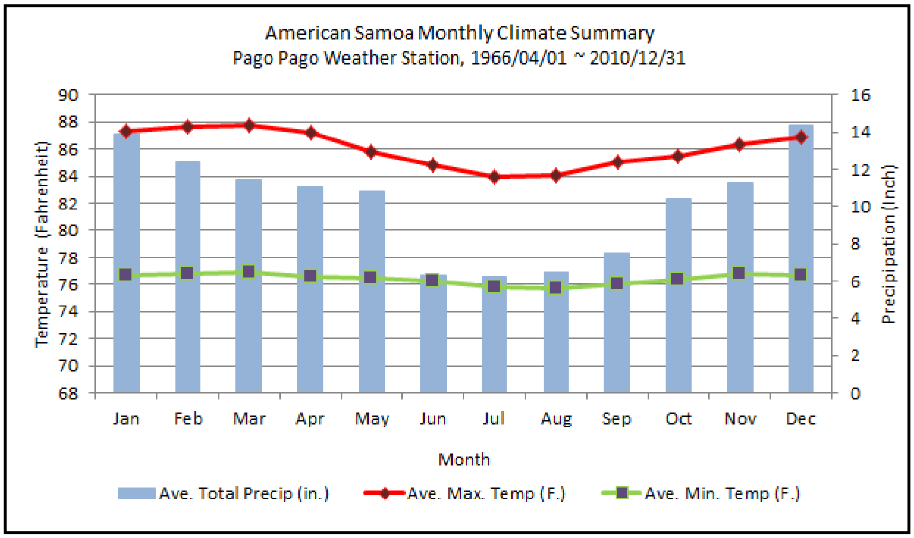


Figure 2. Historic climate data for American Samoa based on Pago Pago weather station records from 1966/04/01 to 2010/12/31 (Western Regional Climate Center, 2009).

Tropical cyclones are fairly common in American Samoa, often inflicting significant damage to the landscape, especially the natural vegetation. Six major storms hit the islands in the last 30 years. Other disturbances include prehistoric volcanic eruptions and human activities. Soil erosion is prevalent on steep volcanic soil slopes and areas cleared by humans for agricultural production and roads. (Cole et al., 1988; Mueller-Dombois & Fosberg, 1998; Donnegan et al., 2004).

Due to their remoteness and relative inaccessibility, Rose and Swains atolls were not included in this mapping project.

DATA AND METHODS

Vegetation of American Samoa and Classification Scheme

A proper classification scheme is critical to the success of any vegetation mapping project. It is, however, often difficult to select a detailed classification system for the tropical Pacific islands due to the natural complexity of species composition and the occurrence of many plant species across multiple vegetation communities. Additionally, a long history of disturbances by both natural and human elements makes categorizing the vegetation on these Pacific islands very difficult. Development of the classification scheme for this project was based on the following considerations:

- needs of end users
- existing literature
- past mapping efforts
- local expertise and support
- ability to discern vegetation types from the source satellite imagery

The natural vegetation of American Samoa is a tropical rainforest type, consisting of various communities influenced by factors such as soil type, precipitation, distance from the sea, elevation, and human and natural disturbances (Mueller-Dombois & Fosberg, 1998; Whistler, 2002). According to Mueller-Dombois and Fosberg (1998), nearly the entire Samoan archipelago was covered by rainforest over the lowlands and cloud forest at higher elevations before the arrival of the Polynesians some 3,000 years ago. However, almost all vegetation in Samoa has been altered after several thousand years of subsistence agriculture greatly reducing the area of native forests.

Seven major vegetation types were recognized by Mueller-Dombois and Fosberg (1998), including littoral vegetation, wetland vegetation, lowland rain forest, montane rain forest, cloud forest and scrub, vegetation on recent volcanic surfaces, and modified vegetation. Whistler (2002), in his book The Samoan Rainforest, provided an up-to-date account of the vegetation of the Samoan islands, including a classification system with detailed descriptions of the vegetation communities. Whistler classified the vegetation into six general types which were further divided into 14 detailed plant communities based on structure and habitat (Table 1).

The Forest Service Pacific Southwest Forest and Range Experiment Station produced a set of detailed

Table 1. Whistler's (2002) vegetation classification scheme for the Samoan Archipelago compared to the classification scheme used in the current mapping output.

Whistler (2002) Classification	Current Mapping Classification
LITTORAL VEGETATION	LITTORAL VEGETATION
1. Littoral Strand	301.Littoral Strand
WETLANDS	WETLANDS
2. Marshes	103. Marshes
3. Mangroves	101. Mangroves
4. Freshwater Swamps	102. Freshwater Swamps
RAINFOREST	RAINFOREST
5. Lowland Forest	302. Rainforest[2]
6. Montane Forest	
7. Cloud Forest[1]	
UPLAND SCRUB VEGETATION	UPLAND SCRUB VEGETATION
8. Summit Scrub	201. Summit Scrub
9. Montane Scrub	202. Montane Scrub
VOLCANIC VEGETATION	
10. Volcanic Scrub[1]	
DISTURBED VEGETATION	DISTURBED VEGETATION
11. Managed Land Vegetation	Managed Land Vegetation
	402. Agriculture
	501. Urban Cultivated
12. Successional Vegetation	401. Secondary Scrub[3]
13. Secondary Forest	303. Rhus Secondary Forest[4]
14. Fernlands[1]	
	BARREN AREAS[5]
	602. Sand Beach/Bare Rocks
	601. Quarry/Landfill
	502. Urban Built-Up
	603. Water

[1]Vegetation type does not occur in American Samoa.
[2]Combines Lowland and Montane Forest of Whistler (2002).
[3]Successional Vegetation of Whistler (2002).
[4]Secondary Forest of Whistler (2002).
[5]Areas without vegetation were not included in Whistler's (2002) classification.

vegetation maps for American Samoa islands in the 1980's, based on stereoscopic interpretation of black and white aerial photography taken in 1984 with a nominal scale of 1:10,000. The interpreted maps were refined by ground checking in 1986 (Cole et al., 1988). A hierarchical classification scheme was used, with four broad land cover classes: forest, secondary vegetation, agroforest, and nonforest. The forest and nonforest classes were further subdivided into detailed types. The forest class was comprised of upland forest, coastal forest, mangrove forest, dwarf forest, and moss forest. The nonforest class included grassland, strand, marsh, cropland, urban, barren, and water. A more recent landcover/vegetation map with a classification scheme adapted from the systems used by Cole et al. (1988) and Mueller-Dombois and Fosberg (1998) was created by the Forest Service Pacific Southwest Region based on high resolution 2002-2004 IKONOS satellite imagery (Liu & Fischer, 2007).

