Commonwealth of the Northern Mariana Islands Vegetation Mapping Using Very High Spatial Resolution Imagery
2006

Methodology

Zhanfeng Liu
Lisa Fischer
USDA Forest Service
Pacific Southwest Region
Forest Health Protection
McClellan, CA

Introduction

The USDA Forest Service Pacific Southwest Region, Forest Health Protection (FHP) and the Pacific Northwest Research Station, Forest Inventory and Analysis (FIA) Programs are leading a collaborative effort to acquire recurring high spatial resolution satellite imagery and develop detailed vegetation maps for the U.S. affiliated Pacific Basin islands. The long-term goal of the program is to provide environmental scientists and resource managers with up-to-date information on land cover and its change through time. This report provides detailed documentation of the methods and techniques used to create the vegetation maps for the islands of Saipan, Rota, and Tinian of the Commonwealth of the Northern Mariana Islands (CNMI).

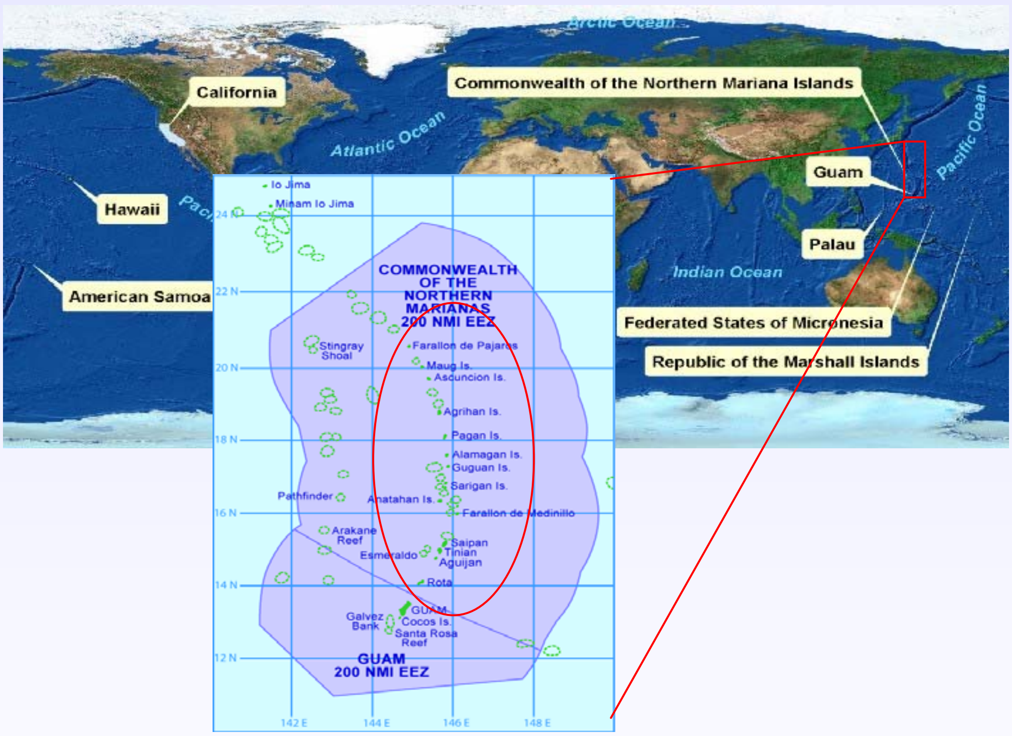

Figure 1. Geographic Location of CNMI

Project Area

Saipan, Rota and Tinian are the three largest and southernmost islands in the CNMI island chain from 14°01' to 15°20' North in latitude and 145°00' to 145°50' East in longitude. Saipan, 47 mi^2, is the second largest island after Guam in the Marianas. It has the greatest topographic diversity with a highest elevation (Mt. Tapotchau) of 472 meters or 1,554 feet. Rota at 33 mi^2 is the smallest of the three islands and has the highest point of elevation, Mt. Manira at 490 meters or 1,612 feet. Tinian, at 39 mi^2, is essentially a terraced platform of elevated limestone (Mueller-Dombois and Fosberg, 1998), and is the least mountainous of the islands. The highest point on Tinian, Puntan Carolinas, is 196 meters or 557 feet above the sea level (Falanruw et al., 1989).

