Guam Forest Action Plan
2020 – 2030

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Glossary

AAFB	Anderson Air Force Base
ADS	Agriculture Development Services
BIOSEC	Guam Department of Agriculture, Biosecurity Division
CFAA	Cooperative Forestry Assistance Act of 1978 as amended
CFHM	Cooperative Forest Health Management Program (Guam)
CFP	Cooperative Fire Program (Guam)
CWA	Clean Water Act
CZMP	Coastal Zone Management Act
DAWR	Division of Aquatic & Wildlife Resources (Guam)
DOAG	Department of Agriculture (Guam)
DOD	Department of Defense
EPA	U.S. Environmental Protection Agency
FAP	Forest Action Plan (Guam)
FEPP	Federal Excess Personal Property
FH	Forest Health
FSRD	Forestry & Soil Resources Division, Department of Agriculture (Guam)
FSP	Forest Stewardship Program (Guam, funded by USDA Forest Service)
GCMP	Guam Coastal Management Program
GFAP	Guam Forest Action Plan
GIS	Geographic Information System
GPA	Guam Power Authority
GWA	Guam Waterworks Authority
GWAP	Guam Wildlife Action Plan (Guam)
LES	Department of Agriculture, Law Enforcement Section
NIPF	Non-Industrial Private Forestlands
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRCE	Natural Resources Education Conservation Program (Guam)
NRCS	National Resources Conservation Service
NWI	National Wetland Inventory
PIV	Pacific Islands Vegetation
PWSS	Public Water Supply System
SDWA	Safe Drinking Water Act
S&PF	State and Private Forestry (USDA Forest Service)
GFAP	State-Wide Assessment and Resource Strategy
U&CF	Urban & Community Forestry (Guam)
UOG	University of Guam
USACE	U.S. Army Corps of Engineers
USFS	U.S. Department of Agriculture, Forest Service
USGS	U.S. Geological Survey
WERI	Water and Environmental Research Institute

Executive Summary

The tropical forests on Guam are comprised of over 600 species of plants, with more than 100 species of trees.[1] The unique biodiversity found within Guam forests supports traditional practices such as agroforestry, collection of plant materials for medicines, harvesting of timber for seafaring, and wood carving practices. In addition to these significant cultural and intrinsic values, Guam's forests provide critical ecosystem services, and habitats for native, endemic, and endangered species. Guam's forests have been impacted by typhoons, drought, wildfires, and invasions of introduced insects, plants and ungulate species. These impacts have greatly altered native communities, and now threaten biodiversity and watershed functions. In addition, Guam is experiencing an increase in development and population associated with the expansion of the U.S. Marine Corps, Navy, Army and Air Force on the island. This assessment recommends strategies for protecting forests, restoring forest ecosystems, and reducing pollution to critical reef systems.

Purpose

This document was completed to meet the requirements of the 2008 and 2010 Farm Bills and the redesigned objectives of the USDA Forest Service State and Private Forestry (S&PF) programs. This Guam Forest Action Plan (GFAP), previously known as the Guam State-wide Forest Assessment and Resource Strategy (GSWARS), has provided the Guam Department of Agriculture, Forestry and Soil Resources Division (DOAG-FSRD) an opportunity to identify the highest priorities for forest resource management, and a vision for the future of Guam's forests and soil resources.

Public Involvement

Local and federal agencies and stakeholder representatives on the *FAP Advisory Council* contributed critical input to complete the plan. The Council consisted of the Forest Stewardship Program (FSP) board, Urban and Community Forestry (UCF) council, and the Cooperative Fire Protection (CFP) Program committee. The Council identified and prioritized major issues and threats to Guam forests and landscapes. This effort of issues and threats guided the development of the assessment and strategies.

Forest Conditions and Trends

While limited documentation of Guam's forest cover and composition exists prior to

[1] (Taborosi, 2013)

1900, World War II represents a significant shift in forest conditions. Events that occurred during the war and immediately after, seem to have set the stage for enduring forest cover conditions, which do not appear to have changed substantially since the early 1950s.[2] A comparison of forest cover types shows that in general, the forest and non-forest components have been relatively stable for much of the island. A significant observation is the change in the urban landscape, with increasing urbanized zones, additional roads, and impervious surfaces (large shopping centers and parking lots). These areas were expanded into mostly non- forest and some forested zones (especially in the north of the island). In the next five years, increased urban development is anticipated to be a significant disturbance to Guam's forest—the creation of Marine Corps Base Camp Blaz has removed or disturbed about 1,000 acres of forest, and the buildup[3] is driving additional development that could impact forests outside the base footprint as well.

A detailed vegetation type map (Figure 7) was developed to provide the foundation for evaluating forest conditions and trends, water resources and water quality impacts. At the island scale (~134,000 acres), approximately 49% of the area on Guam has tree cover, either recognized as forest types or as individual tree fragments; 19% is developed or mixed-use areas, 18% of the landscape is grassland, 9% of the area is open water, 3% consists of wetland vegetation, and 2% is identified as bare land (Table 4).

Forest types for this assessment are aggregated as 'evergreen forest' and include scrub and or shrubs as either Mixed Forests or Secondary Forest. The Mixed Forest is a composite of forest types, including coconut forest, mixed forest types and native limestone forests. These forests are moderately dense, with a collection of understory shrub, vine and fern species, along with germinating and young trees. Forest types are relegated to ravines, sheltered depressions and river drainages in southern Guam, and on limestone soils in northern Guam. Secondary Forests occur on the lower edges of slopes above forested valleys and ravines that generally have a border of thickets of native and introduced woody species. These secondary forests are composed of dense, low-stature thickets with low species diversity, or are composed of a single species. This community contains both thickets dominated by introduced *Leucaena leucocephala* and thickets of native *Hibiscus tilliaceus*.

[2] 2010 Guam SWARS
[3] Joint Guam Program Office. 2015. Supplemental Environmental Impact Statement: Guam and CNMI Military Relocation (2012 Roadmap Adjustments). Navy Facilities Engineering Command Pacific

Assessing ***Non-Forest Community Types*** on Guam is critical in evaluating threats to forested acres, urban areas, and water quality. Non-Forest Communities include several Savanna Communities, Tall Grass communities, and Mixed Grass communities. The non-forest communities exhibit the highest fire prone risk to forests and communities and are the major source of sediment to waterways and the reef system. Other Cover Types were classified as Bare Ground, Developed Areas and miscellaneous other types.

Urbanization and buildup are principal vectors for disturbances from invasive species. Guam is the primary transportation and shipping hub to greater Micronesia and is expected to import large amounts of materials to accommodate the military buildup phase. The large volume of incoming cargo, combined with an estimated 1.1 million tourist arrivals annually, allow for ample opportunities for non-native species to arrive and establish on Guam.

Invasive species significantly alter forest structure, composition and resilience to other disturbance processes. Abiotic disturbances including typhoons and fire contribute to the successful spread and establishment of invasive species, as well as provide points of entry to establish within the interiors of forest fragments. Influxes of equipment from infested areas can also spread invasive species to other parts of the island, especially during the construction phases of the buildup.

Little quantitative data are available about invasive species assemblages, their distribution or their effects on forest health at the island-scale. The best-known major insect species that alter forest health on Guam are the Asian cycad scale (*Aulacaspis yasumatsui*) and the coconut rhinoceros beetle (*Oryctes rhinoceros* L.), but other insect pests are likely contributing to forest changes as well. For instance, a newly discovered gall-forming eulophid wasp and termites affect the health and survival of ironwood trees (*Casuarina equisetifolia)*, which have been declining since a series of severe typhoons in 2002. The insects are part of a complex of biotic and abiotic factors responsible for the dieback.

Given the rapid changes associated with the military buildup that are scheduled to occur on Guam, including the massive influx of raw materials from off-island, it is imperative that Guam Forestry and its partners gain the capacity and resources to help prevent and detect invasive species before they gain a foothold. Quantitative data, personnel and staff capacity are all gaps in the effective management of a forest health program.

Coral Reef Decline and Ridge-to-Reef Management

Coral reef health is in decline where significant chronic sediment plumes occur. Deforestation, invasive species, fire, and land management practices increase the sediment flux from the uplands through freshwater systems, including some drinking water sources, to the mouths of rivers that empty into the fringing reef and bays. A comprehensive Ridge-to- Reef restoration program is the best way to reduce the damage from peak flows and inputs of sediment sources. A Strategy in this document is to adopt a Ridge-to-Reef assessment and implementation approach to improve water quality and reef protection.

Identification of Issues and Threats to Guam Landscapes

The Stakeholder evaluation was based on eleven environmental attributes mapped at a coarse scale using the PIC Veg Layer developed by the Forest Service in 2005 combined with other basic topographic spatial layers. The six key issues identified by the Forest Action Plan Advisory Council were:

- Issue 1. Wildfire and Public Safety
- Issue 2. Water Quality and Water Supply
- Issue 3. Deforestation of Native and Old Forests
- Issue 4. Urban Forest Sustainability, Population Growth and Urbanization
- Issue 5. Degraded Lands
- Issue 6. Invasive Species and Forest Health

Following the identification of these issues, the assessment findings were completed to spatially identify areas and rank the severity of the issue. These fine scale spatial layers provided the foundation for identifying forests and forest fragments, modeling fire behavior and modeling sediment sources.

Fire is a keystone issue on Guam that prevents reestablishment of forests, threatens urban areas and public safety, and maintains or promotes fire prone grasslands. Fire promotes invasive grasses whereas within native savanna complexes there are lower grasses (*Dimeria* sp.) and a mix of shrubs that don't seem to carry the same fuel load as invasive grass complexes. These fire-prone areas increase sedimentation rates that directly degrade water quality and reef systems. Fire behavior risk was evaluated in 300-ft perimeters around forest fragments and 500-ft buffers around urban areas. Evaluating

fire risk in categories from Low to Extreme provided a way to identify the highest priority areas for treatment.

Sediment contributing areas were identified in each watershed using vegetation types and topographic features. This assessment provides a tool to focus on treatment areas that will have the most benefit in reducing sedimentation and improving water quality and reef protection.

A synthesis of the stakeholder issues identifying approximately 13,000 acres of land that are the highest priority areas for treatment, where single treatments of planting forest will decrease sediment loads to reefs, increase forest fragment sizes, and decrease risk of fire to standing forests.

Ten-Year Strategic Plan

The Strategic Plan developed to address the stakeholder issues consists of the Resource Strategies, an Approach for Implementation and an evaluation of Guam Forestry's capacity to implement the plan. Strategies are identified in sequential order to address restoration, conservation of intact forests, reduce impacts to water quality and the reef system, mitigate the impacts of the military expansion, and address invasive species – all unifying themes developed from stakeholder issues. The strategies are organized to address the following components: Forest Service National Themes for State Action Plans, Strategy Description, Next Steps, State and Private Forestry Programs that Contribute, Key Stakeholders, Resources Needed, and Measures of Success. The four strategies are:

Strategy 1: Implement Highest Priority Plantings in Urban, Rural and Undeveloped Areas that Meet Multiple Objectives.

Strategy 2: Protect, Conserve and Restore Forests on Public, Private, And Other Non- Military Lands

Strategy 3: Improve Fire Prevention, Control, Suppression and Prescribed Fire Activities through Organizing, Training and Equipping Staff and Resources.

Strategy 4: Implement a Forest Health Program and Unify Interagency Efforts to Control Invasive Species

These strategies represent a new approach for Guam Forestry Programs that builds on the priority geographic areas identified in the assessment. The new approach stresses increased planning efforts in all program areas, a step-down approach from an island scale to a watershed and site scale, and the need for increased resources to build program capacity to carry out these strategies.

Introduction

Guam People and Resources

Guam is the southernmost island in the Mariana Archipelago, located at 13°28' N, 144°45' E. It is the largest island in Micronesia, with a land mass of 560 km^2, and has a maximum elevation of approximately 405 m and a total shoreline length of 244 km. Guam is a volcanic island completely surrounded by a coralline limestone plateau. The relatively flat northern half of the island, which is primarily composed of uplifted limestone, is the site ofthe island's primary aquifer. The southern half of the island has more topographic relief and is comprised mainly of volcanic rock, with areas of highly erodible lateritic soils. The hilly topography on the southern half of the island creates numerous watersheds drained by 96 rivers.

The climate of Guam is characterized by a dry season that runs from December through May, and a wet season from June through November. The island is located within "Typhoon Alley" and averages 90 to 110 inches of rainfall annually which varies geographically. Temperatures average 81°F annually, with the coolest and least humid period being December through February.[4]

Guam is surrounded by a highly valued reef system that contributes to one of the most species-rich marine ecosystems among U.S. jurisdictions. Guam's coral reef resources contribute $323 million USD per year[5] based on reef-based tourism activities alone. Over 5,100 marine species have been identified from Guam's coastal waters, including over 1,000 nearshore fish species and over 400 species of *scleractinian* coral. Guam's reef resources support numerous cultural and traditional uses, tourism, recreation, fisheries, and shoreline and infrastructure protection. Traditionally, coral reef fishery resources formed a substantial part of the local CHamoru community's diet which included finfish, invertebrates and sea turtle. The Endangered Species Act of 1973 protects all three species of sea turtles that inhabit the waters of Guam.[6]

The Mariana Islands was inhabited by seafaring people believed to have sailed from Southeast Asia at least 4,000 years before the first European explorers. CHamoru culture

[4] WERI. Digital Atlas of Northern Guam. Retrieved April 2021, http://north.hydroguam.net/geographic-climate.php#:~:text=Daily%20maximums%20and%20minimums%20vary,season%20from%20July%20through%20November.
[5] Guam Coral Reef Resilience Strategy, 2018
[6] Guam Wildlife Action Plan, p. 95, 2019

and society were already established by the time the Europeans arrived in the mid-1500s.[7] The original settlers brought in plants – rice, breadfruit, sugar cane, bananas, coconuts and taro – to balance the heavy protein intake of fish.[8] Guam was claimed by Spain in 1565 and colonized by Spain beginning in 1668. Being on the trade route between Mexico and the Philippines, islanders mixed with people of Spanish, Mexican and Filipino heritage. The United States took control of the island in the 1898 Spanish-American war. Guam was taken to strategically provide America a route of commerce and military resources to Asia.[9] During World War II, Guam was invaded by Japan and held by Japan for three years. After the war, Guam was established as an unincorporated territory of the United States.[10] This long history of war, colonization and occupation has shaped the natural resources of the island, through the introduction of invasive species, large-scale disturbances from intensive bombing and military operations, and changing resource exploitation.

Guam is the most heavily populated island in Micronesia, with an estimated population in 2010 of about 159,358.[11] In 2000, the U.S. Census Bureau predicted the population growth rate to steadily decrease over the next 50 years, but this estimate did not take into account the planned movement of additional military units to the island. While preliminary estimates for the U.S. Marine Corps relocation suggested a temporary influx of an additional 80,000 people, the buildup has been scaled to reduce impacts.[12] The military activity continues to drive population increases and additional development.

Guam's economy depends primarily on tourism, Department of Defense (DoD) installations, and locally owned businesses. Although Guam receives no foreign aid, it does receive large transfer payments from the general revenues of the U.S. Federal treasury into which Guam pays no income or excise taxes.