This project sought to update the 2002-2004 mapping product. A hierarchical scheme was followed to facilitate future updates and improvements of the classification system. The Whistler (2002) system was adapted with some adjustments. Table 1 lists the classes used and their correspondence to the Whistler (2002) classes. Appendix A describes in detail each class used in this project. Additional details on each class can be found in Whistler (2002).

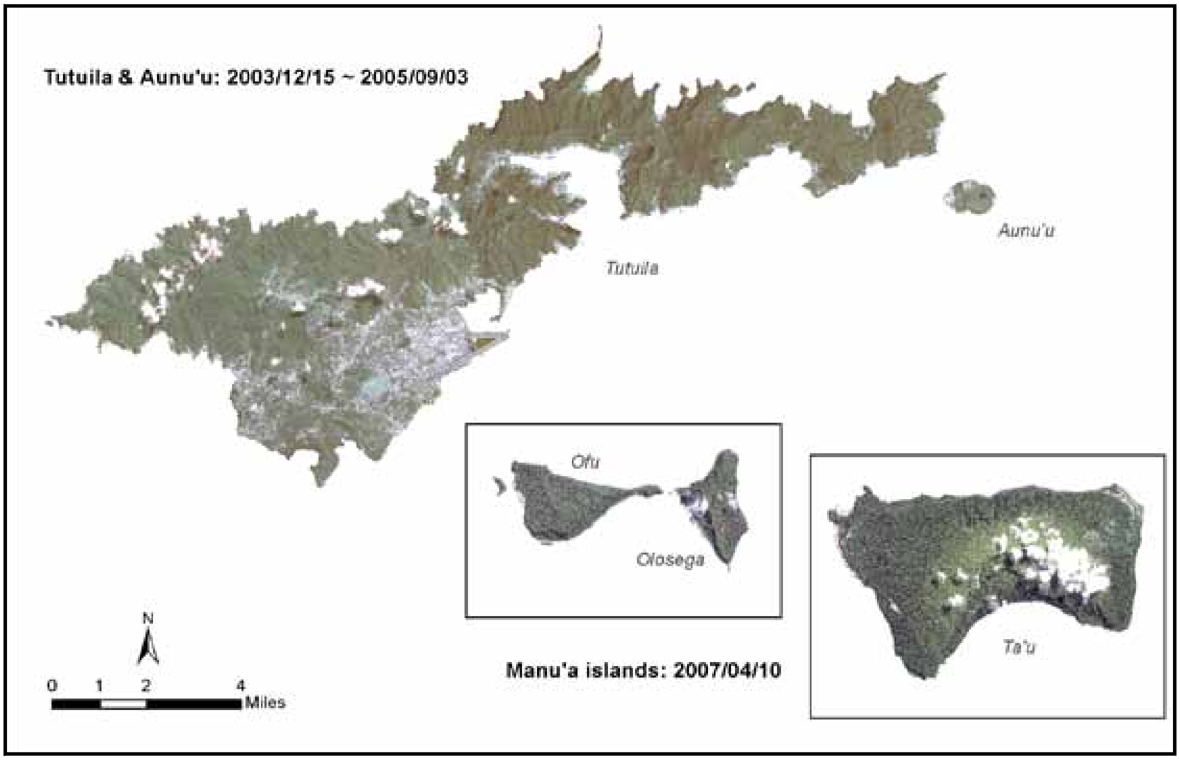


Figure 3. Quickbird images used for this project.

Source Imagery

QuickBird satellite imagery (Figure 3) from DigitalGlobe, Inc. (Longmont, CO), orthorectified and pan-sharpened to 60 centimeter resolution, was used for this mapping project. The image mosaic for Tutuila and Aunu'u was provided by the NOAA Coastal Services Center. Images for the Manu'a islands were purchased through, and pre-processed by, Land Info Worldwide Mapping, LLC. Original satellite scenes for Tutuila and Aunu'u were acquired between 2003/12/15 and 2005/09/03, and for the Manu'a islands on 2007/04/10.

Mapping Method

Mapping tropical Pacific island vegetation into detailed classes is difficult. Species are diverse and many communities share a significant number of species. Adding to the challenge, the American Samoa islands have a very rugged and steep terrain. Constant clouds also make it almost impossible to collect completely clear images via satellite sensors. Fully automated classification algorithms based on satellite imagery can produce acceptable results when the classification scheme is limited to general landcover types such as forest, grassland, barren, and water, but the results are often less than satisfactory for separating detailed vegetation types (Liu & Fischer, 2007).

But using remotely sensed data has its own advantages. Recent technological advancement in the commercial satellite industry has made available to the general public very high spatial resolution imagery such as IKONOS (4-meter multispectral; 1-meter panchromatic), QuickBird (2.4-meter multispectral; 0.6-meter panchromatic), and WorldView (1.85-meter multispectral; 0.46-meter panchromatic). Orbiting at high altitudes, these sensors have short revisit periods and are capable of rapid and targeted data acquisition. New satellite images are also multi-spectral with wide dynamic range, ready for advanced digital image processing software capable of extracting information often not easily detected by conventional visual interpretation. In addition, these images can be delivered orthorectified with good geographic accuracy and much of the terrain distortion already removed.

This mapping project implemented a hybrid approach, designed to maximize the benefits of using remotely sensed data while taking advantage of the islands' small sizes and local knowledge, as well as resources and support provided by the American Samoa partners.

Image Segmentation

Base polygon layers were created from the QuickBird data using automated image segmentation software eCognition Developer 8.0 (Trimble Navigation, Ltd., Sunnyvale, CA). The island of Tutuila (including Aunu'u) was divided into 7 tiles for processing. Ta'u was processed as a single tile. Ofu and Olosega together formed another processing unit.

The Multiresolution Segmentation algorithm provided by eCognition Developer was selected as the image segmentation method. This is a bottom-up approach that consecutively merges neighboring pixels based on relative homogeneity criteria to form image objects (Trimble Germany GmbH, 2010). Object homogeneity is calculated as a combination of color and shape properties. For this project, weight values of 0.8 and 0.2 were given to color and shape respectively. The average size of output image segments is determined by the scale parameter. Optimum choice of scale parameter depends on the input image and thus varies from scene to scene. Scale parameters between 200 and 500 were used in the current project. The image segments were then exported from eCognition as polygon shapefiles.