The weather of CNMI is warm and humid throughout the year, with temperatures averaging around 25.6 degrees Celsius, 78 degrees Fahrenheit, and a mean annual relative humidity about 82 percent. Rainfall is seasonal with the dry season typically lasting from January to April and the rainy season from July to November. Mean annual rainfall is about 85 inches (2159 mm) (Falanruw et al., 1989).

Figure 2. View to the Southeast Tip of Saipan Island from Mt. Tapotchau
(Photo courtesy of Zhanfeng Liu)

Native vegetation of the CNMI islands has been conspicuously altered by a long history of human occupation and agricultural activities. Additionally, Saipan and Tinian experienced major campaigns during WWII, which profoundly disturbed the entire landscape. As a result, the vegetation patterns are neither simple nor stable (Mueller-Dombois and Fosberg, 1998). In the 1980s, the Forest Service in cooperation with the CNMI government conducted a vegetation survey for Saipan, Rota, and Tinian, and developed vegetation maps. These vegetation maps were produced by interpreting black and white aerial photographs taken in 1976 at a nominal scale of 1:8,000 to serve as working tools for land use planning and forest resource management (Falanruw et al., 1989). The mapping scheme used to develop these maps is detailed in Table 1. Results from the mapping showed, overall, these islands were still largely forested. However, the native limestone forest type was only dominant on Rota. Introduced tree species and secondary vegetation occupied significant portions on Saipan and Tinian. In recent years, Saipan in particular has also been experiencing rapid population growth and urban development. The landscape, as a result, is further disturbed and rather fragmented with only a few areas left with pure native limestone forest stands (Figure 2).

Land Class	Detailed Type
Forest	Native Limestone Forest
	Introduced Trees
	Mangrove Forest
	Casuarina Forest
	Atoll Forest
Secondary Vegetation	Secondary Vegetation
Agroforest	Agroforest
	Agroforest with Coconuts
	Coconut Plantation
Nonforest	Marsh (fresh)
	Savanna/Grassland
	Strand
	Cropland
	Urban
	Barren
	Water

Table 1. Mapping Scheme for 1980s Survey

* For detailed vegetation class description, refer to Vegetation Survey of Rota, Tinian, and Saipan, Commonwealth of the Northern Mariana Islands (Falanruw et al., 1989).

Classification Scheme

A proper classification scheme is critical to the success of any vegetation mapping effort. Three main factors need to be considered when establishing a classification scheme: 1) goals of the project; 2) availability of existing data of the project area; and 3) limitations of the source imagery used by the mapping project. An additional factor to consider is creating a scheme that can easily be cross-walked to historic maps for comparison and future change analysis.

The classification scheme used by the historic survey was adopted for this mapping effort with minor modifications (Table 2).

Figure 3. Native Limestone Forest on Rota (Photo courtesy of Zhanfeng Liu)

New Class	Historic Class
Native Limestone Forest	Native Limestone Forest
Mixed Introduced Forest	Introduced Trees
Casuarina Thicket	Casuarina Forest
Leucaena Leucocephala	Introduced Trees/Secondary Vegetation
Agroforest	Agroforest
Agroforest - Coconut	Agroforest with Coconuts/ Coconut Plantation
Savanna Complex	Savanna/Grassland
Other Shrub and Grass	Savanna/Grassland
Strand	Strand
Wetland	Mangrove Forest /Marsh (fresh)
Cropland	Cropland
Urban Vegetation	Urban
Urban and Built-up	Urban
Barren/Sandy Beach/Bare Rocks	Barren
Water	Water