Vegetation on Guam has been shaped by frequent tropical storms and typhoons, human-caused grassland and forest fires, ungulate rooting, browsing and trampling, mass soil movements and erosion, nonnative insects and pathogens, invasive weeds, historical

[7] Perez, Celeste. Fo'na: Mother of the Chamorro People. Guampedia. https://www.guampedia.com/fuuna/, Retrieved April 2021,

[8] Moore, Darlene MA. Ancient CHamoru Agricultural Practices. Guampedia. https://www.guampedia.com/ancient-chamorro-agricultural-practices/, Retrieved April 2021,

[9] https://www.guampedia.com/american-style-colonialism/

[10] https://www.guampedia.com/american-style-colonialism/

[11] A 2020 Census was conducted but said data was not available upon completion of this update. Population data will be updated once made available.

[12] Joint Guam Program Office. 2015. Supplemental Environmental Impact Statement: Guam and CNMI Military Relocation (2012 Roadmap Adjustments). Navy Facilities Engineering Command Pacific.

military actions, and historical timber harvest. The limestone soils in the north are covered with forest in areas that are not cultivated or urbanized. The southern part of the island features rolling to mountainous terrain in the deeply weathered volcanic soils. The volcanic soils on the southern half of Guam are covered primarily by grasslands and savannas, with forest fragments occurring in sheltered and leeward sites. The Government of Guam Department of Agriculture has primary responsibility for conservation management of local government conservation lands; the Forestry and Soil Resources Division (Guam Forestry)[13] is a division of the Department and is the central agency with the responsibility of protecting and restoring forest ecosystems and soil resources on Guam.

Purpose and Scope

The Guam Forest Action Plan (GFAP) is a tool for Guam to identify the highest priorities for forest resource management and seek implementation of these strategies with local partners and with assistance from the United States Department of Agriculture, Forest Service (USFS).

The Forest Action Plan (FAP) is integral to the Forest Service's State and Private Forestry (S&PF) redesign and required as an amendment to the Cooperative Forestry Assistance Act (CFAA), as enacted in the 2008 and 2010 Farm Bills. Each State, Territory and Freely Associated State receiving funds from S&PF programs is required to complete a 10-year update in 2021 to receive funds under the CFAA. The FAP requires two primary components:

1. **State-wide Forest Resource Assessment** – provides an analysis of forest conditions and trends on the island and identifies and delineates priority rural and urban forest landscape areas.

2. **State-wide Forest Resource Strategy** – provides long-term strategies for investing state, federal, and other resources to manage priority landscapes identified in the assessment, focusing federal investment to most effectively stimulate or leverage desired action and engage multiple partners; providing a description of resources necessary for Guam Forestry to address the state-wide strategy; and addressing the national priorities for SP&F.

[13] In this document "Guam Forestry" will be used to refer to the Guam Dept. of Agriculture, Forestry and Soil Resources Division.

The FAP provides a basis for subsequent annual grant proposals, as authorized under several CFAA programs. The redesign deemphasizes program-by-program planning and emphasizes program integration to meet island priorities, which are in turn tied to one or more broad national themes and objectives. A brief description of the S&PF National Themes and Objectives is below:

State and Private Forestry National Themes and Objectives

1. **Conserve Working Forest Lands**
    a. Identify and conserve high priority forest ecosystems and landscapes
    b. Actively and sustainably manage forests
2. **Protect Forests from Harm**
    a. Restore fire-adapted lands and reduce risk of wildlife impacts
    b. Identify, manage and reduce threats to forest and ecosystem health
3. **Protect and Enhance Public Benefits from Trees**
    a. Protect and enhance water quality and quantity
    b. Improve air quality and conserve energy
    c. Assist communities in planning for and reducing wildfire risks
    d. Maintain and enhance the economic benefits and values of trees and forests
    e. Protect, conserve, and enhance wildlife and fish habitat
    f. Connect people to trees and forests, and engage them in environmental stewardship activities
    g. Manage and restore trees and forests to mitigate and adapt to global climate change

Agencies and Stakeholders

This document provides the technical assessment needed to identify priority landscapes for implementation of S&PF Programs at the island scale. This section briefly identifies the key agencies and stakeholders that have participated or played major collaborative roles in the GFAP.

Guam Forestry and Soil Resources Division (Guam Forestry)

The mission of the Forestry & Soil Resources Division (Guam Forestry) is to conserve, protect and enhance Guam's vegetative environment and sustain the natural resources which are dependent on healthy forests. The agency works with stakeholders to promote

healthy and productive forests in both rural and urban areas throughout the island in partnership with the USDA Forest Service and other key stakeholders.

USDA Forest Service, State and Private Forestry Program

The State and Private Forestry (S&PF) organization of the USDA Forest Service provides technical and financial assistance to landowners and resource managers through a variety of programs – Fire Management, Forest Health Program, Forest Legacy Program, Community Forests and Open Space Program, Forest Stewardship Program and Urban and Community Forestry Program. The Landscape Scale Restoration Program provides additional, competitive funding under the authorities of several of the previously mentioned programs.

In 2008, the U.S. Forest Service began implementing a "Redesigned" S&PF program. The intent of the redesign is to improve the ability to identify the greatest threats to forest sustainability and accomplish meaningful change in high priority areas. The 2008 Farm Bill codified the main components of Redesign into law by amending the Cooperative Forestry Assistance Act (CFAA). The three national themes (listed in the *Purpose and Scope* section) are now set in law as national priorities and a FAP is required and is central to S&PF program delivery.

Stakeholder Involvement

Guam Forestry formed the GFAP Advisory Council to participate in issue identification and provide feedback throughout the process. Because Guam is a small community, many of the stakeholders serve on multiple committees and represented those stakeholder groups in the GFAP process. Member organizations are listed in Table 1 with the detailed list provided in Appendix I.

Table 1. Forest Action Plan Advisory Council

Organization
Chamorro Land Trust
Guam Department of Land Management
Guam Department of Agriculture, FSRD/DAWR/BIOSEC/ADS/LES/Animal Health
Guam Bureau of Statistics and Plans
Guam Waterworks Authority
Guam Power Authority
Guam Department of Public Works
Guam Environmental Protection Agency
Guam Fire Department
Northern Guam Soil & Water Conservation District
Southern Guam Soil & Water Conservation District
University of Guam, Cooperative Extension & Outreach
University of Guam, Water & Environmental Resources Institute of the Western Pacific (WERI)
Office of the Governor, Guam Military Buildup
The Nature Conservancy
Naval Facilities Engineering Command (NAVFAC)
USDA Natural Resources Conservation Service
U.S. Fish and Wildlife Service

Conditions and Trends of Forest Resources

Assessment of existing forest conditions provides the foundation for identifying issues and threats to forests. Native forests of Guam have been extensively altered. Some have been converted to mixed forests of non-native trees, and some have been totally transformed to grasslands, savannas and barren lands.[14] Given the extensive conversion of forests, the current condition of the forests is best summarized by accurately identifying where on the landscape forest communities occur in comparison to non-forest vegetation communities, developed areas and barren areas and what the composition of these communities are.

The assessment of the current conditions is summarized by addressing three aspects of the forest ecosystem:

1. A description of the distribution of vegetation communities on the island,
2. A summary of the major forest health issues and disturbances affecting forests, and
3. Connecting forest health and disturbances with watershed-scale effects, including implications for ridge-to-reef management.

The purpose of this section is to compile the base information, major issues and trends, and provide context for forest management that provides benefits for watershed processes (Ridge-to-Reef approach).

Land Ownership & Management

Land ownership on Guam is split between private (53%, 71,093 acres) and public management entities (47%, 63,238 acres). In the public sector, lands managed by the Department of Defense (Air Force and Navy lands) incorporate 34,048 acres, or ~25% of Guam. Approximately 1,814 acres are associated with National Park Service (NPS) and the National Wildlife Refuge (NWR), though the Park also manages marine reserve areas offshore of Agat and Piti/Asan watersheds. Approximately 20% of Guam Island is under local management, Government of Guam (GovGuam), 27,376 acres.

The current forest cover conditions were evaluated (see *FAP Vegetation Maps,* page 16) and attributed to land ownership (Figure 1). Overall, all ownerships reflect the approximate distribution of forest cover found on Guam (56,520 acres, or 42% island-wide). GovGuam,

[14] 2010 Guam SWARS

National Park Service, and Private Lands all have approximately 40-42% forest cover, reflecting the island-scale average. The DoD lands combined have 46% tree cover under their management, with Navy lands slightly below the island average (40%) and Air Force much higher than the island average (52% cover). The National Wildlife Refuge lands, while relatively small in a land-area comparison, are mostly forested with 71% tree cover.

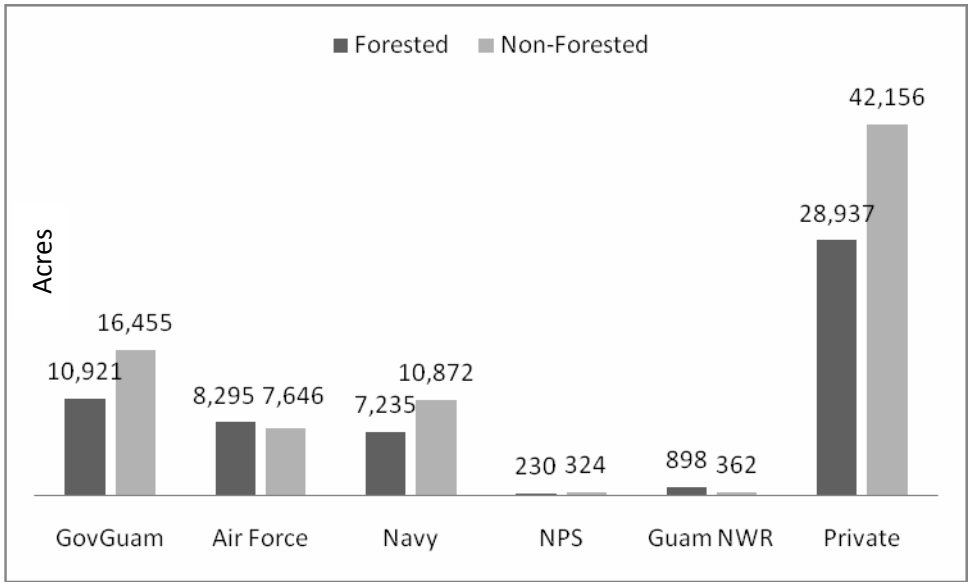

Figure 1. The distribution of forest non-forested acres under each major ownership on Guam.

At watershed scales (see the *Watersheds on Guam* section beginning on page 45), GovGuam has a management presence in all 19 major watersheds, with over one-half of the land ownership in five watersheds in western Guam (Table 2). The DoD has interest in 11 of the 19 watersheds; private ownership is the majority landowner in all but 5 watersheds (Figure 3).

Privately owned forest lands (forest, agroforest or appropriate for reforestation and agroforestry) are eligible for Forest Stewardship and non-federal public forest lands (or lands appropriate for reforestation) are eligible for Forest Stewardship (and Landscape Scale Restoration) under the Rural Forestry Assistance and Reforestation, Nurseries and Genetic Resources authorities of the Forest Stewardship program. Therefore, the eligibility area for Forest Stewardship includes non-federal lands that are also not water and not urban in Figure 2, and that eligibility area is submitted, reviewed and/or updated annually as the "Important Forest Resource Area" (IFRA) used in the Forest Stewardship SMART database and reporting system. More highly prioritized areas for the use of Forest Stewardship and Landscape Scale Restoration funding for any given issue or strategy for this Forest Action Plan are shown in the maps and tables for those issues and strategies.