Polygon Labeling and Editing

Labeling and editing of the base polygons was performed in ArcGIS 9.2 (ESRI, Inc., Redlands, CA). To streamline the process, customized tools were developed using ArcObjects in Visual Basic for Applications (VBA). The project also took advantage of a recent mapping of impervious surfaces by the National Oceanic and Atmospheric Administration (NOAA). The impervious surfaces data of American Samoa produced by the NOAA Coastal Service Center (2009) was merged with the polygon bases. Introducing the existing impervious surfaces data significantly reduced the amount of time required for identifying urban built-up areas.

Subtle differences between vegetation communities often exist in the color, texture, and shape of image objects. Although sometimes difficult to detect automatically and consistently by computer-based algorithms, some of the fine separations could be recognized by locally amplifying the spectral signatures via image contrast-stretching and alternative visualization through the combination of different color bands. Polygons that could not be classified with confidence, such as those on extreme terrains, were checked by field visits.

After labeling and editing was completed, the polygon shapefiles were converted to ESRI Geodatabase format for standardization. A Minimum Mapping Unit (mmu) of 100 pixels was applied. Any polygon smaller than 100 pixels (not necessarily a 10-by-10 square of pixel cluster) was dissolved into a neighboring larger polygon with the longest shared border.

Accuracy Assessment

Accuracy assessment for the completed maps was conducted in January and March of 2011. A two-stage stratified random sampling based on mapped classes within each of the three mapping areas was used to ensure small but important categories were represented. Using ArcGIS, a total of 257 sites were selected. The sample size and the sample allocations on individual islands were determined mainly by the amount of time available for field visits (Table 2).

Each sample site was visited by a field crew and the primary reference class was determined as the class that the field observation matched most closely. When a single definitive class label was difficult to decide, up to two alternative reference labels were also recorded. Alternative class 1 (secondary reference class label) was assigned as the next best match to the landcover at the site and alternative class 2 as the third best match. Map to reference agreement was determined using a simple fuzzy logic. A sample site was marked with an agreement between the map and the field reference if the mapped class matched either the primary or the secondary reference label (Selkowitz & Stehman, 2011). For comparison purposes, a second accuracy assessment calculation was done which specified agreement more strictly (i.e., the map class matching the primary reference label only).

Table 2. Number of samples by island.

Island	Number of Samples
Tutuila & Aunu'u	120
Ofu & Olosega	60
Ta'u	77
Total	257

A standard error matrix was constructed and four accuracy parameters were estimated: overall accuracy, producer's accuracy, user's accuracy, and the Kappa statistic (Congalton & Green, 2009). To ensure the estimations were consistent, a weight was assigned to each sample stratum as the ratio of the stratum's proportion in the entire map to the actual inclusion probability of that stratum in the sample (Appendix E) (Stehman, 1995; Selkowitz & Stehman, 2011).

Overall map accuracy is the proportion of project area correctly classified, estimated as the weighted total number of samples at which the map class matched the reference class divided by the total number of samples. Producer's and user's accuracies were calculated for each class. The producer's accuracy is estimated as the proportion of the sample determined by field observation to be in a given class for which the observed class matched that shown on the map. The estimated user's accuracy is the proportion of the sample that fall within a given class on the map and which are determined by field observation to actually be that class. A high producer's accuracy means that a large proportion of the land area of a given cover type is mapped correctly. A high user's accuracy means that a large proportion of the area mapped as a given class is actually covered by that type on the ground.

The Kappa statistic and its 95% confidence interval were also calculated from the sample data. Kappa provides a measure of the degree to which the actual agreement between the classifications determined from the field observations and those on the map differs from the amount of agreement that might be expected to occur from chance alone. When applied for a single map's accuracy, it provides additional information on how effective the mapping method is.

Kappa is of less importance to map users than to map producers who may want to use this measure to evaluate different mapping methods, and its interpretation requires caution (Stehman, 1997). The value of the Kappa statistic can range from -1 to 1 and a higher value indicates stronger agreement between the sample site reference classifications and the map classifications. Congalton and Green (2009) describe accuracy assessment calculations in detail.

RESULTS AND DISCUSSION

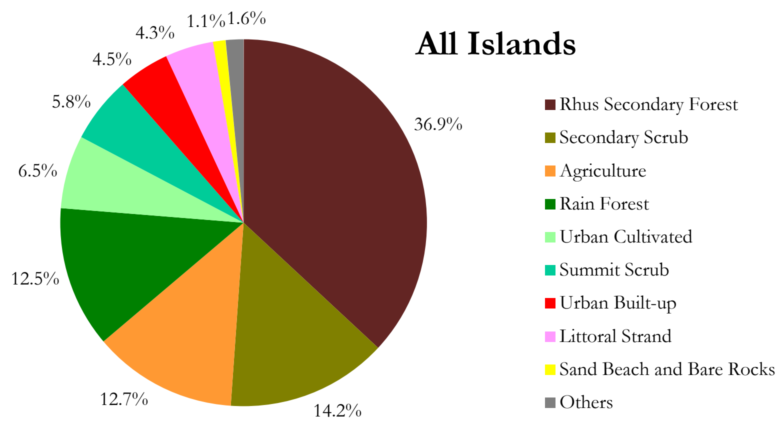
Vegetation Cover

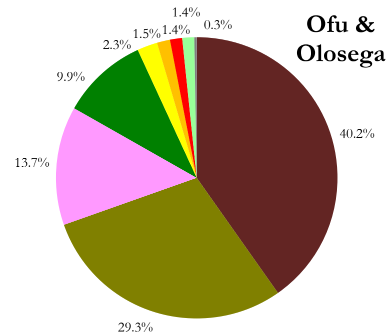
The American Samoa islands mapped in this project were found to be mostly covered by forest but dominated by

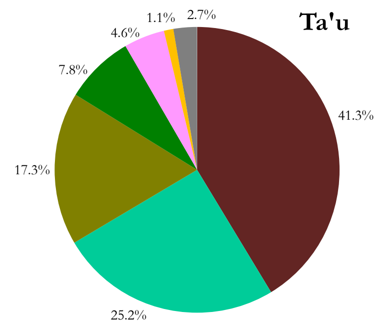
Table 3. Summary by cover type and island in acres.