Table 2. Classification Scheme for Saipan, Rota, and Tinian

Imagery Data

Two sets of satellite imagery were used for this project including IKONOS (Space Imaging ®) and QuickBird (DigitalGlobe ®). IKONOS 2.4-meter resolution 4-band images were used for the initial mapping, and QuickBird 60-centimeter resolution pan-sharpened natural-color images were used to fill in areas covered under cloud and shadow in the IKONOS data. The QuickBird data was also used to edit and refine the vegetation maps. All these images except the IKONOS for Tinian are mosaic images. A mosaic is created by stitching together data from multiple individual scenes in order to produce a relatively cloud-free image and to generate a complete coverage for the entire project area.

IKONOS multispectral images were provided by the USDA, USFS, Pacific Northwest Research Station, Forest Inventory and Analysis program (FIA). Spectral specifications of the sensor are detailed in Table 3. Figures 4a, 4b, and 4c show the false-color composites of the images for each island.

Band	Bandwidth (nm)	Center Wavelength (nm)
Blue	71.3	480.3
Green	88.6	550.7
Red	65.8	664.8
Near-Infrared	95.4	805.0

Table 3. IKONOS Multispectral Data Specifications (Space Imaging)

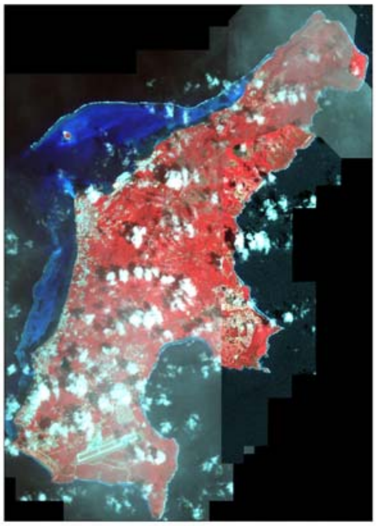

Figure 4a. IKONOS Saipan

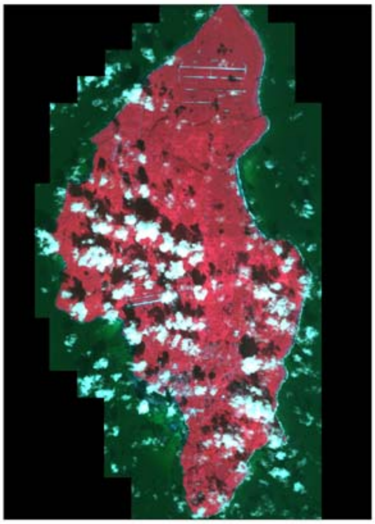

Figure 4b. IKONOS Tinian

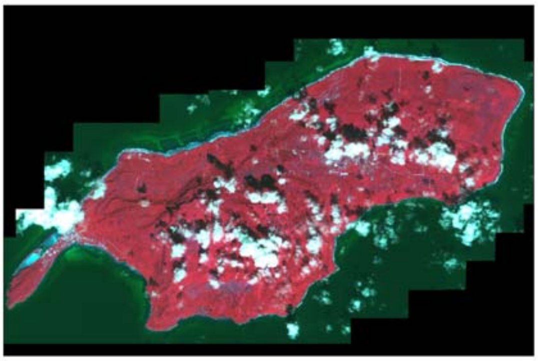

Figure 4c. IKONOS Rota

Table 4 shows the spatial and spectral specifications of the QuickBird sensor. Pan-sharpened natural-color QuickBird images (Figure 5a, 5b, and 5c) are enhanced data produced by fusing the higher spatial resolution (60-centimeter) gray-scale panchromatic band with the coarser resolution (2.4-meter) multispectral bands (color). As a result, the image not only has a higher spatial resolution of 60 centimeters but also preserves the three spectral bands. The 60-centimeter resolution gives the image a nominal scale of approximately 1:6,000 at 250dpi printer resolution, relatively comparable to the aerial photographs used for the historic survey.