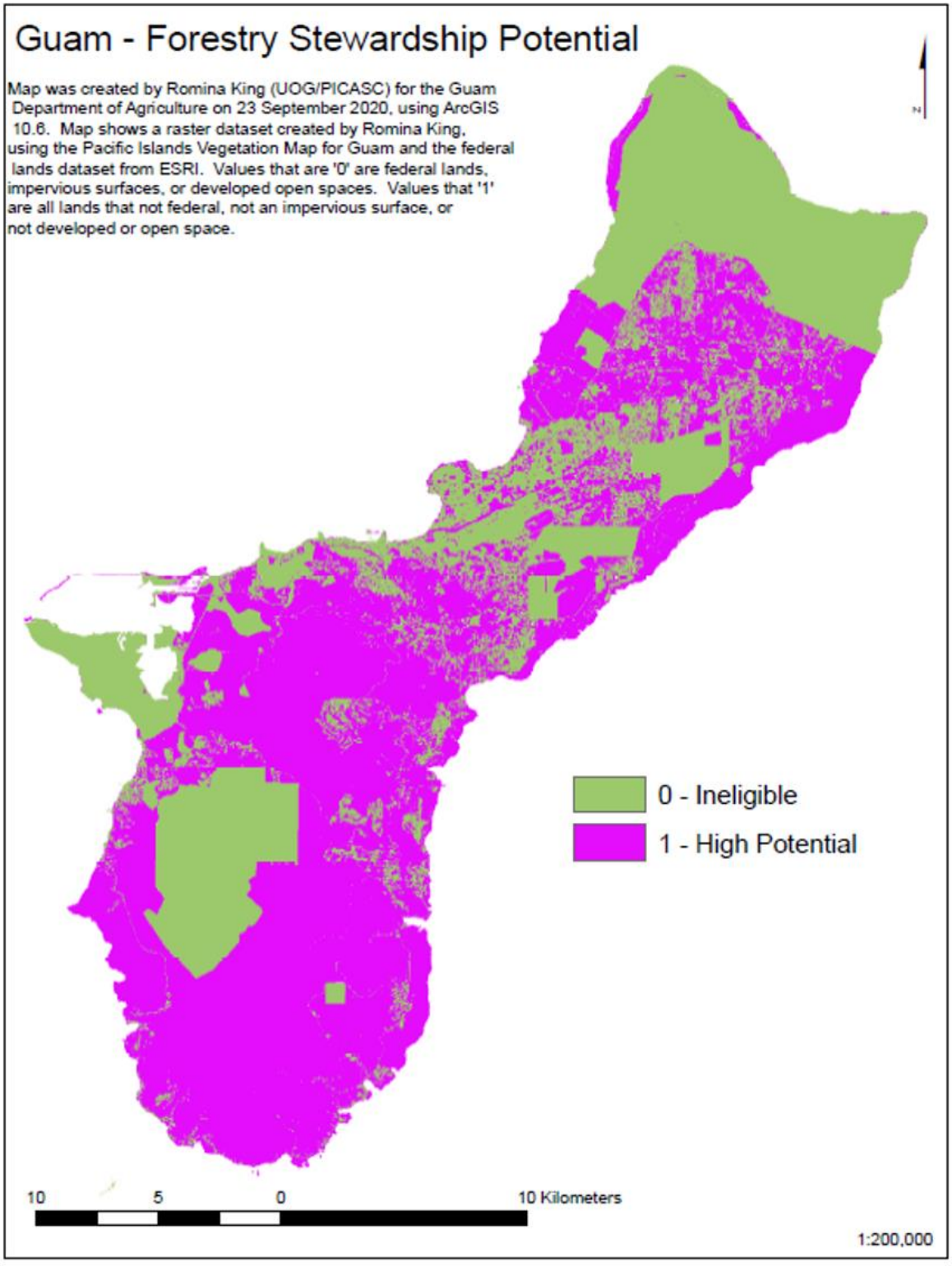

Figure 2. Guam Forestry Stewardship Potential Map

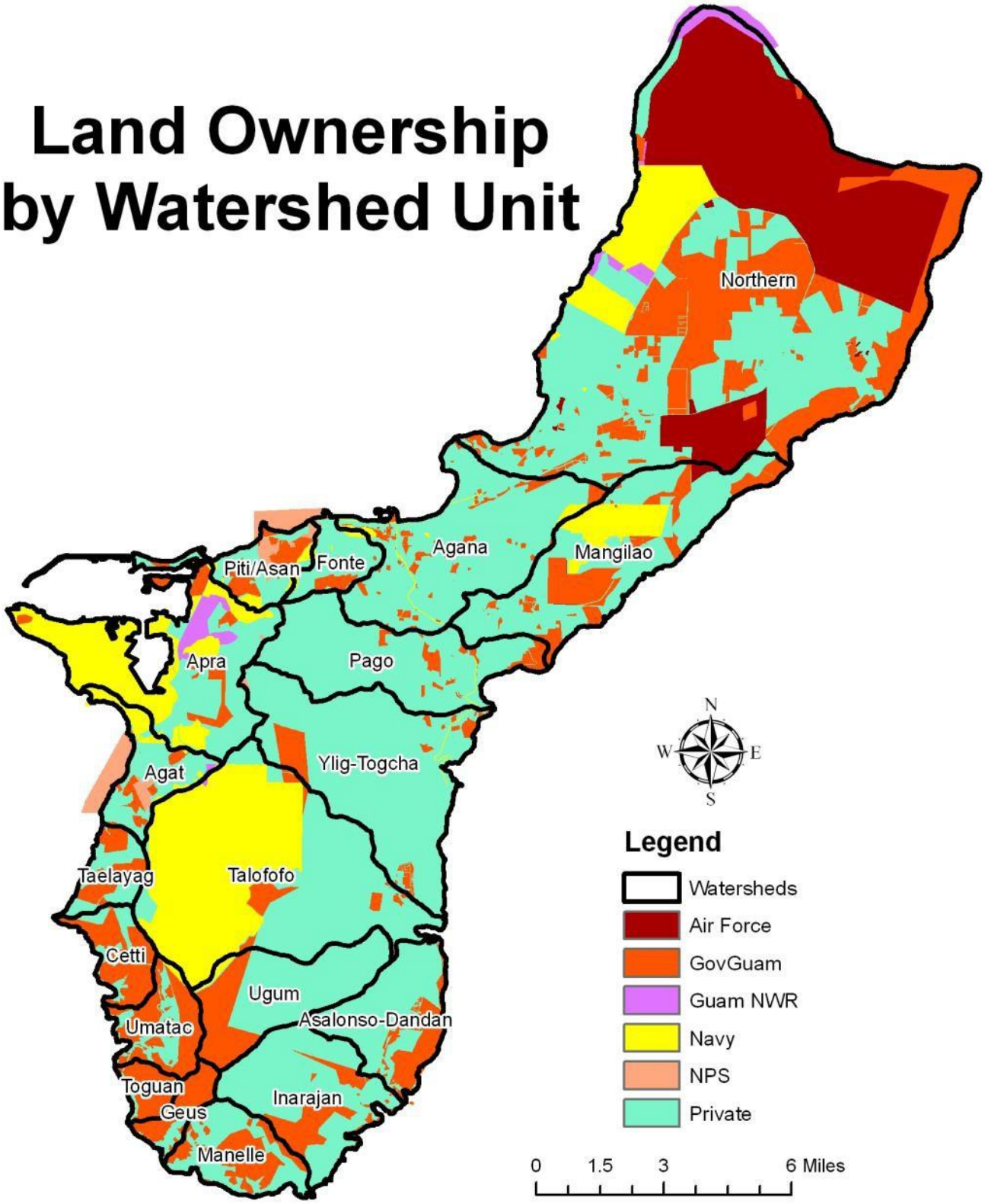

Figure 3. Land ownership distribution on Guam by watershed unit., 2010 SWARS.

Vegetation Maps

This section provides an overview of the geospatial data used to estimate vegetation coverage of Guam from 2005 to the present.

Background of Vegetation Mapping using Satellite imagery on Guam

In 2005, the island's vegetation map was created using IKONOS and Quickbird imagery of Guam by the U.S. Forest Service.[15] In 2009 the National Oceanic and Atmospheric Administration (NOAA) produced general landcover maps of the Marianas Islands (including Guam, using Quickbird imagery as part of their Coastal Change Analysis Program (CCAP). NOAA has CCAP landcover data for Guam for 2005, 2011, and 2016. In 2014, the Forest Service and NOAA teamed up on an updated classification of Guam using 2012 Worldview 2 imagery.

In 2016, Amidon et al (2017) augmented the 2014 Pacific Islands Vegetation Map from the USDA Forest service. They used a composite of three satellite images, consisting of World View 3 (19 January 2016 & 16 August 2017), World View 2 (09 June 2017); a high-resolution digital elevation model (DEM) and a digital surface model (DSM) derived from the 2011 LIDAR dataset (Amidon et al. 2017). Amidon et al. (2017) focused on delineating vegetation types, such as Vitex, Bamboo, Hibiscus, to update the 2014 Pacific Islands Vegetation Map. Due to a lack of field survey data, Amidon et al. (2017) were unable to ground truth their classification scheme and instead, conducted a visual accuracy assessment using pan-sharpened satellite imagery. Amidon et al. (2017) also provided a useful table outlining the relationships between USDA Forest Service and NOAA CCAP landcover classifications

Stakeholders

The detailed vegetation map of Guam by Liu & Fischer (2006) was used to identify broad stakeholder issues (Figure 31). Liu & Fischer (2006) co-developed this map (Figure 31). with USDA Forest Service and used IKONOS imagery from 2003-2004, as well as field data collected in June 2004 and March 2005. Categories of vegetation display include: limestone forest, ravine forest, scrub forest, acacia plantation, *Casuarina* thicket (ironwood stands), palma brava grove, *Leucaena* stand (tangantangan), coconut plantation, wetland, savanna complex, strand vegetation, agricultural field, urban cultivated, urban build-up, water, and barren areas (Figure 31). The following categories were not included: badland, mangrove swamp, marsh land, other shrub/grass, sand beach/bare rocks (Figure 31).

[15] (Liu and Fischer 2006)

Stakeholders expressed that they wished to see additional subcategories of forest, particularly, vitex and bamboo. The Guam Department of Agriculture will share a modified version of Amidon et al. (2017)'s detailed vegetation map (Figure 7) with stakeholders. Figure 7 will replace Figure 31. Dr. Romina King, from the Pacific Islands Climate Science Center will be providing geospatial analysis support and is currently doing a land change analysis between 2006, 2014, and 2017 vegetation maps. Preliminary results have been included in this document.

Updated vegetation delineation for the island of Guam based on 2016 WorldView 2 imagery and the 2014 Forest Service/NOAA vegetation map of the island includes general (Figure 6) and detailed (Figure 7) vegetation categories which are cross-referenced with landcover categories for NOAA's CCAP classification and the Forest Service's assessment of Guam (Table 2).

Table 2. Vegetation and Landcover mapping categories used in 2016 Guam Vegetation Map and relationships to 2005, 2011, & 2016 NOAA CCAP and the 2006 USDA Forest Service land classification schemes. Reprinted from Amidon et al. (2017)

General 2016	Detailed 2016	NOAA CCAP (2005, 2011, & 2016)	USDA Forest Service 2006
Developed	Developed	Developed, High, Medium, and Low Intensity	Urban and Built-up
	Developed Vegetation	Developed, Open Space	Urban Vegetation/Urban Cultivated
	Agriculture	Cultivated Crops	Cropland/Agriculture Field
Barren	Bare Rock	Barren Land	Barren/Sandy Beach/Bare Rocks/Bad Land
	Bare Soil/Gravel		Barren/Sandy Beach/Bare Rocks
	Sand	Unconsolidated Shore	
Grass/Herbaceous	Mixed Grass/Herbaceous	Grassland/Herbaceous	Other Shrub and Grass
	Grassland		Savanna Complex
Scrub/shrub	Coastal Scrub	Scrub/Shrub	Strand/Strand Vegetation
	Scrub/Shrub		Other Shrub and Grass
Forest	Bamboo Thicket	Evergreen Forest, Palustrine Forested, Scrub/Shrub Wetland	Mixed Introduced Forest
	Hibiscus Thicket		(Native) Limestone Forest, Ravine Forest
	Leucaena Thicket	Evergreen Forest	*Leucaena Leucocephala/Leucaena* Stand
	Acacia Forest		Mixed Introduced Forest/Acacia Plantation
	Casuarina Forest		Casuarina Thicket
	Coconut Forest		Agroforest - Coconut/Coconut Plantation
	Vitex Forest		Mixed Introduced Forest
	Mixed Introduced Forest		Mixed Introduced Forest/Scrub Forest
	Native Limestone Forest		(Native) Limestone Forest
	Native Volcanic Forest	Evergreen Forest, Palustrine Forested, Scrub/Shrub Wetland	Ravine Forest
Wetlands/Water	Emergent Wetland	Palustrine, Estuarine Emergent Wetland	Wetland/Marsh Land
	Mangrove Wetland	Estuarine Forested, Scrub/Shrub Wetland	Mangrove Swamp
	Open Water	Open Water	Water

GFAP Vegetation Map

Description of Forests and Vegetation Types

According to the 2014 Guam Pacific Islands Vegetation Map[16] (Guam PIVM), approximately 41% of the area on Guam has tree cover, either recognized as forest types or as individual tree fragments; 19% is developed or mixed-use areas; 18% of the landscape is in non-forest vegetation community types; 9% are cultivated crops and unconsolidated shore; 3% are wetland vegetation communities; and 2% is identified as bare ground (Table 3). The 2014 Guam PIVM has detailed landcover data classified using a NOAA CCAP scheme as well as PIMV scheme (Figure 5 and Table 3). Table 3 displays the 2014 Guam PIVM detailed land cover, using the NOAA CCAP classification scheme and respective areas. Based on guidance from Department of Agriculture, these categories were aggregated into general subcategories (Table 4) and mapped (Figure 4).

Table 3: Area (sq km) of detailed landcover categories of the 2014 Pacific Island Vegetation map of Guam.

Landcover Category 2014	Area (sqkm)	Percentage (%)
Bare Land	11.22	1.88
Developed, Open Space	58.90	9.89
Impervious	52.55	8.83
Estuarine Emergent Wetland	0.03	0.00
Estuarine Forested Wetland	0.48	0.08
Estuarine Scrub/Shrub Wetland	0.27	0.05
Palustrine Aquatic Bed	0.01	0.00
Palustrine Emergent Wetland	3.92	0.66
Palustrine Forested Wetland	9.73	1.63
Palustrine Scrub/Shrub Wetland	1.90	0.32
Evergreen Forest	246.50	41.41
Scrub/Shrub	46.82	7.86
Grassland/Herbaceous	107.57	18.07
Pasture/Hay	0.11	0.02
Cultivated Crops	2.36	0.40
Unconsolidated Shore	0.16	0.03
Open Water	52.78	8.87

[16] https://www.fs.usda.gov/internet/FSE_DOCUMENTS/stelprd3821659.zim

Table 4: Area (sq km) of General Landcover Categories of the 2014 Pacific Island Vegetation map of Guam

Landcover (Detailed) - 2014	Landcover (General) -2014	Area (sq km)	Percentage (%)
Bare Land	Bare Land	11.22	1.88
Developed, Open Space	Developed Land	111.46	18.72
Impervious			
Estuarine Emergent Wetland	Wetlands	16.33	2.74
Estuarine Forested Wetland			
Estuarine Scrub/Shrub Wetland			
Palustrine Aquatic Bed			
Palustrine Emergent Wetland			
Palustrine Forested Wetland			
Palustrine Scrub/Shrub Wetland			
Evergreen Forest	Forest	246.50	41.41
Scrub/Shrub	Shrub and Grassland	154.50	25.95
Grassland/Herbaceous			
Pasture/Hay			
Cultivated Crops	Other	2.52	0.42
Unconsolidated Shore			
Open Water	Open Water	52.78	8.87

According to the 2014 Guam PIVM, approximately 41% of Guam is forested (246.5 sq km); 26% is shrub and grassland (154.50 sq km); 19% is developed land (111.46 sq km); 2% is bare land (11.22 sq km), 3% are wetlands (16.33 sq km); less than 1% is cultivated crops and unconsolidated shore (2.52 sq m); and 9% is open water (52.78 sq. km) (Table 4 and Figure 4).

The 2016 general landcover scheme is slightly different from the 2014 PIVM. Thus, slight modifications were made and the 2016 general landcover was customized to match the general landcover categories for 2014. In order to compare the two datasets, some of the 2016 detailed categories had to be regrouped into the appropriate general landcover, to be consistent with 2014 (Table 5). Nomenclature shifted between 2014 and 2016 when referencing ironwood (*Casuarina)* and *tangantangan* (*Leucaena)* vegetation landcover. The 2014 classifications reference "Ironwood" and "Tangantangan" whereas the 2016 classifications list ironwood and tangantangan as, "*Casuarina*" and "*Leucaena*", respectively.

Table 5: 2014 Detailed and General Landcover as it relates to 2016 Detailed and General Landcover classifications.

Landcover (Detailed) 2014	Landcover (General) 2014	Landcover (General) 2016	Landcover (Detailed) 2016
Bare Land	Bare Land	Bare Land	Bare Rock
			Bare Soil/Gravel
Developed, Open Space	Developed Land	Developed Land	Developed
Impervious			Developed Vegetation
Estuarine Emergent Wetland	Wetlands	Wetlands	Emergent Wetland
Estuarine Forested Wetland			
Estuarine Scrub/Shrub Wetland			
Palustrine Aquatic Bed			
Palustrine Emergent Wetland			Mangrove Wetland
Palustrine Forested Wetland			
Palustrine Scrub/Shrub Wetland			
Evergreen Forest	Forest	Forest	Bamboo Thicket
			Hibiscus Thicket
Scrub			*Leucaena* Thicket
Limestone Primary			*Acacia* Forest
Ravine			*Casuarina* Forest
Tangantangan[17]			Coconut Forest
Coconut Plantation & Remnants			Vitex Forest
Acacia Plantation			Mixed Introduced Forest
Ironwood Stand[18]			Native Limestone Forest
			Native Volcanic Forest
Scrub/Shrub	Shrub and Grassland	Shrub and Grassland	Mixed Grass/Herbaceous
Grassland/Herbaceous			Grassland
Pasture/Hay			Coastal Scrub
			Scrub/Shrub
Cultivated Crops	Other	Other	Agriculture
Unconsolidated Shore			Sand
Open Water	Open Water	Open Water	Open Water

[17] 2014 vegetation figures and tables reference "*Tangantangan*" whereas 2016 vegetation figures and tables reference *tangantangan* by the genus, "*Leucaena spp.*".
[18] 2014 vegetation figures and tables reference "Ironwood" whereas 2016 vegetation figures and tables reference ironwood by the genus *"Casuarina".*