Class		Tutuila & Aunu'u		Ofu & Olosega		Ta'u		Total	
Number	Class Name	Acres	%	Acres	%	Acres	%	Acres	%
101	Mangroves	90	0.3%	--	--	--	--	90	0.2%
102	Freshwater Swamps	56	0.2%	--	--	--	--	56	0.1%
103	Marshes	21	0.1%	8	0.3%	18	0.2%	47	0.1%
201	Summit Scrub	--	--	--	--	2,823	25.2%	2,823	5.8%
202	Montane Scrub	379	1.1%	--	--	--	--	379	0.8%
301	Littoral Strand	1,116	3.3%	424	13.7%	520	4.6%	2,060	4.3%
302	Rain Forest	4,834	14.2%	307	9.9%	879	7.8%	6,021	12.5%
303	Rhus Secondary Forest	11,968	35.2%	1,250	40.2%	4,633	41.3%	17,851	36.9%
401	Secondary Scrub[1]	4,006	11.8%	911	29.3%	1,941	17.3%	6,858	14.2%
402	Agriculture[1]	5,976	17.6%	47	1.5%	119	1.1%	6,142	12.7%
501	Urban Cultivated	2,994	8.8%	43	1.4%	85	0.8%	3,123	6.5%
502	Urban Built-up	2,049	6.0%	43	1.4%	84	0.8%	2,176	4.5%
601	Quarry/Landfill	104	0.3%	0	0.0%	5	0.0%	110	0.2%
602	Sand Beach & Bare Rocks	353	1.0%	73	2.3%	106	0.9%	531	1.1%
603	Water	76	0.2%	--	--	--	--	76	0.2%
Total		34,023	100.0%	3,106	100.0%	11,214	100.0%	48,344	100.0%

[1]Accuracy assessment suggested that Secondary Scrub and Agriculture classes were not reliably distinguished from each other.







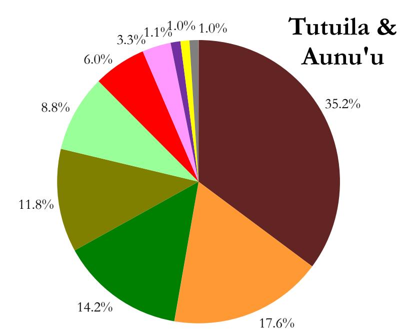


Figure 4. The American Samoa islands were still mostly covered by forest but dominated by disturbed vegetation types. Rhus Secondary Forest was the largest cover type on all islands.

disturbed vegetation types, including Rhus Secondary Forest, Secondary Scrub, and Agriculture (Table 3). Rhus Secondary Forest was the largest vegetation type across the entire group, covering 36.9% of the land surface. It was also the dominant cover type on each individual island (Figure 4). Secondary Scrub was the second largest class overall, covering 14.2% of the total land area. It was also the second largest class on Ofu and Olosega, covering 29.3% of these two islands' combined area. On Ta'u, Rhus Secondary Forest covered 41.3% of the land area, and Summit Scrub was the second largest class, occupying 25.2% of the island.

Comparison with Previous Mapping

Direct cross-comparison with previous mapping projects is mostly not possible because of the differences in classification schemes and class definitions. For the mangrove forest, however, such comparison can be made due to its unique characteristics. In the 1988 USFS vegetation survey map, 121 acres of mangrove forest were delineated (Cole, et al. 1988). Only 89.6 acres were identified in this project (Table 3), representing a loss of 26% of the total mangrove forest. The remaining stands of mangrove forest exist mostly on Tutuila with a few acres found on Aunu'u island.

For future projects, a consistent classification scheme and standardized mapping protocol should be used in order to produce readily comparable map products. Change detection based on such quantitative mapping will provide useful information about land use and landcover dynamics that can be valuable to government officials, resource managers, and scientific researchers.

Map Accuracy

Based on field data collected for the 257 sample sites and when agreement was defined as a match between the map class and either the primary or the secondary reference label, the estimated overall map accuracy was 89% with a 95% confidence interval between 85% and 93%. The Kappa value was 0.86, and the 95% confidence interval estimated for Kappa was (0.82, 0.91).

Producer and user accuracies for individual classes were also calculated (Table 4). Accuracy was quite high for most classes with errors mainly coming from two of the disturbed vegetation types, Agriculture and Secondary

Table 4. User's and producer's accuracies by class.

Class Number	Class Name	Fuzzy Agreement[1] User's	Fuzzy Agreement[1] Producer's	Strict Agreement[2] User's	Strict Agreement[2] Producer's
101	Mangroves	100%	100%	100%	100%
102	Freshwater Swamps	100%	100%	100%	100%
103	Marshes	100%	100%	100%	100%
201	Summit Scrub	100%	85%	100%	85%
202	Montane Scrub	80%	100%	80%	100%
301	Littoral Strand	100%	99%	89%	99%
302	Rain Forest	98%	95%	91%	84%
303	Rhus Secondary Forest	93%	90%	90%	82%
401	Secondary Scrub	88%	73%	64%	55%
402	Agriculture	57%	100%	35%	92%
501	Urban Cultivated	89%	87%	89%	86%
502	Urban Built-up	100%	100%	100%	100%
601	Quarry/Landfill	81%	100%	81%	100%
602	Sand Beach & Bare Rocks	100%	100%	100%	100%
603	Water	100%	100%	100%	100%

[1]Agreement defined as a match between the map class and either the primary or seconadry reference class.
[2]Agreement defined as a match between the map class and the primary reference class only.

Scrub. The low user's accuracy for Agriculture suggests that a large portion of the land mapped as Agriculture may not actually be covered by agricultural vegetation, and the low producer's accuracy for Secondary Scrub suggests that a significant portion of land covered by this vegetation type was mapped as something else. As previously discussed, it can be very difficult to separate these classes due to the overlap of plant species. In American Samoa, abandoned agricultural land quickly becomes overrun by secondary scrub type vegetation, but coconuts, bananas, and breadfruit often persist. Similarly, secondary scrub vegetation, most common around villages and farms, can quickly be converted to agriculture or other uses, but may retain some secondary scrub vegetation. In addition to the overlap in species composition, some conversion to and from the agriculture and secondary scrub classes could have taken place during the interval between the dates of the satellite imagery and the dates of the accuracy assessment. During the accuracy assessment it was noted that high wind damage to the canopy in many areas of Rhus Secondary Forest in Manu'a had opened gaps that were often filled in with vegetation more typical of Secondary Scrub. This could explain why some areas in Manu'a were labeled as Secondary Scrub from the satellite imagery even though they contained numerous Rhus trees and were labeled as Rhus Secondary Forest in the ground observations.