Band	Spatial Resolution (m)	Spectral Bandwidth (nm)
Panchromatic	0.6	445 ~ 900
Blue	2.4	450 ~ 520
Green	2.4	520 ~ 600
Red	2.4	630 ~ 690
Near-IR	2.4	760 ~ 900

Table 4. QuickBird Sensor Resolution & Spectral Bandwidth (DigitalGlobe)

Figure 5a. QuickBird Saipan

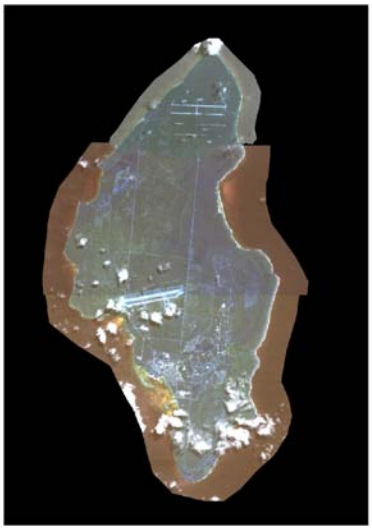

Figure 5b. QuickBird Tinian

Figure 5c. QuickBird Rota

Image Processing and Classification

Constrained by data quality and limited by software access, a semi-automatic image interpretation and delineation method was used. The method is similar to conventional photo interpretation in that vegetation types are identified and labeled by visually examining differences in image color, tone, texture, patterns, and contextual associations. However, polygons were generated automatically using eCognition Professional 3.4 (Definens ®) and labeled efficiently with a customized tool in ArcMap 9.1 (ESRI ®).

The entire procedure included four steps as illustrated in the following flow chart (Figure 6).

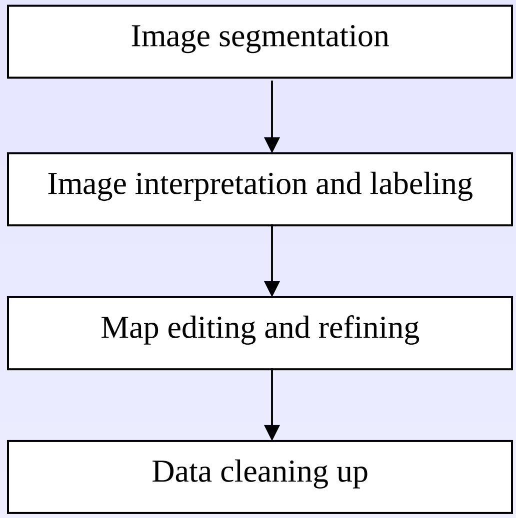

Figure 6. Mapping Procedure Flow Chart

Image segmentation

Special software, eCognition 3.4 professional version from Definiens, was used to segment the IKONOS multispectral images. This software generates discrete segments (polygons) from a continuous image by analyzing the spectral and textural characteristics of its pixels. Scale parameter, an input parameter required by the software, determines the average size of output segments/polygons. The scale parameter value of 50 was used for Saipan, Rota and Tinian. This value was used based on previous work using IKONOS imagery for Guam (Liu and Fischer, 2006). Figure 7 shows the IKONOS false-color composite subset of an area on Saipan. Segmentation result (polygons) for this area from eCognition is shown in Figure 8.