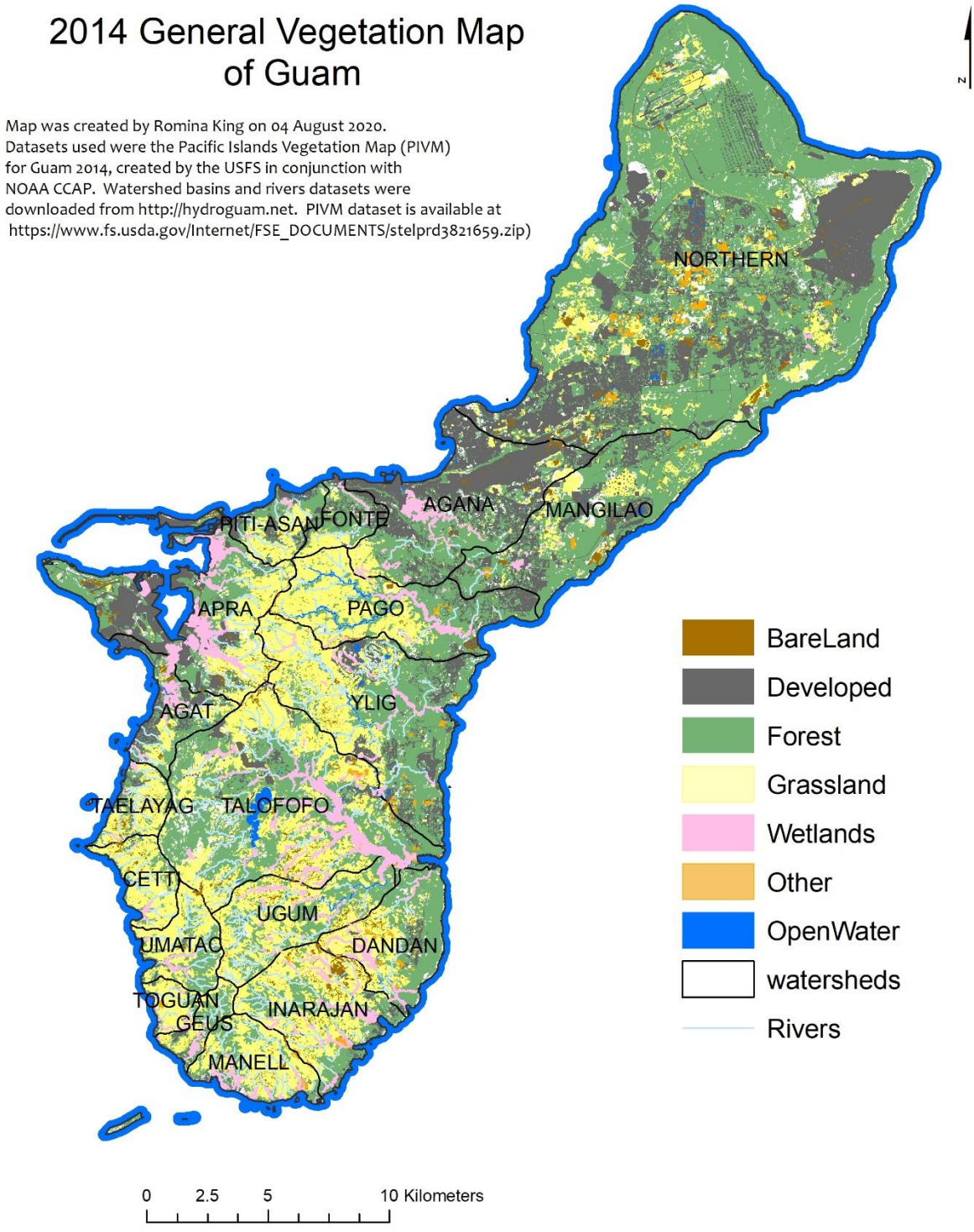

Figure 4: 2014 General Vegetation Map of Guam

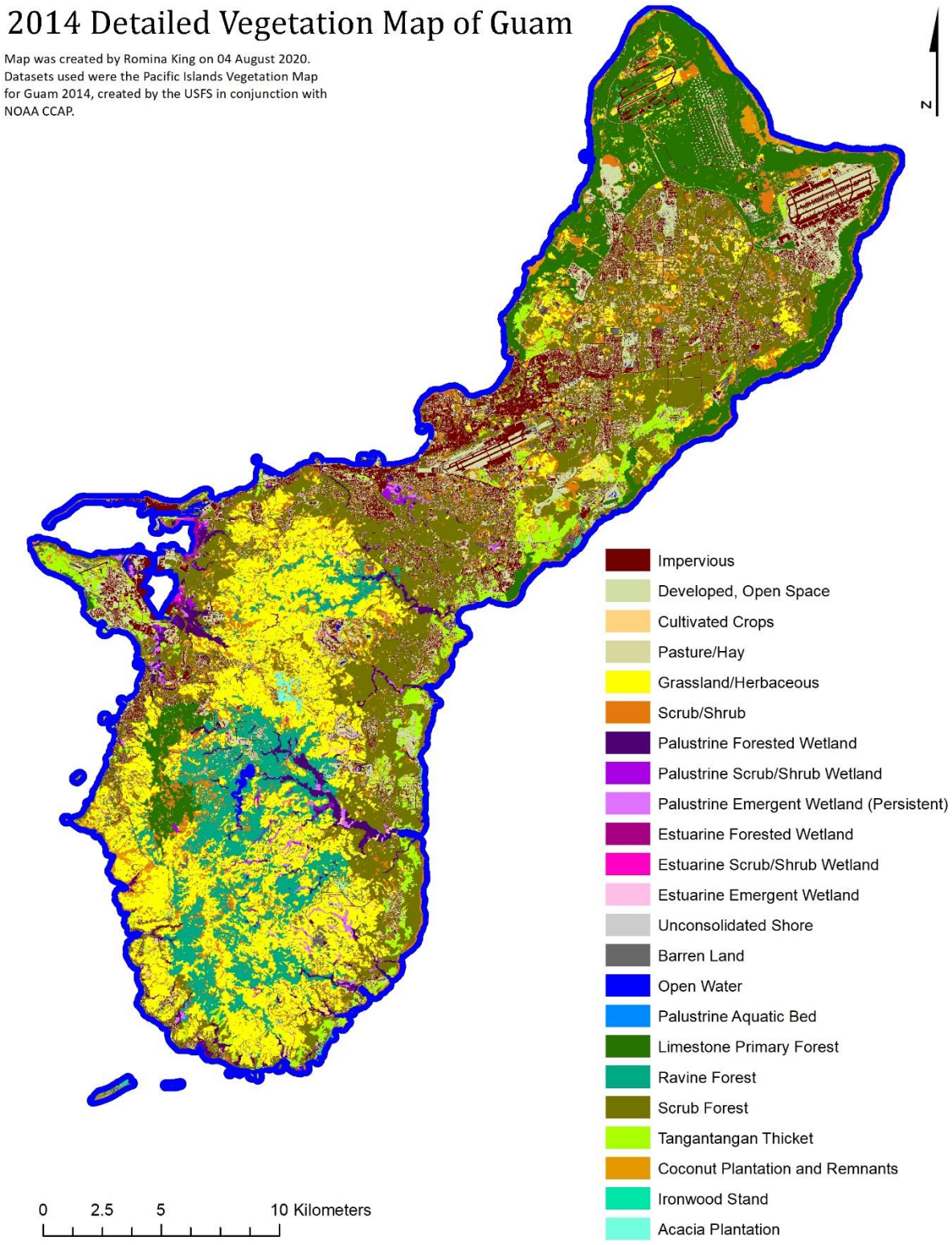

Figure 5. 2014 Detailed Vegetation Map of Guam.

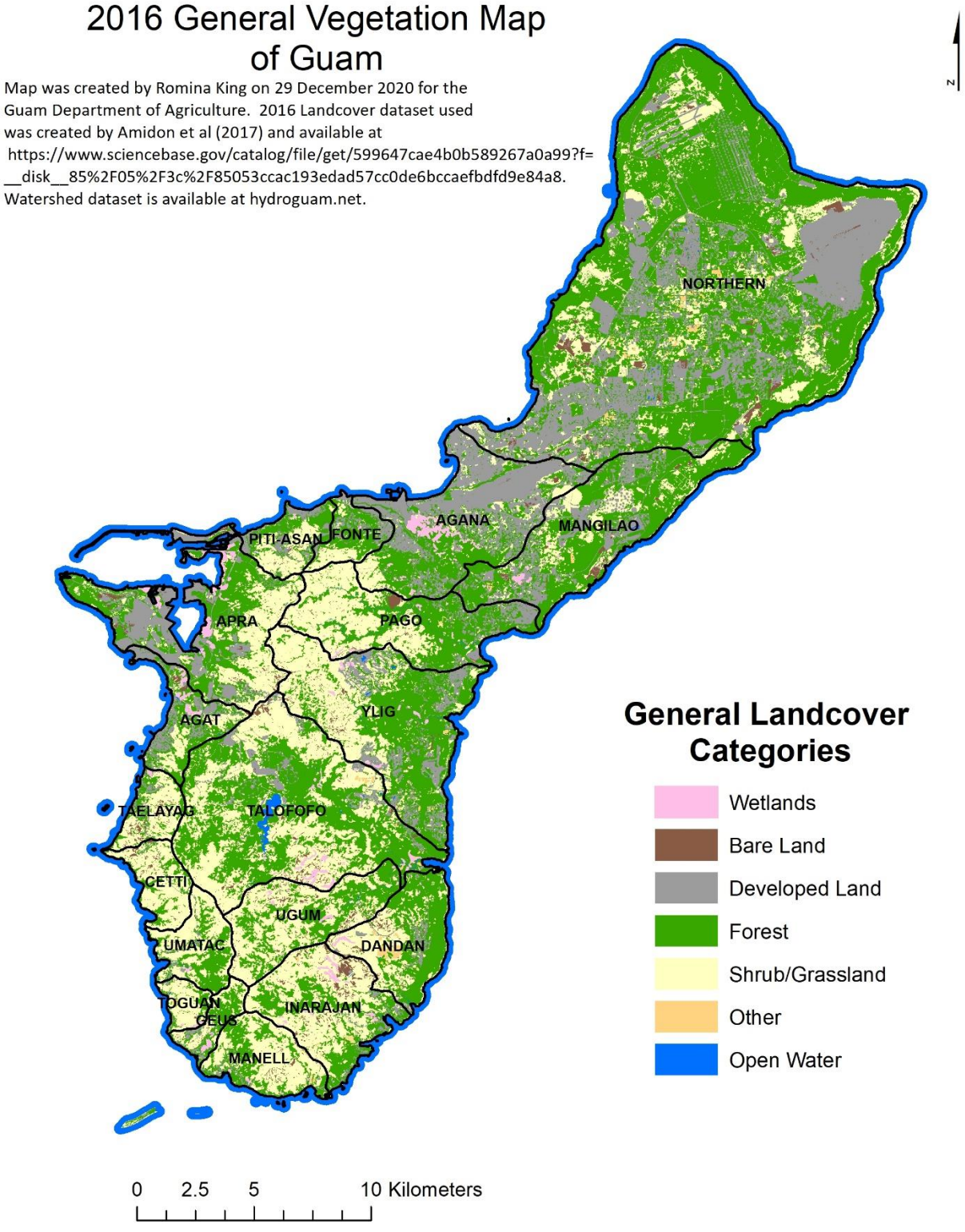

Figure 6. 2016 General Vegetation Map of Guam.

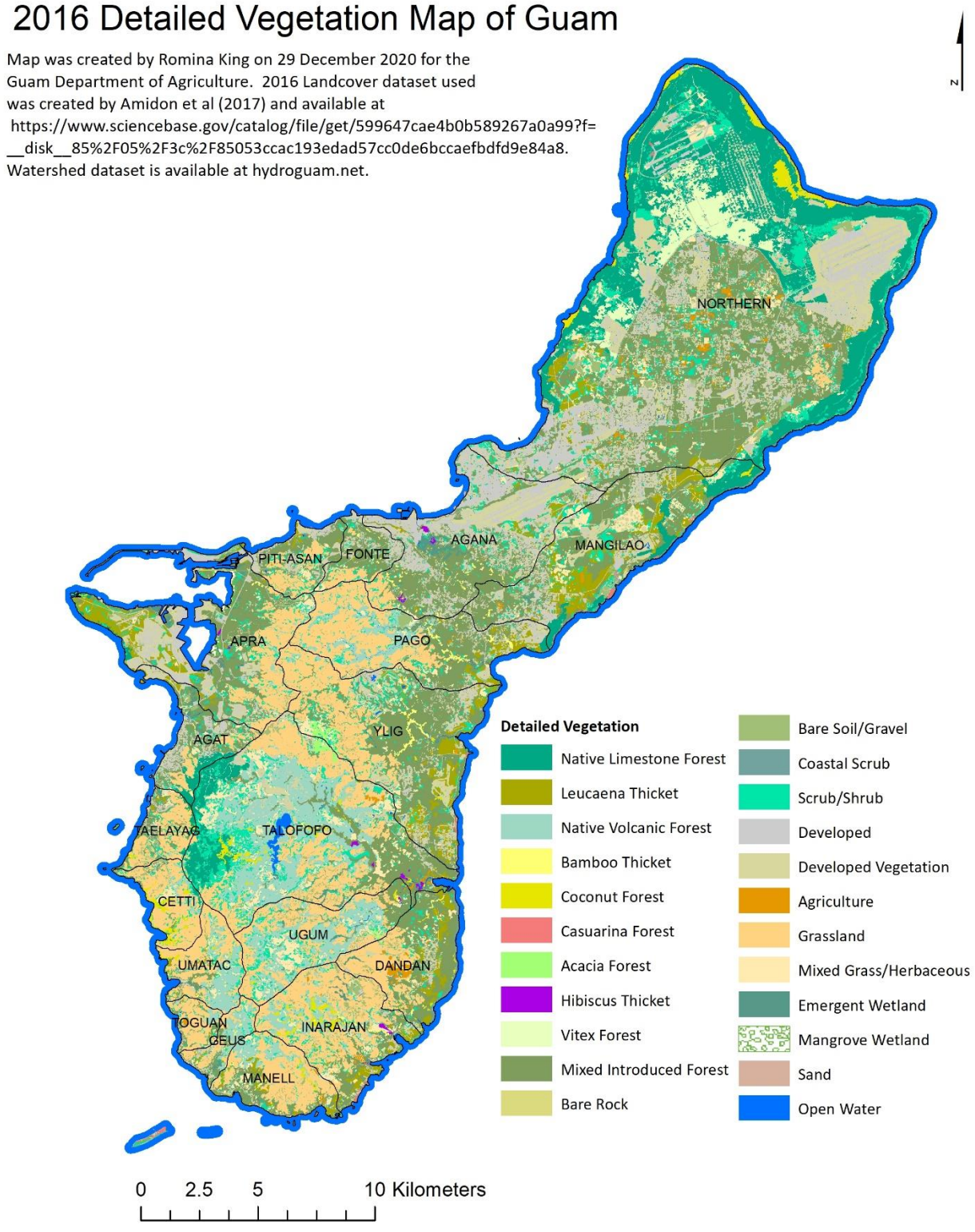

Figure 7. 2016 Detailed Vegetation Map of Guam.