It was also found during the ground checking that some sample sites could be correctly labeled into more than one class because of ambiguities in the class definitions. A refined classification scheme with more details in class descriptions that better ensure the classes are mutually

Table 5. Summary of samples by agreement type.

Match Type	*Number of Samples*	*% by Sample Count*	*Total Weighted*	*% Weighted*
No Match	25	10%	27.99	11%
Strict Match[1]	210	82%	207.20	81%
Fuzzy Match Additional[2]	**22**	**9%**	**21.81**	**8%**
Total	257	100%	257.00	100%

[1]Number of reference samples where primary reference class agreed with the map.
[2]Number of reference samples where the secondary reference class agreed with the map and the primary reference class did not.

Table 6. Summary by primary to secondary reference label change for samples with fuzzy agreement.

Primary Reference vs. Secondary Reference	*Number of Samples*	*% by Sample Count*	*Total Weighted*	*% Weighted*
Rainforest vs. Littoral Strand	1	0%	1.19	0%
Rainforest vs. Rhus Secondary Forest	1	0%	2.55	1%
Rhus Secondary Forest vs. Rainforest	2	1%	2.00	1%
Rhus Secondary Forest vs. Secondary Scrub	**9**	**4%**	**7.84**	**3%**
Secondary Scrub vs. Agriculture	**7**	**3%**	**7.08**	**3%**
Agriculture vs. Secondary Scrub	1	0%	1.03	0%
Urban Cultivated vs. Agriculture	1	0%	0.13	0%
Total	22	9%	21.81	8%

exclusive could help resolve this uncertainty (Congalton and Green, 2009). Adding a class for agroforest may also reduce some of the ambiguity.

When agreement was defined as a strict match between the map class and primary reference class label only, overall map accuracy declined from 89% to 81% with a 95% confidence interval between 76% and 85% and the Kappa value decreased from 0.86 to 0.75 with a 95% confidence interval of (0.69, 0.82). The decline in individual class accuracy was most significant for the producer's accuracy for Secondary Scrub (from 73% to 55%), and for the user's accuracy for Agriculture (from 57% to 35%) (Table 4). A total of 22 samples obtained map-to-reference agreement via secondary reference class label (Table 5). Of the 22, 9 had primary reference class of Rhus Secondary Forest with a secondary label of Secondary Scrub; another 7 could be classified as either Secondary Scrub (primary) or Agriculture (secondary) according to field observation (Table 6).

Overall, and for most classes, the map's accuracy was quite good. But mapping areas of disturbed vegetation, especially Agriculture and Secondary Scrub, remains a challenge.

As American Samoa's economy and society continue to change, and the influence of climate change becomes more apparent, American Samoa's vegetation will continue to change as well. These changes will have important implications for conservation of critical ecosystems, biodiversity, and Samoan culture. The authors hope that this mapping effort will spawn additional work that will result in improved mapping protocols and a greater capacity for monitoring the state of American Samoa's unique natural resources.

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Appendix A - Class Descriptions and Photos

The classification scheme was based on Whistler (2002), and more detailed descriptions are available there. Table 1 above shows the crosswalk between the current classification and Whistler's.

Littoral Strand

Littoral Strand refers to the narrow zone of vegetation along the coastlines formed by herbaceous strand, littoral shrubland, Pandanus scrub, and littoral forest. This class occurs on undisturbed shores and does not extend very far inland. Littoral forest is sometimes further divided into associations based on dominant tree species (usually *Barringtonia asiatica*, *Calophyllum inophyllum*, or *Pisonia grandis*). The various zones within Littoral Strand were not distinguished in this mapping project.

Littoral Strand in Vatia, Tutuila Island

Marshes

Marshes occur in waterlogged soils and are dominated by herbaceous species, usually *Eleocharis dulcis* or *Cyclosorus interruptus*. Several different associations within the marsh community were distinguished by Whistler (2002) based on flora and topography, but are not differentiated in the present mapping.

Marsh surrounding lake on Aunu'u Island

Freshwater Swamps

Like Marshes, Freshwater Swamps occur in waterlogged soils but in contrast are dominated by woody species. According to Whistler (2002), freshwater swamps can be further divided into at least five different associations based on the dominant species (Hibiscus, Inocarpus, Erythrina, Barringtonia, and Pandanus).

Freshwater Swamp in Malaeloa, Tutuila Island

Mangroves

All mangroves grow on the coast, forming stands displayed on images with unique color, texture and distinctive boundaries. Two different associations were recognized by Whistler (2002) identified by the dominant species—*Bruguiera gymnorrhiza* or *Rhizophora mangle*.

Mangroves at Leone, Tutuila Island

Rainforest

Originally covering almost the entire land surface of the American Samoa islands, most of the Samoan rainforests have been altered by human agriculture and other disturbances over the past several thousands of years (Mueller-Dombois & Fosberg, 1998). Some areas with very steep terrain and away from the population still preserve, or have reverted back to, forest stands similar to the original Samoan rainforest. This class corresponds to the Rainforest type by Whistler, which is further divided into three communities—Lowland Rainforest, Montane Rainforest, and Cloud Forest (Whistler, 2002).

Rainforest at Afono, Tutuila Island

Rainforest stands have irregularly closed canopies and are usually only found on the steepest slopes and ridges. The three communities recognized by Whistler (2002) tend to form a continuum, blending into each other along gradual environmental gradients. According to Whistler (2002), the main distinction between Montane Forest and Lowland Forest is that the former is typically dominated by a single species (*Dysoxylum huntii*), while the latter is dominated by several other species, as monodominants or co-dominants. Cloud Forest does not exist in American Samoa. It is extremely difficult to separate these communities reliably and consistently based on satellite imagery or even field observation. Thus this project did not attempt to do so.

Summit Scrub on Mt. Lata, Ta'u Island

Summit Scrub

Summit Scrub is restricted to the highest elevations on Ta'u Island, where topographic and elevation characteristics produce an area of extremely high precipitation that may prohibit larger trees from growing in the waterlogged soil, or may give large trees insufficient rooting to withstand hurricanes that periodically sweep the archipelago (Whistler, 2002). Like Montane Scrub, the vegetation is characterized by small trees, ferns, and coarse vines, but the flora of these two types of scrubby vegetation is quite different. This class may blend into the adjacent rainforest (Montane Forest), making it difficult to accurately delineate the exact boundaries.