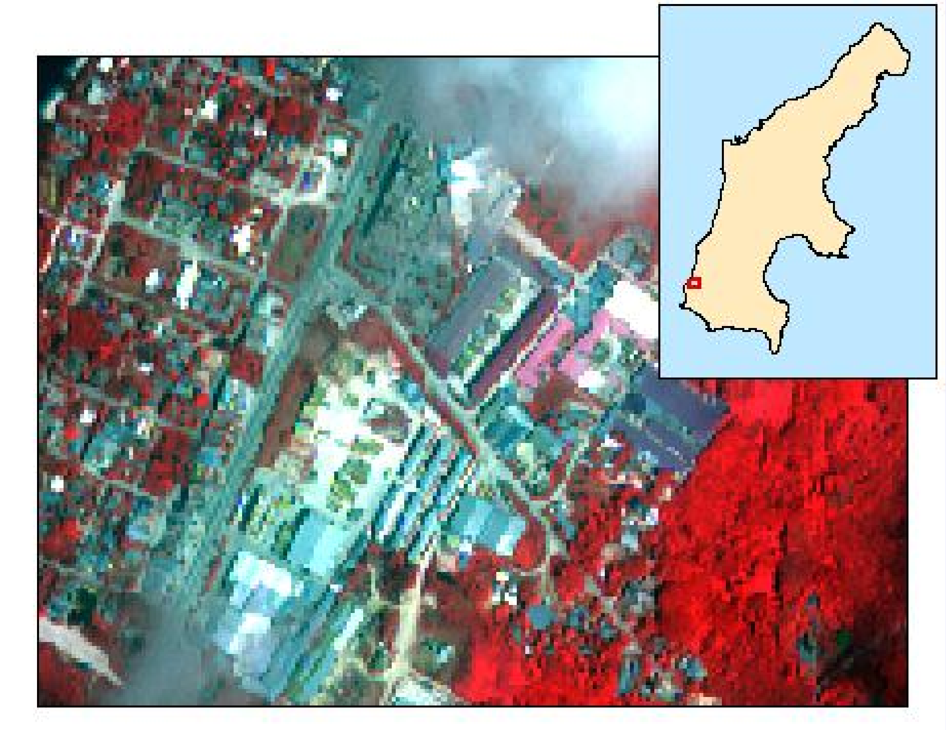

Figure 7. IKONOS False-color Composite

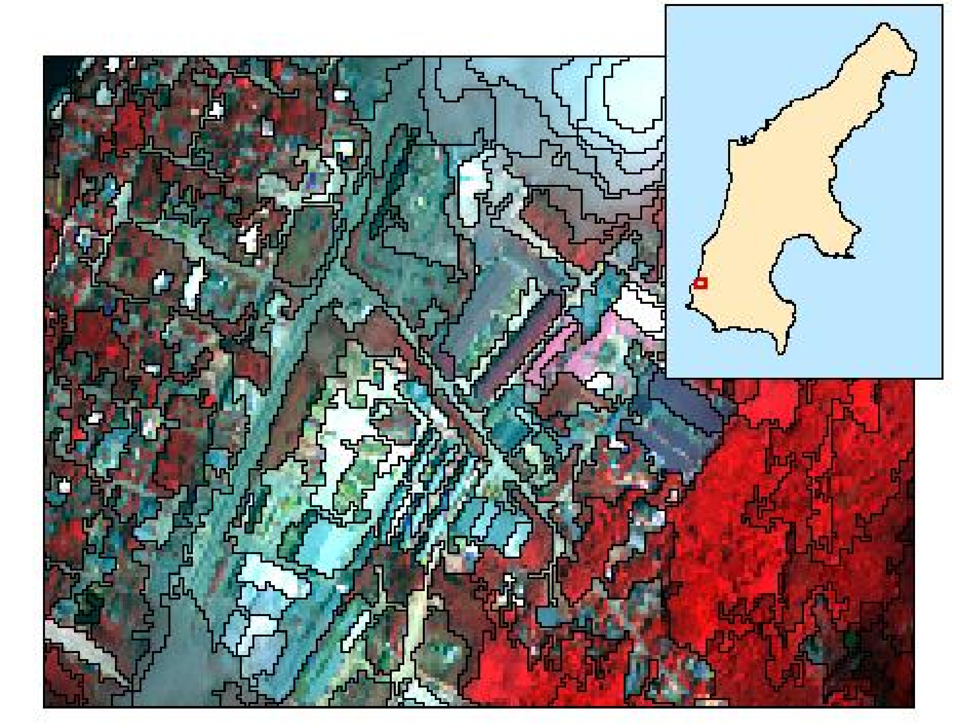

Figure 8. Segments/Polygons Generated by eCognition

Image interpretation and labeling

Based on the best visual interpretation of the image, polygons were assigned class labels according to the established classification scheme (refer to Table 2). Image color, tone, texture, patterns and contextual associations were examined to recognize individual landcover and vegetation classes. The near-infrared band was especially helpful in identifying subtle differences between vegetation classes. Such subtle variations were further amplified by applying local contrast stretching.

A customized label tool in ArcMap 9.1 was developed using ArcObjects and Microsoft Visual Basic for Applications (VBA). The label tool provides an interactive dialog as shown in Figure 9. When executed, it automatically assigns the class label selected on the dialog to all polygons currently