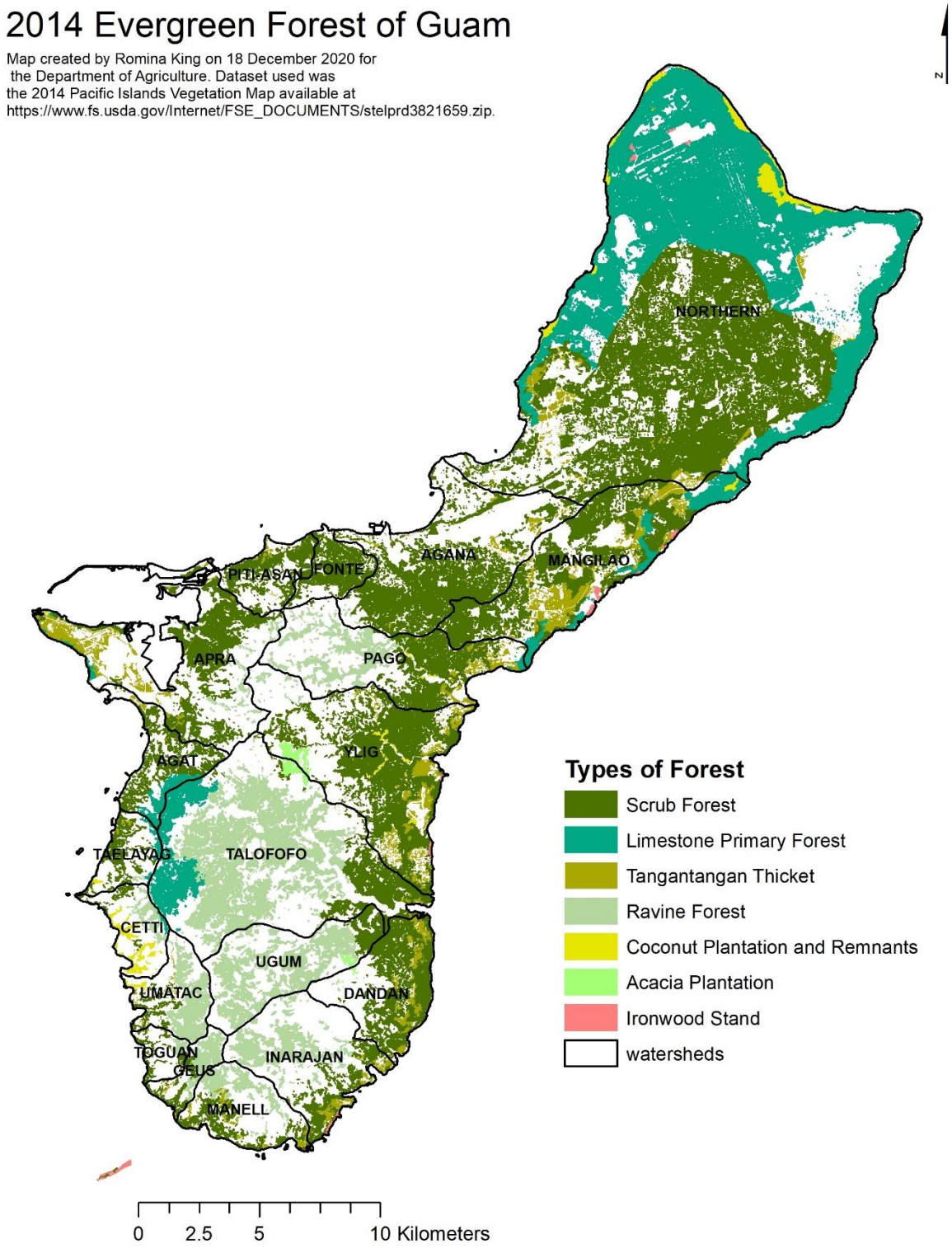

Figure 8. 2014 Forest of Guam.

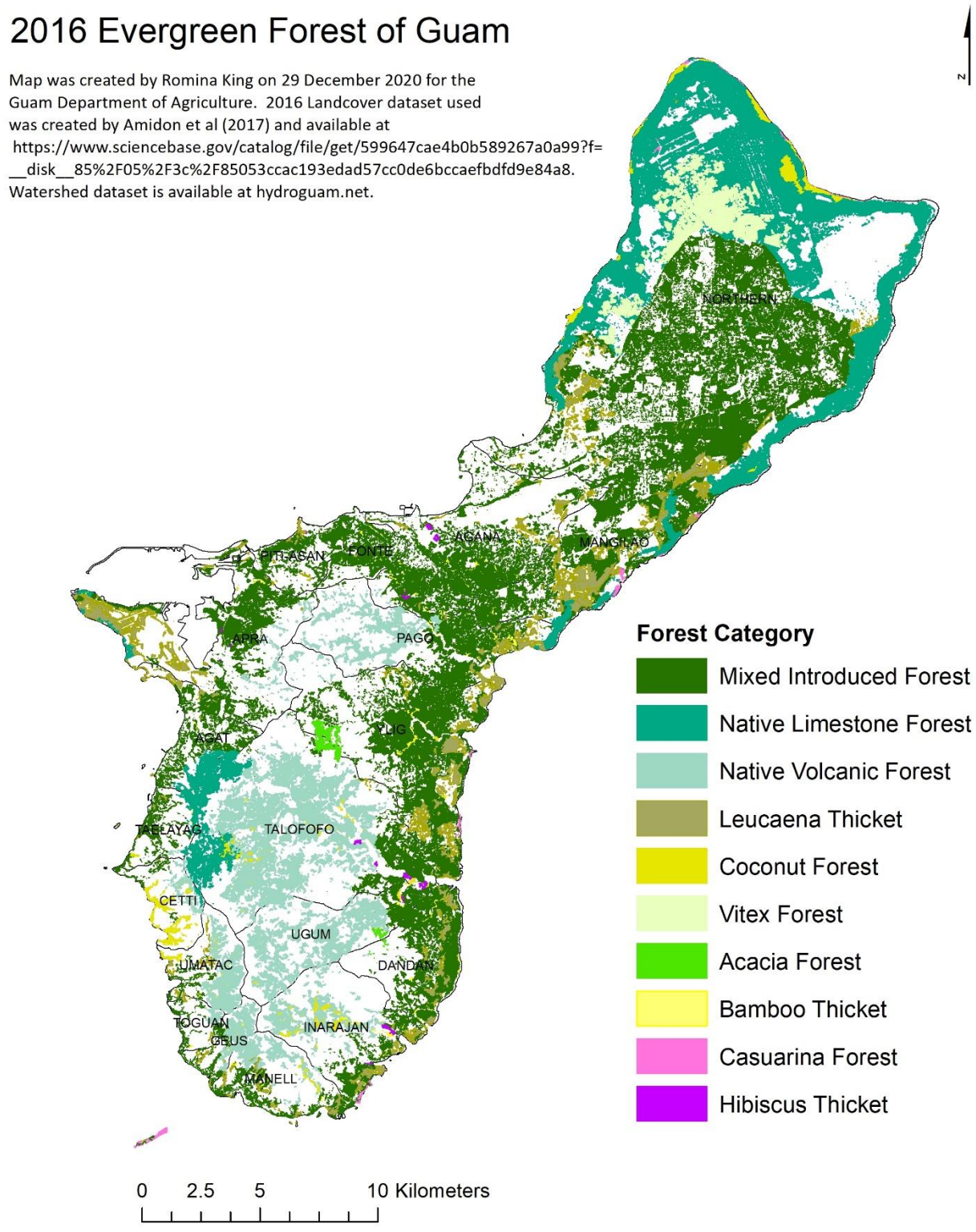

Figure 9. 2016 Forest of Guam.

Change in Forested Communities (2014 vs 2016)

Figure 9 provides the most current available detailed classification of Guam's Evergreen Forest, showcasing the subcategories of native limestone primary, scrub forest, *tangantangan*[19], ravine forest, coconut plantation, acacia plantation, and ironwood stands.[20] Areas for each of these evergreen subcategories are estimated in Table 6. Total forest cover for Guam in 2016 is estimated to be 240 sq km (Table 6). Figure 8 depicts Guam's evergreen forest in 2014. There is approximately 6.39 sq km less evergreen forest in 2016 than 2014 (Table 6). For each forest category, percentage change was calculated in the final column of Table 6. There were positive percentage gains (depicted in green) in scrub forest (+4.6); very minor gains in *tangantangan* (*Leucaena*) (.01), coconut (.9), acacia (.02), and ironwood (*Casuarina*) (Table 6). There were decreases in native limestone forest (-4.42%) and native volcanic forest (-1.1%).

Table 6. General comparison of 2016 and 2014 areas of the subcategories of 'evergreen' forest on Guam.

Amidon et al. 2016				Guam PIVM -2014			Change (%)
Forest Type	**Area (sq km)**	**Percentage (%)**	**Percentage (%)**	**Forest Type**	**Area (sq km)**	**Percentage (%)**	
Mixed Introduced Forest (Scrub)	115.32	48.04	52.5	Scrub	118.05	47.9	4.6
Vitex Forest	9.07	3.78					
Bamboo Thicket	1.19	0.49					
Hibiscus Thicket	0.46	0.19					
Native Limestone Forest	52.52	21.88	21.88	Limestone Primary	64.81	26.3	-4.42
Native Volcanic Forest	34.71	14.46	14.46	Ravine	38.37	15.57	-1.11
Leucaena Thicket	19.89	8.28	8.28	Tangantangan	20.38	8.27	0.01
Coconut Forest	5.44	2.27	2.27	Coconut Plantation & Remnants	3.37	1.37	0.9
Acacia Forest	0.88	0.37	0.37	Acacia Plantation	0.87	0.35	0.02
Casuarina Forest	0.59	0.25	0.25	Ironwood Stand	0.6	0.24	0.01
Total	240.06				246.45		

[19] 2014 vegetation figures and tables reference "Tangantangan" whereas 2016 vegetation figures and tables reference tangantangan by the genus, "*Leucaena spp.*".
[20] 2014 vegetation figures and tables reference "Ironwood" whereas 2016 vegetation figures and tables reference ironwood by the genus *"Casuarina".*

Mixed forests are moderately dense, with a collection of understory shrub, vine and fern species, along with germinating and young trees. Forest types are relegated to ravines, sheltered depressions and river drainages in southern Guam, and on limestone soils in northern Guam. Major species include *Pandanus tectorius*, *P. dubius, Ficus prolixa, Phyllanthus mariannensis, Areca catechu, Premna serratifolia, Cocos nucifera*, and in some areas, *Artocarpus mariannensis, Cananga odorata, Ochrosia oppositifolia, Ochrosia mariannensis, Calophyllum inophyllum, Hernandia labyrinthica, Vitex parviflora, Spathodea campanulata, Tabebuia* species and *Bambusa vulgaris*. Species richness drops toward the forest edges as this forest type transitions out of ravines and into upland savanna or grassland environments.

- **Secondary Forest.** Lower edges of slopes above forested valleys and ravines that generally have a border of thickets of native and introduced woody species. These secondary forests are composed of dense, low-stature thickets with low species diversity, or are composed of a single species. This community contains both thickets dominated by the introduced *Leucaena leucocephala* and thickets of the native Hibiscus *tilliaceus*. Areas dominated by *Pandanus tectorius* (*P. fragrans*), and bamboo, common at forest edges may be included in this mapping unit.

For purposes of the 2014 and 2016 General Vegetation Maps of Guam, forest environments consolidated as 'forest' (Table 5).

Non-Forest Communities

The non-forest communities in 2016 Detailed Vegetation Map of Guam (Figure 7) are further elaborated below:

- **Savanna Communities with Trees:** Savanna lands with mid- to tall structure grasses and scattered tree species. *Pandanus tectorius, Casuarina equisetifolia,* and *Cerbera odollam* may be present.

- **Savanna with Shrub Component:** Savanna with scattered, generally short-stature native shrubs. The most abundant shrub is *Scaevola taccada*, with the endemic *Phyllanthus mariannensis*, *Timonius nitidus* and *Myrtella bennigseniana*; *Wikstroemia elliptica* and *Geniostoma rupestre* may also be found in this association. This complex is notable as the habitat for the endangered savanna species, *Phyllanthus saffordii* and *Hedyotis megalantha.* In some locations, the endangered shrub *Eugenia bryanii* may be present.

- **Savanna with Low Grass:** Mostly open savanna types as described above

with little tree cover. Mid- to low-grass structures dominate. *Dimeria chloridiformis* is a short statured (< 0.5 m) endemic soft low-growing bunch grass covered with silvery hairs. *Dimeria* grows in scattered clumps and is often mixed with other species complex occurs within low-grass savanna areas which are often associated with rare and listed savanna species making the management and protection of these areas essential for the recovery of rare and listed species.

- **Eroded Savanna:** Low grass structures and bare soils are interspersed with "clusters" of other savanna types. Expansion of native vegetation from clusters to bare soil areas will require focused soil improvement treatments. Areas of unusually high species diversity can be found in these "clusters" and offer good sources for propagating and direct expansion of native vegetation into neighboring types. Endangered savanna plant species are often found at the edges of eroded areas; *Phyllanthus saffordii* particularly seems to colonize the areas immediately adjacent to badland scars.

- **Tall Grass:** This community type is dominated by tall grasses, especially the native *Miscanthus floridulus*, a 2-3m tall, flammable coarse cane-like grass called *neti* or swordgrass. Also, in moist communities, this type also contains *Phragmites* marshes; these types are generally monospecific dense patches of *Phragmites karka*, a 2-5m tall grass growing densely in moist depressions (seeps, springs) and along shallow waterways in open areas.

- **Mixed Grass:** Mixed grass communities are dominated by low to medium stature (generally <1m tall) grasses such as the introduced *Pennisetum* spp., *Paspalum* spp., and *Dichanthium bladhii*. *Pennisetum* generally grows admixed with other grasses, sedges and shrubs, while *Dichanthium bladhii* forms extensive, dense, almost monospecific stands on upper slopes. Some fern and herb species (e.g., *Stachytarpheta jamaicensis*, *Hyptis capitata*) also occur within the grass community. *Dimeria* grasslands are also included in this type. *Dimeria* grows in scattered clumps and is often mixed with other species such as the native *Lycopodium cernuum*, *Miscanthus*, and invasive *Pennisetum* spp. *Dimeria* favors level to gently rolling terrain and often occurs with other grasses on slopes. *Dimeria* meadows generally occur on more level ground where erosion is not as high and where there may be some relief from fire; in areas with frequent wildfires, *Dimeria* meadows seem to be replaced by *Dichanthium*.

Other Cover Types

Cover types that did not focus on vegetation profiles are included in the 2016 General Vegetation Map of Guam (Figure 6 and Table 4). These types included bare ground, developed lands, open water, etc. Significant types are described below:

- **Bare Ground.** Areas designated as Badlands were used to characterize exposed soils on the landscape. These are typified by mostly bare soil, with exposed C-horizon, saprolite or hard bedrock and very little vegetation. Some areas have early successional vegetation, principally *Gleichenia* and *Lycopodium cernuum*. Vegetation occurring on erosion scars of red soils differs somewhat from those on grey soils. This classification was also used to identify signatures of exposed soils between trees, grasses, and other classifications.

- **Development.** Areas of development were estimated to be 18.72% of total land area (Table 4).

- **Other Types:** Open water and other designations with low confidence were consolidated. Few instances were lumped into this category.

Characterization of Vegetation According to Watershed

The major watersheds of Guam were divided into three groups: western, eastern, and northern regions to capture the major changes in soils and topography (Table 7). The western and eastern watersheds are mostly relegated to southern Guam. Further discussion on the delineation of watersheds and watershed groups is described in the *Watersheds on Guam* section. Using 2016 General Landcover geospatial dataset of Amidon et al. (2017) (Figure 6), areas of each category were calculated for each watershed and graphed as percentages of total area of the watershed (Figure 10).

Most developed areas fall in the Northern Region (Northern, Agana, and Mangilao) and least amount of development occurs in the western and eastern watersheds (Table 7). Non-forested cover is mostly found within the western and eastern watersheds of southern Guam; on average, these watersheds have 45% of the land area in non-forested cover (Table 7).