Montane Scrub on Mt. Pioa, Tutuila Island

Montane Scrub

Montane Scrub only exists on a peculiar type of rock formation referred to as trachyte found at more than a dozen locations on Tutuila Island (Whistler, 2002). The two most conspicuous sites are Rainmaker Mountain (Le Pioa) and Mt. Matafao. It is characterized by stunted vegetation dominated by small trees, ferns, and coarse vines. This class exhibits a unique scrubby texture and its locations are often readily identified on existing geological and soil maps of the island.

Agriculture land, Tutuila Island

Agriculture

Agriculture refers to vegetated land used for agricultural purposes at a relatively large scale for commercial production, such as coconut, banana, and vegetable plantations, and cow pasture. This class is included in the Managed Land class by Whistler (2002).

Urban Cultivated vegetation at Lion's Park in Tafuna

Urban Cultivated

Urban Cultivated basically means all vegetated areas within a general urban boundary. This type can be tricky to identify and is especially easily confused with the Agriculture class. Note that there is usually no clear urban boundary on most islands, and food-producing trees, such as bananas, coconuts, breadfruit, and mangoes are often grown near homes. Simple gardens, parks, sports fields, and lawns all fall under this class.

Secondary Scrub at Maloata, Tutuila Island

Secondary Scrub

In most cases, Secondary Scrub is an intermediate type of vegetation that occurs when cultivated land is abandoned and allowed to revert to natural forest. It is usually dominated by laupata (*Macaranga harveyana*), soga (*Pipturus argenteus*), fau (*Hibiscus tiliaceus*), and other small trees that require sunlight for establishment and growth. Secondary Scrub will eventually be replaced by larger trees. This later replacement usually leads to Rhus Secondary Forest. Secondary Scrub also occurs on steep cliffs where rock-falls, land-slides, and the effects of gravity lead to a perpetually disturbed type of secondary vegetation (Whistler, 2002).

Rhus Secondary Forest at Poloa, Tutuila Island

Rhus Secondary Forest

This disturbed vegetation class corresponds to the Secondary Forest community recognized by Whistler (2002). In American Samoa, abandoned agriculture land, if left undisturbed, eventually reverts to a high forest that in its early stages is dominated by tall secondary forest species. The most characteristic tree of these forests, which cover much of Tutuila, especially on the south-facing slopes on the south side of the island is tavai (*Rhus taitensis*). Other common species include toi

(*Alphitonia zizyphoides*), maota (*Dysoxylum maota*), lopa (*Adenanthera pavonina*), and moso'oi (*Cananga odorata*). Rhus secondary forest can often be identified on satellite imagery by its smooth, even canopy. In comparison, Rainforest dominated by a mixture of species usually displays an uneven canopy.

Sandy Beach / Bare Rocks, Tutuila Island
Photo: Z. Liu

Sand Beach and Bare Rocks

Rocky and sandy areas without vegetation cover occur almost exclusively on the coast. This class includes some of the low sea stacks off the north coast of Tutuila.

Quarry and Landfill

Areas recently bulldozed for quarrying activities or used for solid waste disposal.

Quarry / Landfill at Futiga, Tutuila Island

Urban Built-Up

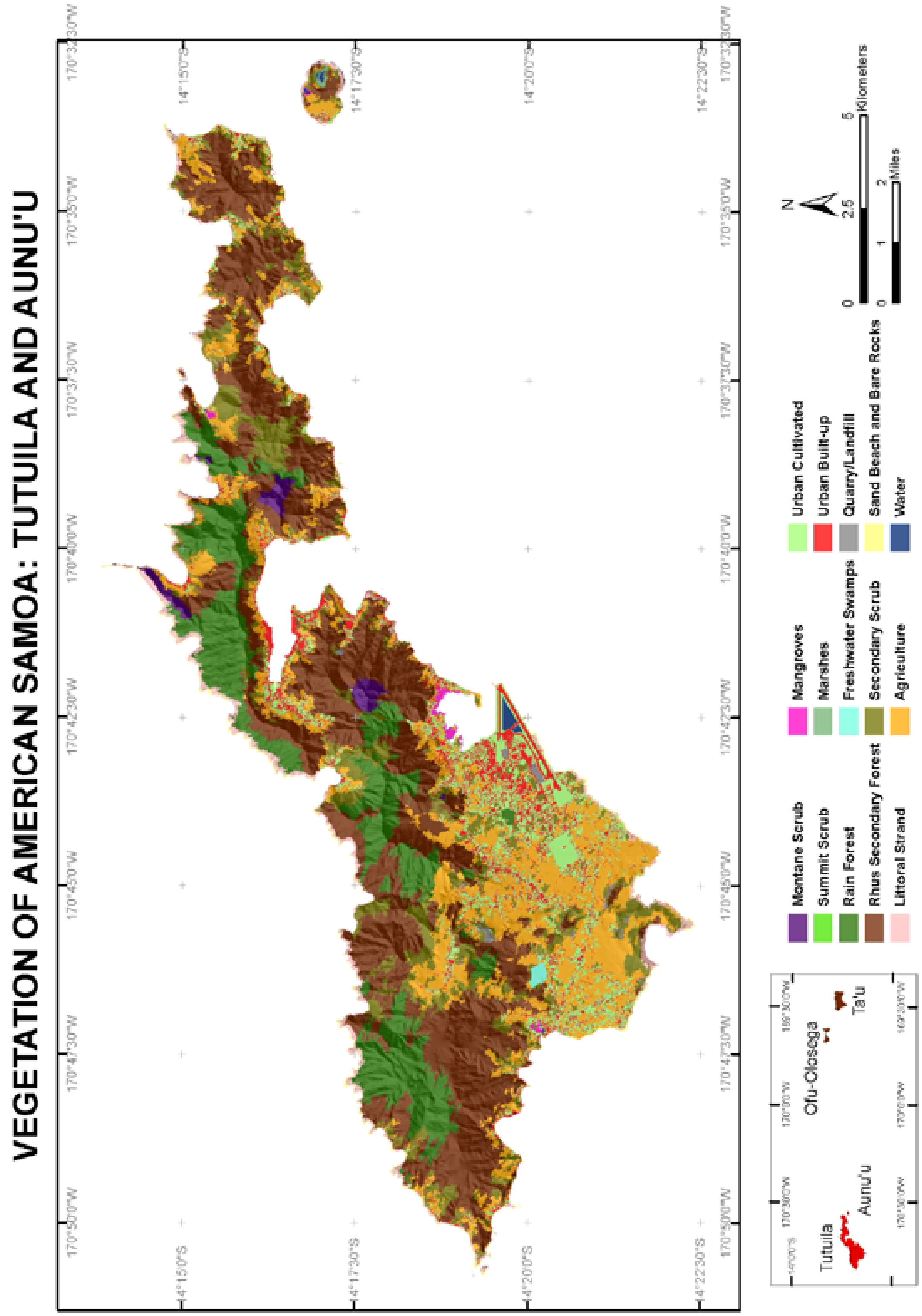
Urban Built-Up land refers to impervious urban surfaces such as houses and paved roads.