selected. This tool was highly customized to the specific needs of this project for these three CNMI islands. Although still rough, this tool significantly improved the efficiency of the labeling process.

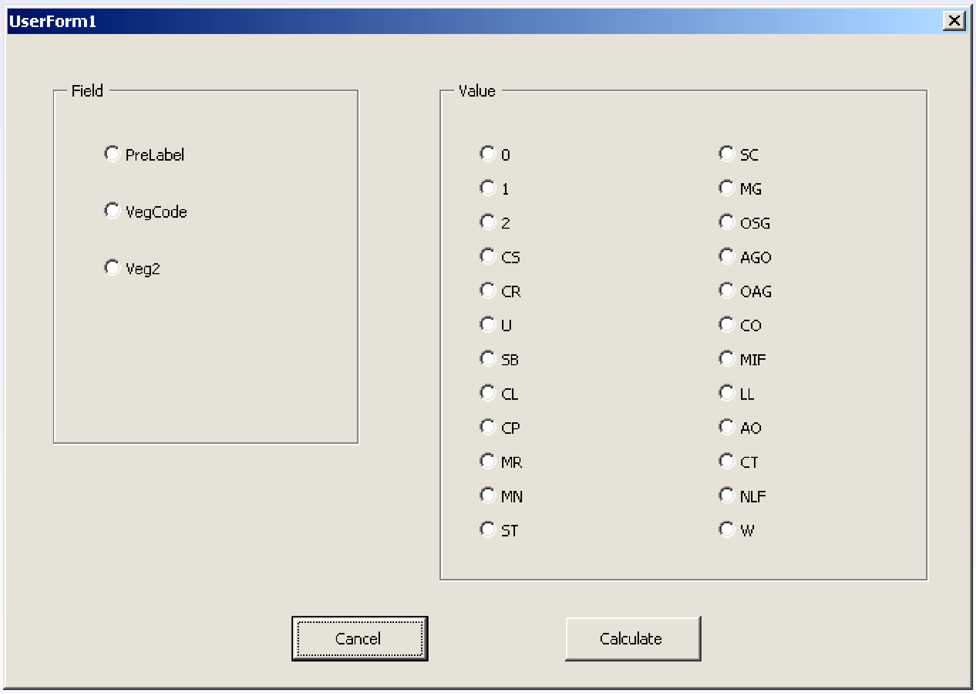

Figure 9. Customized ArcMap Label Tool Dialog

Map editing and refining

Polygons were converted to Erdas Imagine images (.img) for editing and refining. Editing is more manageable and efficient in Erdas Imagine than in other vector-based software programs.

Map editing relied heavily on ancillary data including digital photographs and video clips collected through fieldwork conducted in May 2005. QuickBird pan-sharpened natural-color images were used to fill in areas covered under cloud/shadow in the IKONOS images as well as to validate previous interpretations. Editing improved the map quality significantly. However, one drawback was that it made the field data and QuickBird images unsuitable for an unbiased accuracy assessment.