Developed cover types were predominantly found in the northern watersheds, and the western watersheds beginning in Agat and extending to the North and Ylig in the East. Overall, between 20% and 50% of the land area within these watersheds are developed (Table 7, Figure 10).

The highest proportions of forest lands were found in the Northern, Mangilao, and Talofofo watersheds; combined these three watersheds contain 59% of all the forest cover of Guam (Table 7, Figure 10). This is of particular importance as they also contain the majority of the proposed military buildup lands (see *Threats to Forests from the Military Build-up* p74).

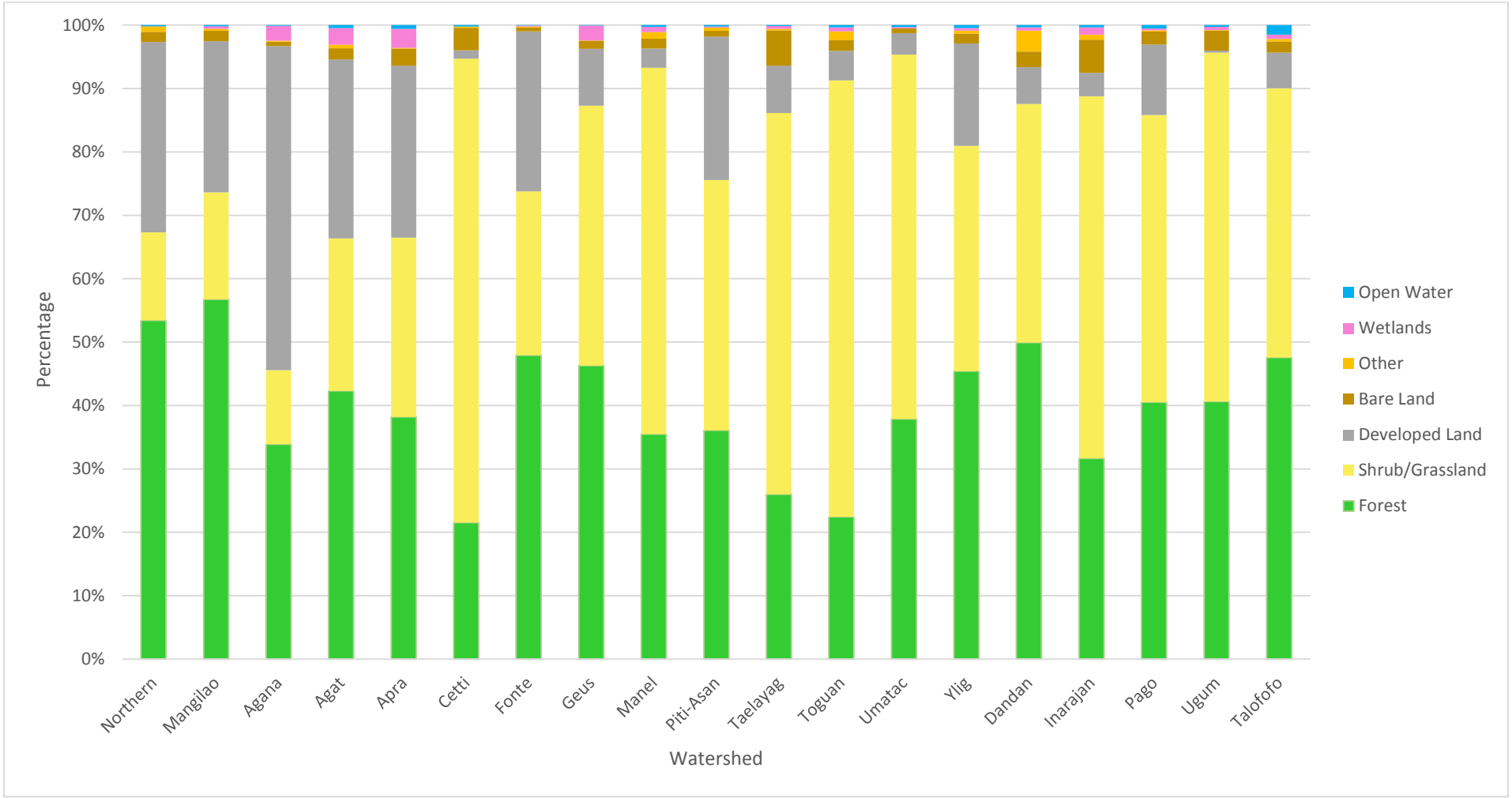

Figure 10. Bar graph showing the 2016 percentage of area landcover within each watershed. Data depicted in the graph are derived from the geospatial dataset of Amidon et al. (2017).

Table 7: Area of general landcover within each watershed. Dataset used is from Amidon et al. (2017)

Region	Watershed	Landcover General 2016	Area (sqkm)	Percentage
Northern	MANGILAO	Bare Land	0.57	2%
		Developed Land	8.47	24%
		Forest	20.14	57%
		Open Water	0.07	0%
		Other	0.12	0%
		Shrub/Grassland	6.00	17%
		Wetlands	0.13	0%
	NORTHERN	Bare Land	2.84	2%
		Developed Land	54.67	30%
		Forest	97.22	53%
		Open Water	0.33	0%
		Other	1.61	1%
		Shrub/Grassland	25.29	14%
		Wetlands	0.02	0%
	AGANA	Bare Land	0.24	1%
		Developed Land	18.04	51%
		Forest	11.95	34%
		Open Water	0.03	0%
		Other	0.06	0%
		Shrub/Grassland	4.12	12%
		Wetlands	0.84	2%
Western	AGAT	Bare Land	0.18	2%
		Developed Land	2.88	28%
		Forest	4.32	42%
		Open Water	0.05	0%
		Other	0.05	1%

		Shrub/Grassland	2.46	24%
		Wetlands	0.27	3%
	APRA	Bare Land	0.92	3%
		Developed Land	9.10	27%
		Forest	12.84	38%
		Open Water	0.19	1%
		Other	0.04	0%
		Shrub/Grassland	9.50	28%
		Wetlands	1.00	3%
	CETTI	Bare Land	0.28	4%
		Developed Land	0.10	1%
		Forest	1.68	22%
		Open Water	0.02	0%
		Other	0.01	0%
		Shrub/Grassland	5.72	73%
	FONTE	Bare Land	0.04	1%
		Developed Land	1.61	25%
		Forest	3.05	48%
		Open Water	0.00	0%
		Other	0.01	0%
		Shrub/Grassland	1.65	26%
		Wetlands	0.01	0%
	GEUS	Bare Land	0.06	1%
		Developed Land	0.41	9%
		Forest	2.10	46%
		Open Water	0.00	0%
		Other	0.00	0%
		Shrub/Grassland	1.86	41%
		Wetlands	0.11	2%

		Bare Land	0.20	2%
		Developed Land	0.38	3%
		Forest	4.48	35%
	MANELL	Open Water	0.03	0%
		Other	0.13	1%
		Shrub/Grassland	7.29	58%
		Wetlands	0.11	1%
		Bare Land	0.07	1%
		Developed Land	1.83	23%
		Forest	2.91	36%
	PITI-ASAN	Open Water	0.02	0%
		Other	0.04	1%
		Shrub/Grassland	3.18	39%
		Wetlands	0.01	0%
		Bare Land	0.37	6%
		Developed Land	0.50	7%
		Forest	1.73	26%
	TAELAYAG	Open Water	0.01	0%
		Other	0.02	0%
		Shrub/Grassland	4.01	60%
		Wetlands	0.03	0%
		Bare Land	0.06	2%
		Developed Land	0.17	5%
		Forest	0.82	22%
	TOGUAN	Open Water	0.01	0%
		Other	0.05	1%
		Shrub/Grassland	2.52	69%
		Wetlands	0.02	1%
	UMATAC	Bare Land	0.07	1%

		Developed Land	0.33	3%
		Forest	3.75	38%
		Open Water	0.03	0%
		Shrub/Grassland	5.69	57%
		Wetlands	0.02	0%
Eastern	YLIG	Bare Land	0.64	2%
		Developed Land	6.58	16%
		Forest	18.50	45%
		Open Water	0.19	0%
		Other	0.19	0%
		Shrub/Grassland	14.48	36%
		Wetlands	0.17	0%
	DANDAN	Bare Land	0.42	2%
		Developed Land	0.98	6%
		Forest	8.45	50%
		Open Water	0.06	0%
		Other	0.56	3%
		Shrub/Grassland	6.37	38%
		Wetlands	0.09	1%
	INARAJAN	Bare Land	1.18	5%
		Developed Land	0.83	4%
		Forest	7.13	32%
		Open Water	0.08	0%
		Other	0.19	1%
		Shrub/Grassland	12.87	57%
		Wetlands	0.26	1%
	PAGO	Bare Land	0.54	2%
		Developed Land	3.01	11%
		Forest	10.96	41%

		Open Water	0.15	1%
		Other	0.05	0%
		Shrub/Grassland	12.26	45%
		Wetlands	0.08	0%
	UGUM	Bare Land	0.62	3%
		Developed Land	0.06	0%
		Forest	7.97	41%
		Open Water	0.05	0%
		Other	0.02	0%
		Shrub/Grassland	10.81	55%
		Wetlands	0.10	1%
	TALOFOFO	Bare Land	1.06	2%
		Developed Land	3.41	6%
		Forest	28.91	48%
		Open Water	0.91	1%
		Other	0.26	0%
		Shrub/Grassland	25.81	42%
		Wetlands	0.41	1%

Forest Inventory Analysis (FIA)

The information presented in this section is drawn from a forest inventory analysis (FIA) conducted by the U.S. Forest Service in 2013.[21] Forty-eight plots spaced uniformly at 1.9-mile intervals in a hexagonal grid were sampled over the entire island (Figure 11). In addition, 67 plots were sampled by the Micronesia Challenge (MC) in 2013 using similar methodology, but with a focus on protected conservation areas in northern Guam and in ravine forests in southwestern Guam.[22]

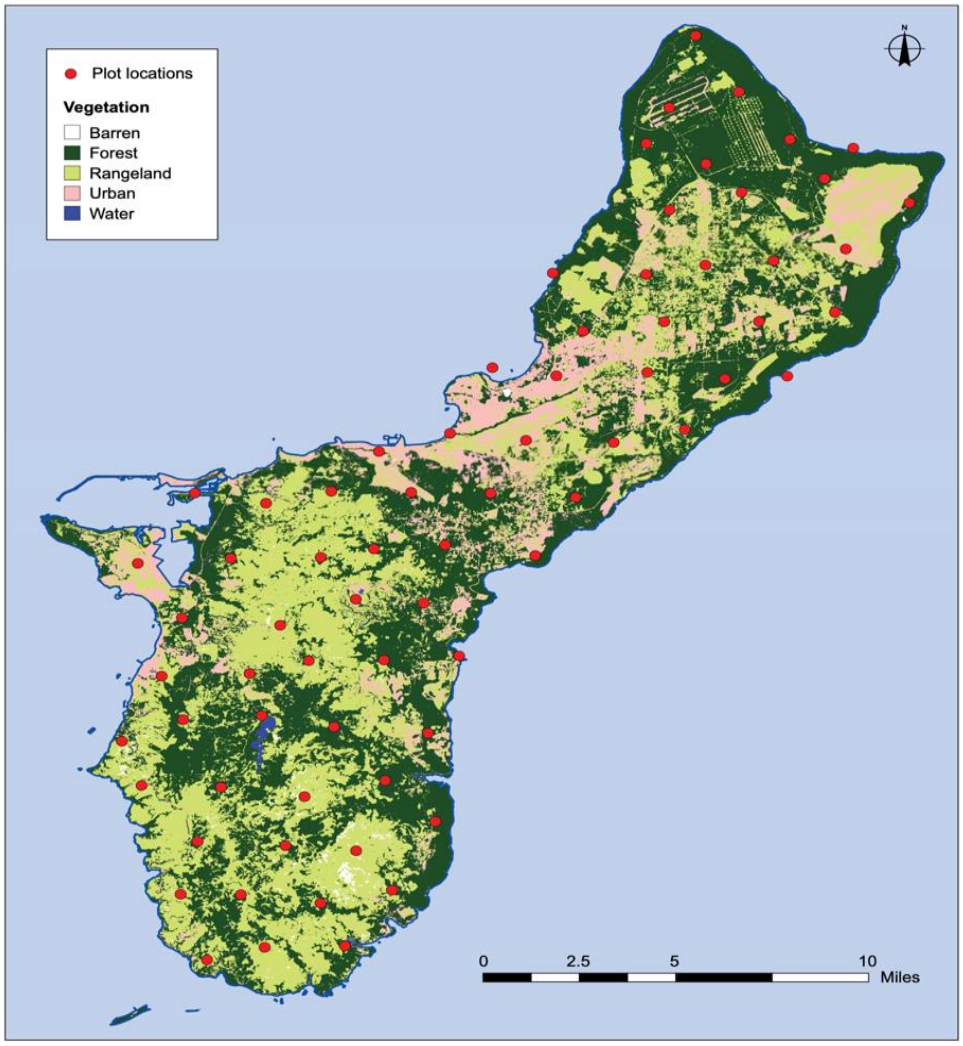

Figure 11. Map of Guam showing location of Forest Inventory and Analysis (FIA) plots, and plots sampled by the Micronesian[23] Challenge (MC) in 2013[24].

[21] (Lazaro *et al*. 2020)
[22] (Micronesia Challenge 2019)
[23] Figure 14 is only a representation of the FIA grid plots and the overlay used across the islands.

[24] (Lazaro *et al*. 2020; Micronesia Challenge 2019.)

Forest Structure

Important factors in forest structure are tree species, diameter, height, and presence of damage. The FIA and MC forest inventories of 2013 identified 64 tree species on Guam (Table 8). The five most prevalent species were *Leucaena leucocephala, Hibiscus tilliaceus, Triphasia trifolia, Meiogyne cylindrocarpa,* and *Vitex parviflora.* There was a total of 74 million trees estimated to be on Guam in 2013.