Water

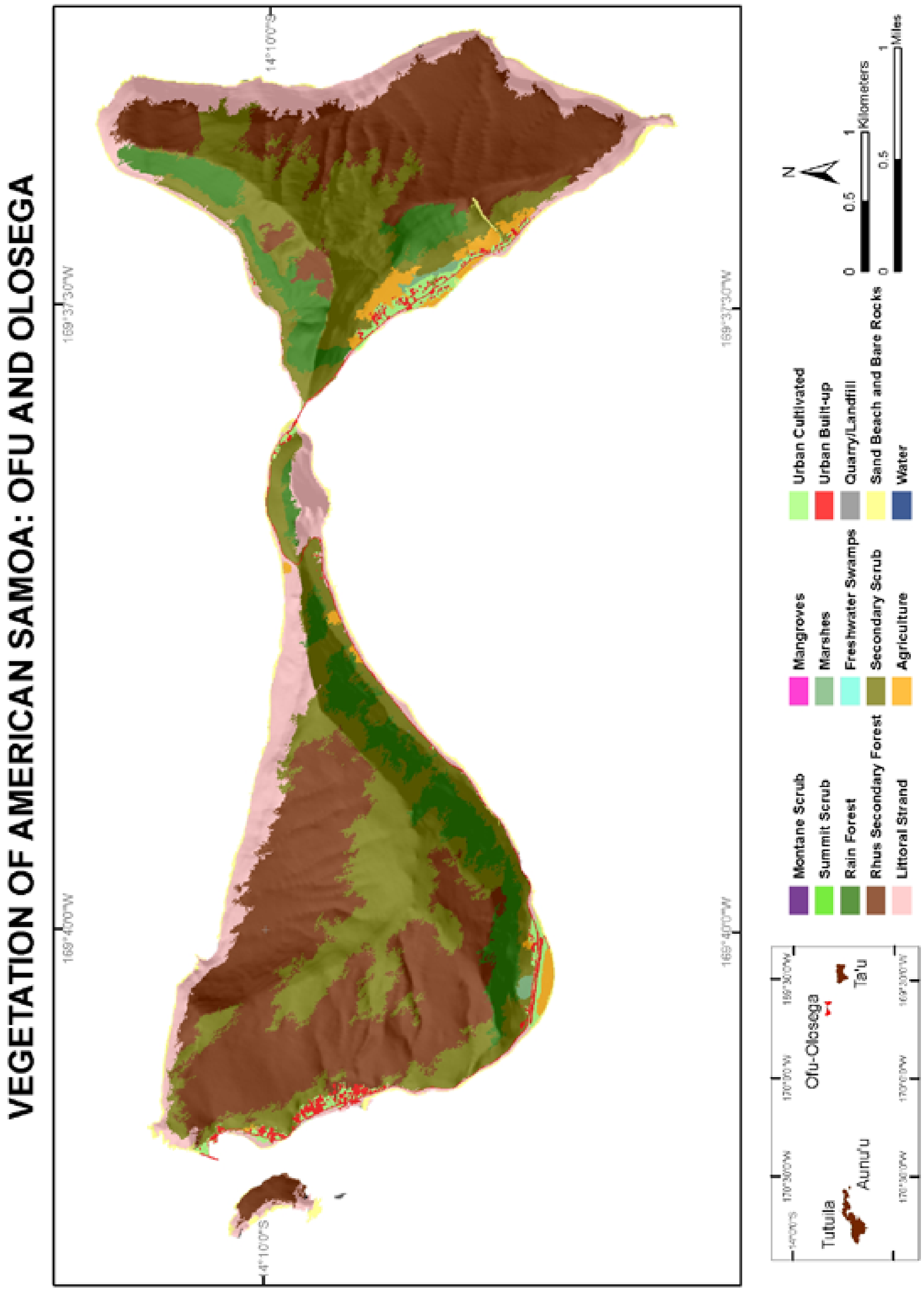
Open water bodies such as streams and lakes.