Figure 10 shows the draft map after the initial interpretation and labeling for the same area in Figure 7. The QuickBird image for this subset is shown in Figure 11. The higher spatial resolution QuickBird image not only reveals more details in land cover features but also provides clear data for the upper-center portion in the subset previously covered under clouds in the IKONOS image.

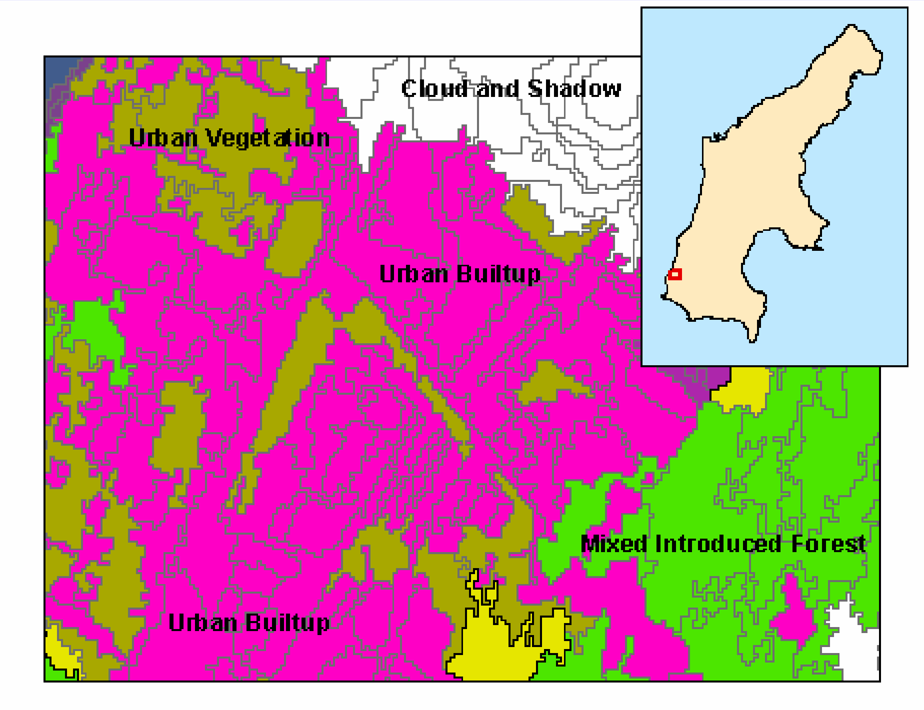

Figure 10. Draft Vegetation Map

Figure 11. QuickBird Pan-sharpened Natural-color Image

Data Finalization

Final maps were converted to ESRI polygon shapefiles. The area (acres) of each polygon was calculated and stored in the attribute table. Full class names were assigned to replace the simplified class codes which were used for efficiency during image interpretation and labeling. All polygons were checked to make sure there were no "NoData" polygons. Figure 12 is the final result of the subset on Saipan discussed above.