Table 8. Estimated number of trees on Guam by species.[25]

Tree Names		Micronesia Challenge Area		Outside Micronesia Challenge Area (FIA)		Overall	
Scientific	English[1] / *CHamoru*[2]	Subtotal	SE	Subtotal	SE	Total	SE
Leucaena leucocephala	*tangantangan*	4,459,705	2,171,776	6,302,290	1,817,474	10,761,995	2,689,749
Hibiscus tilliaceus	*pagu*	1,578,467	869,145	7,805,348	1,786,613	9,383,814	1,985,109
Triphasia trifolia	limeberry, *lemon di china*	1,697,407	1,349,782	7,243,737	5,283,780	8,941,143	5,435,135
Meiogyne cylindrocarpa	*paipai*	5,200,278	1,853,394	3,268,481	1,420,873	8,468,759	2,318,477
Vitex parviflora	vitex	1,351,624	853,922	3,601,971	1,282,622	4,953,595	1,518,022
Morinda citrifolia	Indian mulberry, *lada*, *noni*	611,713	328,651	2,866,450	1,029,824	3,478,163	1,055,177
Ochrosia oppositifolia	*fagot*	931,834	944,842	2,033,735	1,072,194	2,965,570	1,429,100
Premna serratifolia	*ahgao*	531,183	291,923	2,130,232	816,616	2,661,415	848,394
Heterospathe elata	*palma brava*	14,809	11,000	2,307,962	1,150,560	2,322,771	1,149,858
Aglaia mariannensis	*Mapunyao*	2,287,016	1,406,335	--	--	2,287,016	1,406,335
Averrhoa bilimbi	pickle tree, *pikols*	836,046	631,612	1,355,450	1,058,491	2,191,497	1,210,989
Casuarina equisetifolia	ironwood, *gagu*	81,838	120,515	1,495,881	880,929	1,577,719	888,275
Cocos nucifera	coconut palm, *niyok*	275,301	149,756	907,506	307,845	1,182,807	340,068
Cananga odorata	*ilang-ilang*	--	--	1,019,825	785,866	1,019,825	785,866
Pandanus tectorius	pandanus, *kafu*	212,153	151,210	769,035	207,657	981,188	256,099
Adenanthera pavonina	red bead tree, *kulalis*	--	--	883,076	680,588	883,076	680,588
Annona muricata	soursop, *laguana*	--	--	637,128	353,797	637,128	353,797
Ochrosia mariannensis	lipstick plant, *langiti*	539,821	663,350	--	--	539,821	663,350
Bauhinia monandra	orchid tree, *mariposa*	--	--	509,913	398,198	509,913	398,198
Mammea odorata	Chopak	318,810	703,193	187,240	146,218	506,050	718,234
Calophyllum inophyllum	palomaria, *da'ok*	--	--	403,301	229,116	403,301	229,116
Ficus tinctoria	*hodda*, *tagete*	32,377	55,319	348,576	251,829	380,953	257,833
Tarenna sambucina	*sumac-lada*	194,056	467,103	161,336	125,990	355,393	483,796
Cycas micronesica	*fading*, *federico*	326,773	158,298	25,903	13,959	352,677	158,912
Areca catechu	betel nut palm, *pugua*	184,469	293,102	137,202	62,558	321,671	299,704
Eugenia reinwardtiana	*a'abang*	247,966	319,511	--	--	247,966	319,511
Mangifera indica	mango, *manga*	--	--	220,179	161,661	220,179	161,661

[25] (Lazaro et al. 2020; Micronesia Challenge 2019)

Melanolepis multiglandulosa	*alom*	23,132	53,875	174,288	136,104	197,421	146,379
Annona reticulata	custard apple, *annonas*	41,937	30,783	155,421	88,724	197,357	92,026
Chrysophyllum caimito	star apple, *kaimito*	161,336	125,990	--	--	161,336	125,990
Maytenus thompsonii	*luluhut*	154,013	326,649	--	--	154,013	326,649
Spathodea campanulata	African tulip tree	--	--	129,517	66,653	129,517	66,653
Pisonia grandis	grand devil's claw, *umumu*	7,703	7,915	90,662	70,799	98,366	71,240
Ficus prolixa	banyan, strangler fig, *nunu*	92,427	86,886	--	--	92,427	86,886
Scaevola taccada	half-flower, *nanasu*	77,006	185,358	--	--	77,006	185,358
Tristiropsis obtusangula	*faia*	10,785	19,095	64,759	50,571	75,543	54,056
Macaranga thompsonii	*pengua*	69,331	64,832	--	--	69,331	64,832
Artocarpus altilis	*breadfruit, lemmai*	3,714	5,909	64,759	41,232	68,473	41,653
Eugenia thompsonii	*atoto*	63,917	78,381	--	--	63,917	78,381
Intsia bijuga	*ifit*	21,570	19,023	38,855	30,343	60,425	35,812
Cestrum diurnum	*inkberry, tintan-china*	57,755	102,693	--	--	57,755	102,693
Hernandia Sonora	*nonak*	54,536	100,606	--	--	54,536	100,606
Cordia subcordata	*niyoran*	53,924	72,547	--	--	53,924	72,547
Psychotria mariana	*aploghating*	46,207	67,356	--	--	46,207	67,356
Dendrocnide latifolia	*katot*	44,666	93,081	--	--	44,666	93,081
Artocarpus mariannensis	*seeded breadfruit, dukduk*	4,938	6,753	38,855	16,663	43,794	17,980
Cynometra ramiflora	*gulos*	41,585	92,659	--	--	41,585	92,659
Barringtonia asiatica	*fish kill tree, puting*	--	--	38,855	30,343	38,855	30,343
Schleinitzia fosbergii	*native tangantangan*	38,855	30,343	--	--	38,855	30,343
Phyllanthus mariannensis	*Chosgo, abas duendes*	14,498	40,245	11,635	9,595	26,133	41,373
Averrhoa carambola	*star fruit, bilimbines*	23,132	53,875	--	--	23,132	53,875
Eugenia palumbis	*agatelang*	20,792	46,405	--	--	20,792	46,405
Pithecellobium dulce	*kamachile*	18,570	43,250	--	--	18,570	43,250
Pandanus dubius	*pahong*	2,705	4,918	12,952	10,114	15,656	11,247

An important feature of forest structure is the proportion of small, medium, and large trees in an area. A basic unit of measurement for determining these proportions is tree diameter at breast height (DBH). DBH classification can be used as a defining feature of Guam's forests. The majority of trees on Guam are characteristically small with a DBH ranging from one to three inches (Figure 12), with very few trees exceeding a DBH of 13 inches and most tree heights between 15-24 ft (Figure 13).

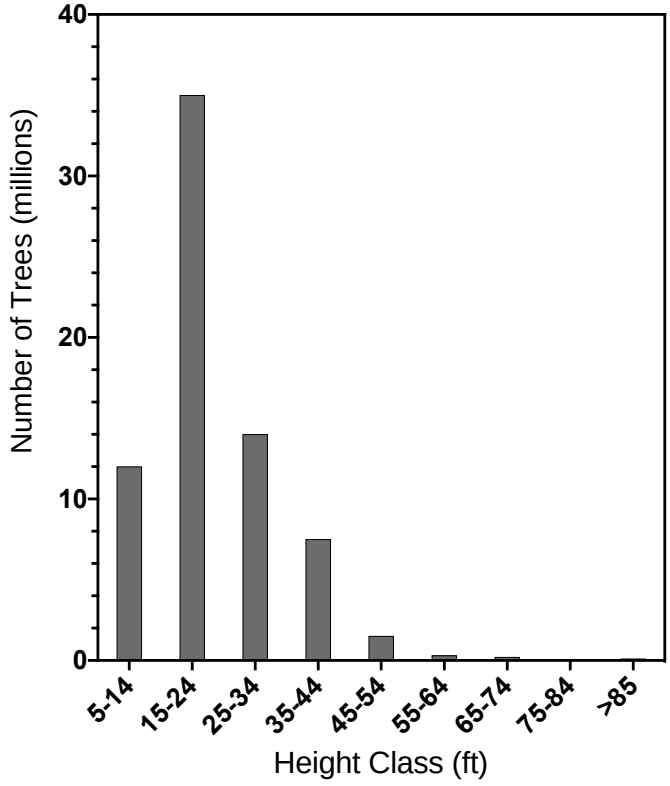

Figure 13. Estimated number of trees by height (ft) on Guam.

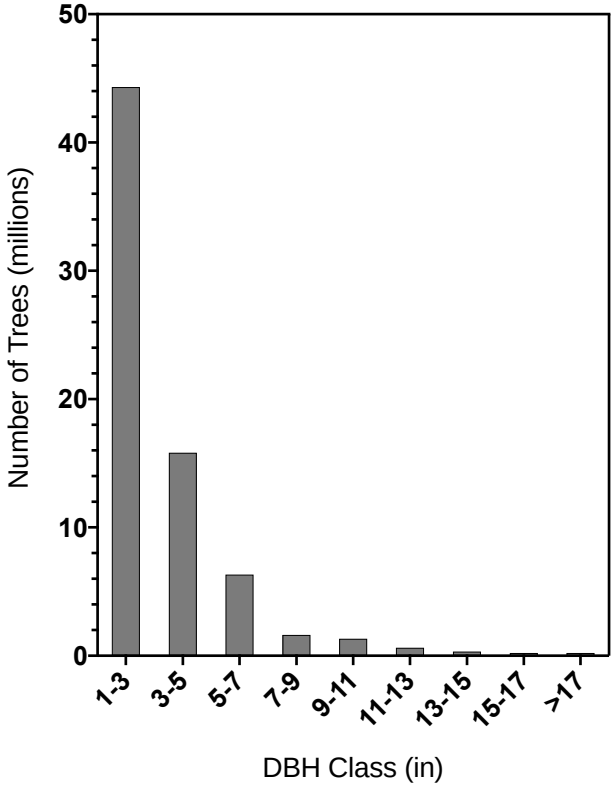

Figure 12. Estimated number of live trees by diameter class in 2013.

Observed Trends in Forest Cover

The two salient trends throughout the recorded history of Guam's forests are a decrease in native trees and an increase in introduced trees. Guam was a primarily forested environment before human contact.[27] The pollen record indicates Guam was an entirely forested landscape from 9300 years to about 4300 years calibrated years before present (BP).[28] Change to the forests began when CHamoru voyagers arrived, and the appearance of charcoal particles began to appear in the pollen record.[29] Grass and pollen concentrations also significantly increased in the pollen record at this time. Additionally, a transition from native to introduced species accelerated through the Spanish, Japanese, and American colonial periods. WWII had an especially pronounced impact on the island's natural environment. Large tracts of forest were destroyed by bombardment, battles, and the construction of military facilities, such as airfields. This history of human disturbances, coupled with the effects of typhoons, has left little native or undisturbed primary forest on the island.[30] Native forests are now fragmented and restricted to scattered patches on cliffs and in other relatively inaccessible areas on military installations in northern Guam. In southern Guam, pockets of native forests can be found in ravines, valley bottoms, and on steep hillsides.[31] The few endemic trees that can still be commonly observed

[26] (Micronesia Challenge 2019)
[27] (Peterson and Wescom, 2019)
[28] (Athens, Stephen J., Michael F. Dega and Jerome V. Ward, 2004)
[29] (Athens, Stephen J., Michael F. Dega and Jerome V. Ward, 2004)
[30] (Mafnas, 2010)
[31] (Mueller-Dombois and Fosberg, 1998)

are *Meiogyne cylindrocarpa*, *Aglaia mariannensis*, and *Ochrosia mariannensis* (Table 8).

Forest cover is increasingly dominated by invasive species. Three introduced trees comprise over 1/4th or 26% of the island's forest cover. These three trees are *Vitex parviflora* (13% cover), *Leucaena leucocephala* (9% cover) and *Heterospathe elata* (4% cover) (Figure 14, Table 8). [32]

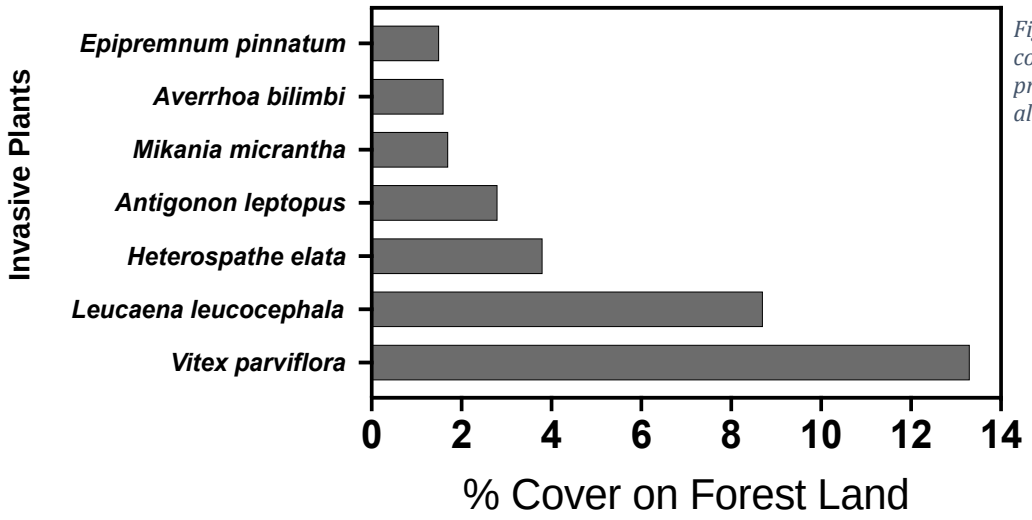

Figure 14. Percentage of cover of invasive species present in the vegetation in all of Guam's forested lands.

A long history of wildland fires, typically started by arsonists, has shaped the vegetation of southern Guam.[33] The trends associated with fires are addressed in other sections.

Observed Trends in Urban Environment

Guam's urban environment can be characterized by steady population growth and increasing urbanization (Figure 15). In 1960 the population was 66,742 and in 2019 the population was 167,294.[34] This is an increase of over 100,000 people in 59 years. The trend for urbanization is similarly upward. In 1960 50% of the population lived in urban areas. In 2019 it increased to 95%. Urban and non-forest developed areas on Guam, at present, account for 47% of the land area (Table 9). Forests comprise 41% of the land area (Lazaro et al. 2020).

[32] (Lazaro et al. 2020)
[33] (Mafnas, 2010)
[34] (World Bank, 2020)

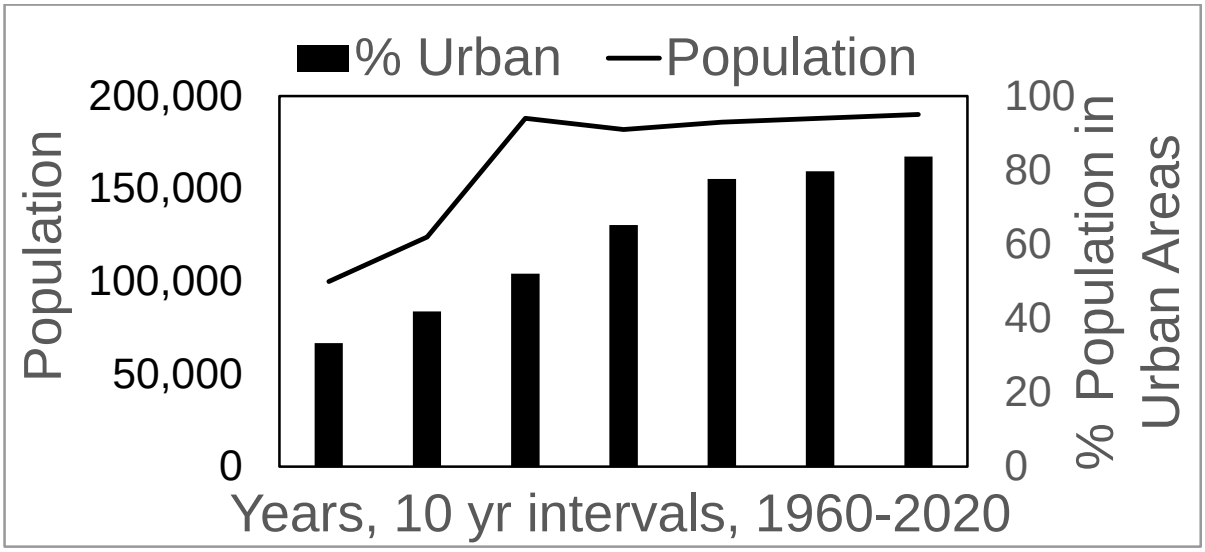

Figure 15. Population estimates for residents of Guam and percent urbanization, 1960-2020[35].

Table 9. Estimated land area by status, 2013[36].