Urban Built-Up land in Tafuna, Tutuila Island
Photo: Z. Liu

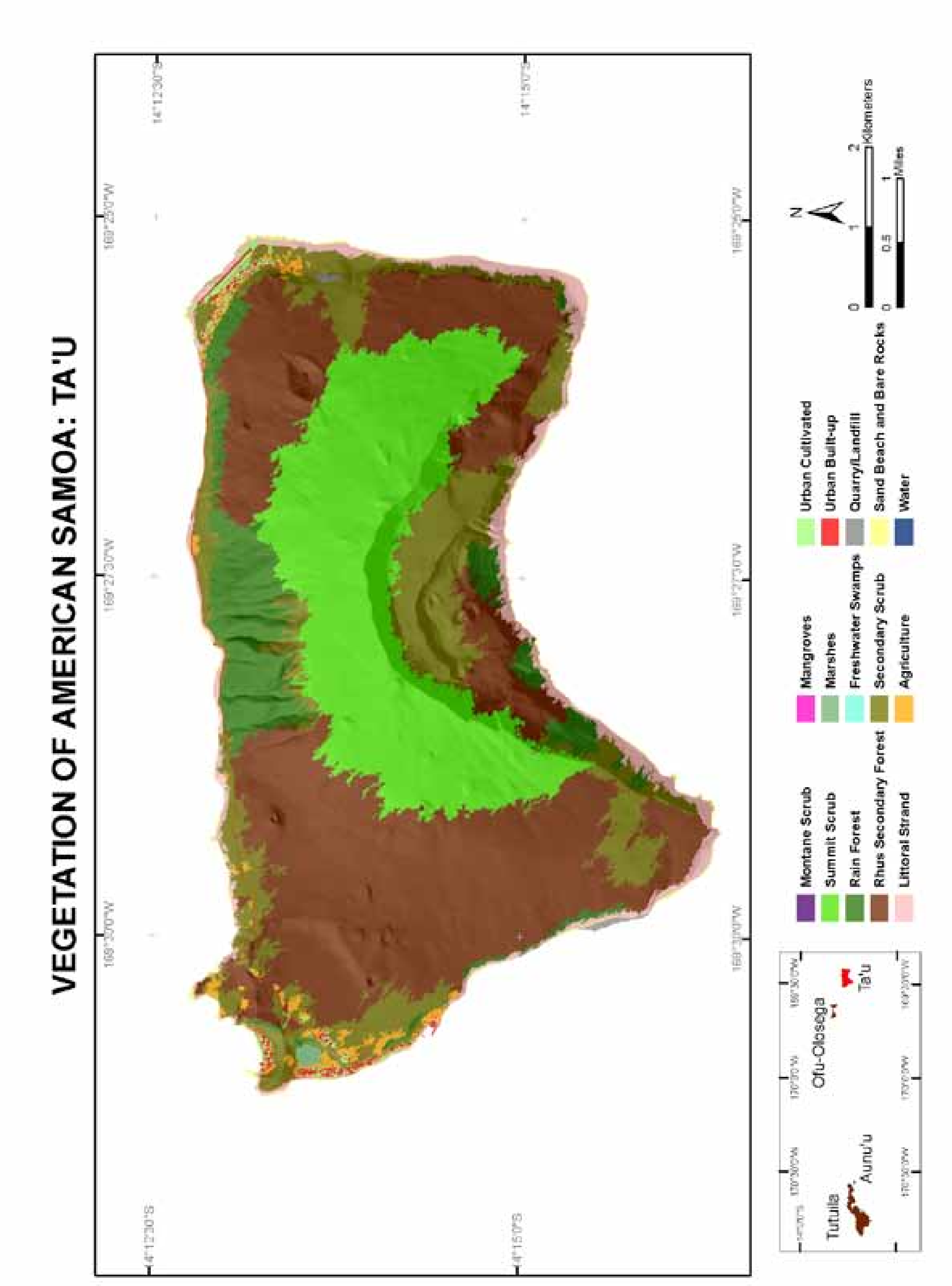
Appendix B - Vegetation Map of Tutuila and Aunu'u



Appendix C - Vegetation Map of Ofu and Olosega



Appendix D - Vegetation Map of Ta'u



Appendix E - Analysis Weights for Sample Strata

Island	Class	Proportion	Inclusion Probability	Weight
Tutuila & Aunu'u	101	0.0019	0.0195	0.10
Tutuila & Aunu'u	102	0.0012	0.0195	0.06
Tutuila & Aunu'u	103	0.0004	0.0195	0.02
Tutuila & Aunu'u	202	0.0078	0.0195	0.40
Tutuila & Aunu'u	301	0.0231	0.0195	1.19
Tutuila & Aunu'u	302	0.1000	0.0545	1.84
Tutuila & Aunu'u	303	0.2476	0.0973	2.55
Tutuila & Aunu'u	401	0.0829	0.0467	1.77
Tutuila & Aunu'u	402	0.1236	0.0545	2.27
Tutuila & Aunu'u	501	0.0619	0.0350	1.77
Tutuila & Aunu'u	502	0.0424	0.0233	1.82
Tutuila & Aunu'u	601	0.0022	0.0195	0.11
Tutuila & Aunu'u	602	0.0073	0.0195	0.38
Tutuila & Aunu'u	603	0.0016	0.0195	0.08
Ta'u	103	0.0004	0.0195	0.02
Ta'u	201	0.0584	0.0389	1.50
Ta'u	301	0.0108	0.0195	0.55
Ta'u	302	0.0182	0.0389	0.47
Ta'u	303	0.0958	0.0584	1.64
Ta'u	401	0.0401	0.0389	1.03
Ta'u	402	0.0025	0.0195	0.13
Ta'u	501	0.0018	0.0195	0.09
Ta'u	502	0.0017	0.0195	0.09
Ta'u	601	0.0001	0.0078	0.01
Ta'u	602	0.0022	0.0195	0.11
Ofu & Olosega	103	0.0002	0.0195	0.01
Ofu & Olosega	301	0.0088	0.0195	0.45
Ofu & Olosega	302	0.0064	0.0389	0.16
Ofu & Olosega	303	0.0259	0.0389	0.66
Ofu & Olosega	401	0.0189	0.0389	0.48
Ofu & Olosega	402	0.0010	0.0195	0.05
Ofu & Olosega	501	0.0009	0.0195	0.05
Ofu & Olosega	502	0.0009	0.0195	0.05
Ofu & Olosega	602	0.0015	0.0195	0.08

Appendix F - Error Matrices

Error matrix based on sample numbers

Class	101	102	103	201	202	301	302	303	401	402	501	502	601	602	603	Total
101	5															5
102		5														5
103			15													15
201				10												10
202					4				1							5
301						15										15
302							31	1	2							34
303				1			1	46	2							50
401				1			1	2	28							32
402						2		3	5	13	1					24
501									1		18					19
502												16				16
601								1					6			7
602														15		15
603															5	5
Total	5	5	15	12	4	17	33	53	39	13	19	16	6	15	5	257

Error Matrix based on weighted sample numbers

Class	101	102	103	201	202	301	302	303	401	402	501	502	601	602	603	Total
101	0.48															0.48
102		0.30														0.30
103			0.25													0.25
201				15.01												15.01
202					1.61				0.40							2.01
301						10.95										10.95
302							31.21	0.47	0.33							32.01
303				1.64			0.66	88.40	4.19							94.90
401				1.03			1.03	2.26	32.14							36.46
402						0.10		6.81	4.92	18.56	2.27					32.65
501									1.77		14.83					16.60
502												11.57				11.57
601								0.11					0.47			0.58
602														2.82		2.82
603															0.41	0.41
Total	0.48	0.30	0.25	17.68	1.61	11.05	32.91	98.05	43.74	18.56	17.10	11.57	0.47	2.82	0.41	257.00