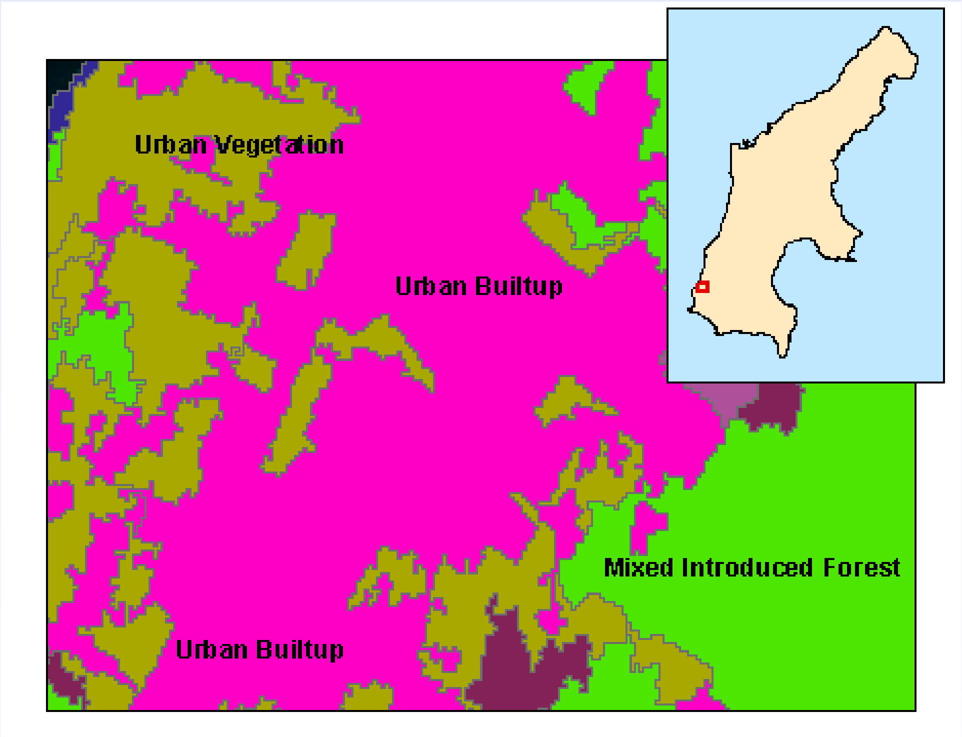

Figure 12. Final Vegetation Map

Summary

The combination of 2.4-meter IKONOS multispectral data and 0.6-meter QuickBird pan-sharpened natural-color image provided an efficient and effective base for mapping the vegetation on Saipan, Tinian and Rota. The use of eCognition and the customized ArcMap label tool greatly simplified the amount of work and time spent on iterative editing and labeling. Direct involvement of local experts in the future may make the process much more accurate and efficient. Heavy cloud/shadow cover is still the most challenging issue when mapping in this environment

Data Distribution

Vegetation mapped data is available in vector format. Vector layers are checked for topology errors, corrected if detected, and attribute tables are standardized. Only two non-spatial attributes are kept, "Class" and "Acres." Sample symbology layers for displaying the data in ArcMap 9.1 are created. FGDC-compliant metadata files using tools provided in ArcCatalog 9.1 (ESRI ®) are provided. The final distribution package includes the vector data and other documents and is downloadable through the FHP website at http://www.fs.fed.us/r5/spf/fhp.

Acknowledgments

We would like to acknowledge Joe Donnegan, USDA Forest Service for his cooperation. Thanks to former Commonwealth Forester Manny Pangelinan and his wonderful staff from the forestry section of the CNMI Department of Lands and Natural Resources for their valuable inputs and providing resources for field works.

References

Falanruw, M.C., Cole, T.G., and Ambacher, A.H. 1989. Vegetation Survey of Rota, Tinian, and Saipan, Commonwealth of the Northern Mariana Islands. Resource Bulletin.

Liu, Z., and Fischer, L. 2006. Guam Vegetation Mapping Using Very High Spatial Resolution Imagery – Methodology. USDA Forest Service, Pacific Southwest Region, Forest Health Protection.

(http://www.fs.fed.us/r5/spf/fhp/fhm/landcover/islands/index.shtml.)

Mueller-Dombois, D., and Fosberg, F.R. 1998. Ecological Studies 132: Vegetation of the Tropical Pacific Islands. Springer-Verlag New York, Inc.

PSW-27. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture.

U.S. Census Bureau. 2001. Census Bureau 2000 Population Counts for the Commonwealth of the Northern Mariana Islands (CB01-CN.173).

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, DC 20250-9410, or for Forest Service issues please call, toll free, (866) 632-9992 (Voice). TDD users can contact USDA through local relay or the Federal Relay at (800) 877-8339 (TDD) or (866) 377-8642 (relay voice users). USDA is an equal opportunity provider and employer.