Land Status	Total Acres
Accessible forest land:	
Unreserved forest land	51,813
Reserved forest land (Guam National Wildlife Refuge, Bolanos Conservation Area, Cocos Island Reserve)	17,890
All accessible forest land	69,703
Nonforest and other areas:	
Nonforest urban	35,605
Nonforest vegetation	26,875
All nonforest and other	62,379
Total area	132,183

[35] (World Bank Group, 2020)
[36] (Lazaro et al. 2020)

Forest Management Using a Ridge-to-Reef Approach

Coral reefs are degraded by sediment runoff from watersheds, particularly from the steep landscapes in southern Guam. Deforestation, invasive species, fire, and land management practices increase the sediment flux from the uplands to rivers that empty into the fringing reef and bays. In addition to harming water quality in rivers and freshwater bodies, these chronic sediment plumes contribute to significant declines in coral reef health.

The **Ridge-to-Reef** management approach provides an important connection between land management practices and the health of Guam's fringing reefs. Guam Forestry provides a critical role in abating the threat of declining water quality issues to waterways and coral reefs through maintaining and improving forest health, forest stewardship, fire control programs and watershed-scale restoration efforts. Organizing spatial information and issues by watershed provides a powerful tool in developing multi-objective strategies to abate the pollution of these critical water resources.

Watersheds on Guam

The island of Guam has been subdivided into 19 watersheds[37] (Figure 16 and Figure 17). For the purposes of this report, we divided these nineteen watersheds into three groupings; Eastern, Western and Northern Guam watersheds (Table 10Table 7). Watersheds on the eastern side of Guam are generally larger in size and gentler in slope then those found on the western side of the island. The three northern Guam watersheds generally lack significant stream systems, reflecting the porous nature of the limestone geology of the northern half of the island. Precipitation increases with elevation in all of the watersheds.

[37] (WERI, undated)

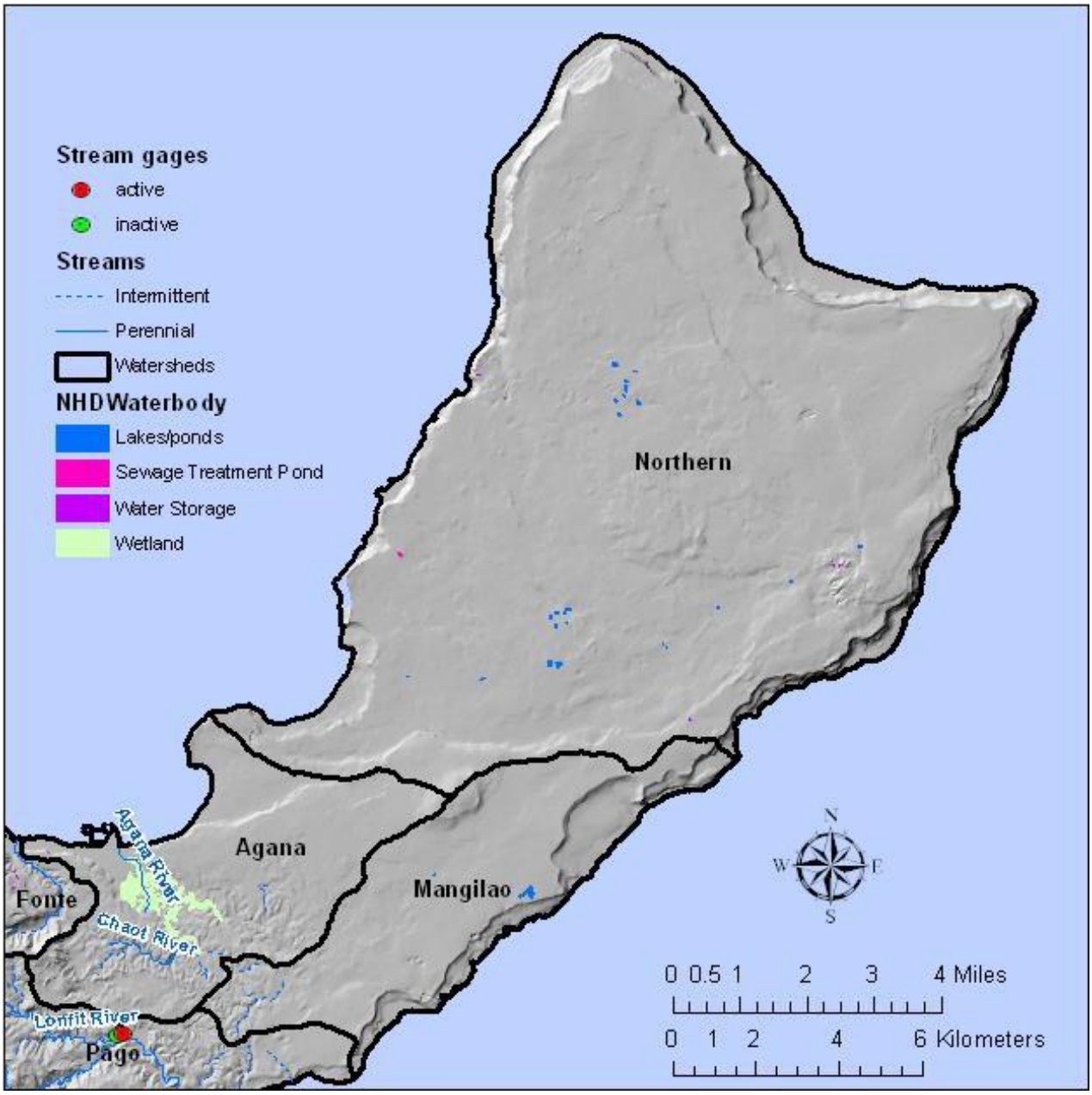

Figure 16. Water features of northern Guam.

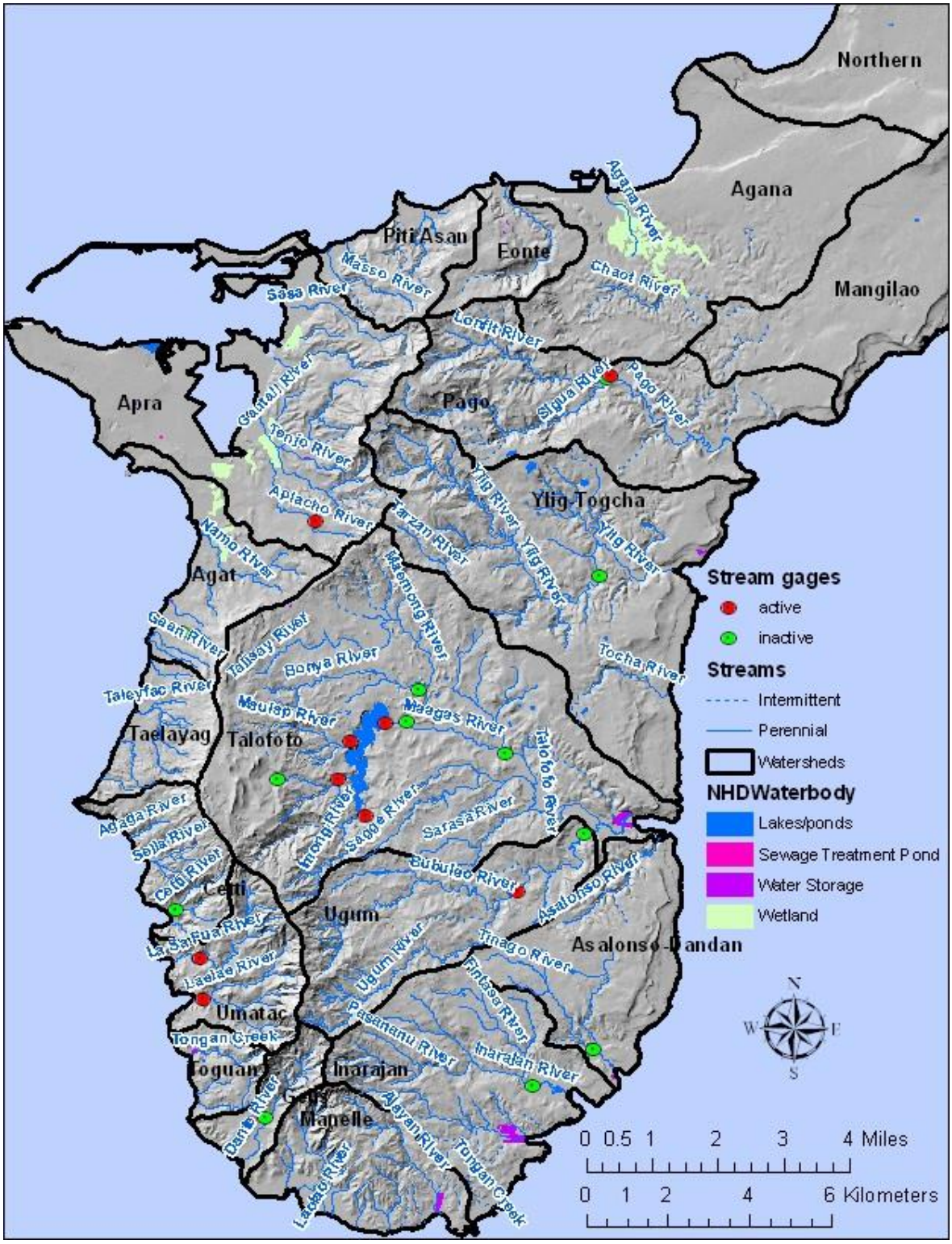

Figure 17. Water features of southern Guam. Data are summarized in Table 9.

Table 10. Watershed characteristics

Region	Watershed	Area		Mean elevation		Max elevation		Mean slope	Mean annual precipitation	
		mi^2	km^2	ft	m	ft	m	%	in	cm
Eastern	Pago	10.4	27	288	88	1,066	325	21	97	247
	Ylig-Togcha	15.7	40.7	262	80	1,001	305	18	101	256
	Talofofo	23.5	60.8	347	106	1,322	403	18	105	266
	Ugum	7.6	19.6	419	128	1,238	377	20	107	271
	Asalonso-Dandan	6.5	16.9	207	63	425	129	13	102	258
	Inarajan	8.7	22.5	264	81	1,096	334	16	100	254
Western	Manell	4.9	12.6	226	69	1,106	337	27	96	244
	Geus	1.7	4.5	331	101	1,122	342	33	100	253
	Toguan	1.4	3.7	234	71	1,036	316	24	99	251
	Umatac	3.8	9.9	408	124	1,233	376	36	106	270
	Cetti	3	7.8	361	110	1,286	392	31	107	271
	Taelayag	2.6	6.6	244	74	1,117	341	20	104	265
	Agat	3.9	10.2	152	46	756	231	12	97	247
	Apra	12.9	33.5	158	48	1,045	319	13	92	235
	Piti/Asan	3.1	8.1	243	74	725	221	20	93	237
	Fonte	2.5	6.4	320	97	706	215	20	95	242
Northern	Agana	13.6	35.3	162	49	666	203	9	93	237
	Mangilao	13.7	35.5	277	85	655	200	8	94	238
	Northern	70.3	182	419	128	832	254	7	94	238

Table 11. Water features of Guam.

Region	Watershed	Length of streams						Area of water bodies							
		Perennial		Intermittent		Total		Lake/ Pond		Sewage Treatment		Water Storage		Wetland	
		mi	km	mi	km	mi	km	ac	ha	ac	ha	ac	ha	ac	ha
Eastern	Pago	13.8	22.1	9	14.5	22.7	36.6	3.3	1.3	-	-	-	-	-	-
	Ylig- Togcha	28.5	45.9	3.4	5.5	31.9	51.4	15.6	6.3	-	-	1.9	0.8	3.3	1.4
	Talofofo	42.9	69.1	8.8	14.1	51.7	83.2	195.3	79	-	-	15.9	6.4	-	-
	Ugum	21	33.8	2.2	3.6	23.2	37.4	0.7	0.3	-	-	-	-	-	-
	Asalonso-Dandan	10.1	16.2	0.9	1.5	11	17.7	4	1.6	-	-	0.5	0.2	-	-
	Inarajan	19.6	31.6	6.3	10.2	26	41.8	2.2	0.9	-	-	30.3	12.2	-	-
Western	Manell	12.7	20.5	3.6	5.8	16.3	26.3	-	-	-	-	8.6	3.5	-	-
	Geus	3.3	5.3	-	-	3.3	5.3	-	-	-	-	-	-	-	-
	Toguan	4.3	6.9	-	-	4.3	6.9	0.3	0.1	-	-	1.1	0.4	-	-
	Umatac	10.8	17.4	0.4	0.6	11.2	18	-	-	-	-	-	-	-	-
	Cetti	7.4	12	-	-	7.4	12	-	-	-	-	-	-	-	-
	Taelayag	7.7	12.4	-	-	7.7	12.4	-	-	-	-	-	-	-	-
	Agat	8.3	13.4	-	-	8.3	13.4	-	-	0.2	0.1	0.3	0.1	64.1	25.9
	Apra	15.9	25.5	2.3	3.6	18.1	29.1	18.8	7.6	0.4	0.2	2	0.8	124	50.1
	Piti/Asan	4.8	7.8	2.7	4.3	7.5	12.1	-	-	-	-	0.2	0.1	-	-
	Fonte	1.9	3	1.3	2.1	3.1	5.1	-	-	-	-	0.7	0.3	-	-
Northern	Agana	2.7	4.3	2.1	3.4	4.8	7.7	-	-	-	-	-	-	268	108.4
	Mangilao	-	-	1.8	2.9	1.8	2.9	6.5	2.6	-	-	-	-	-	-
	Northern	-	-	-	-	-	-	15.6	6.3	0.6	0.2	0.8	0.3	-	-
Totals		**216**	**347**	**49**	**72**	**261**	**419**	**262**	**106**	**1.2**	**0.5**	**62**	**25**	**459**	**186**

Approximately 260 miles of streams are mapped on the island of Guam; the majority are identified as having perennial flow (Table 11). Few streams occur in the limestone- dominated northern Guam watersheds, and none in the Northern watershed itself. The largest water body on the island is the human-made Fena Reservoir located in the Talofofo watershed (195 acres). Large, primarily estuarine wetland areas occur in the Agana, Apra and Agat watersheds.

Reef Resources

Guam is surrounded by an extensive and species-rich reef system that provides many services including cultural and traditional uses, tourism and recreation, fisheries, and shoreline and infrastructure protection. Over 38 square miles of shallow coral reef are found within 3 miles of Guam's coastline (Figure 18). Guam's reef resources are currently in decline due to degradation of water quality, chronic crown of thorns seastar (COTS) outbreaks, and low abundance of major herbivorous (algae-eating) fishes. There is also a documented decline of coral recruitment rates over the past few decades.[38]

[38] (Burdick, Brown, et al, 2008)

Primary threats to Guam's coral reefs include sedimentation and pollutants associated with terrestrial runoff, and overfishing. Secondary threats include COTS outbreaks, coral diseases, dredging, boat groundings, marine debris, coral bleaching, and recreational misuse and overuse. Storm activity can also cause direct damage to reef structure, and coral bleaching is emerging as a potential threat which will likely become more severe with increasing sea surface temperatures associated with global climate change.

Linkages between Guam's coral reef communities and Guam Forestry objectives are directly related activities that affect the quantity and quality of water and sediment pollution runoff to the reef communities. In particular, reef resources are affected by fire and post-fire management, and quality and health of forested upland and riparian systems that can increase sediment trapping from grass or bare ground hill slopes.

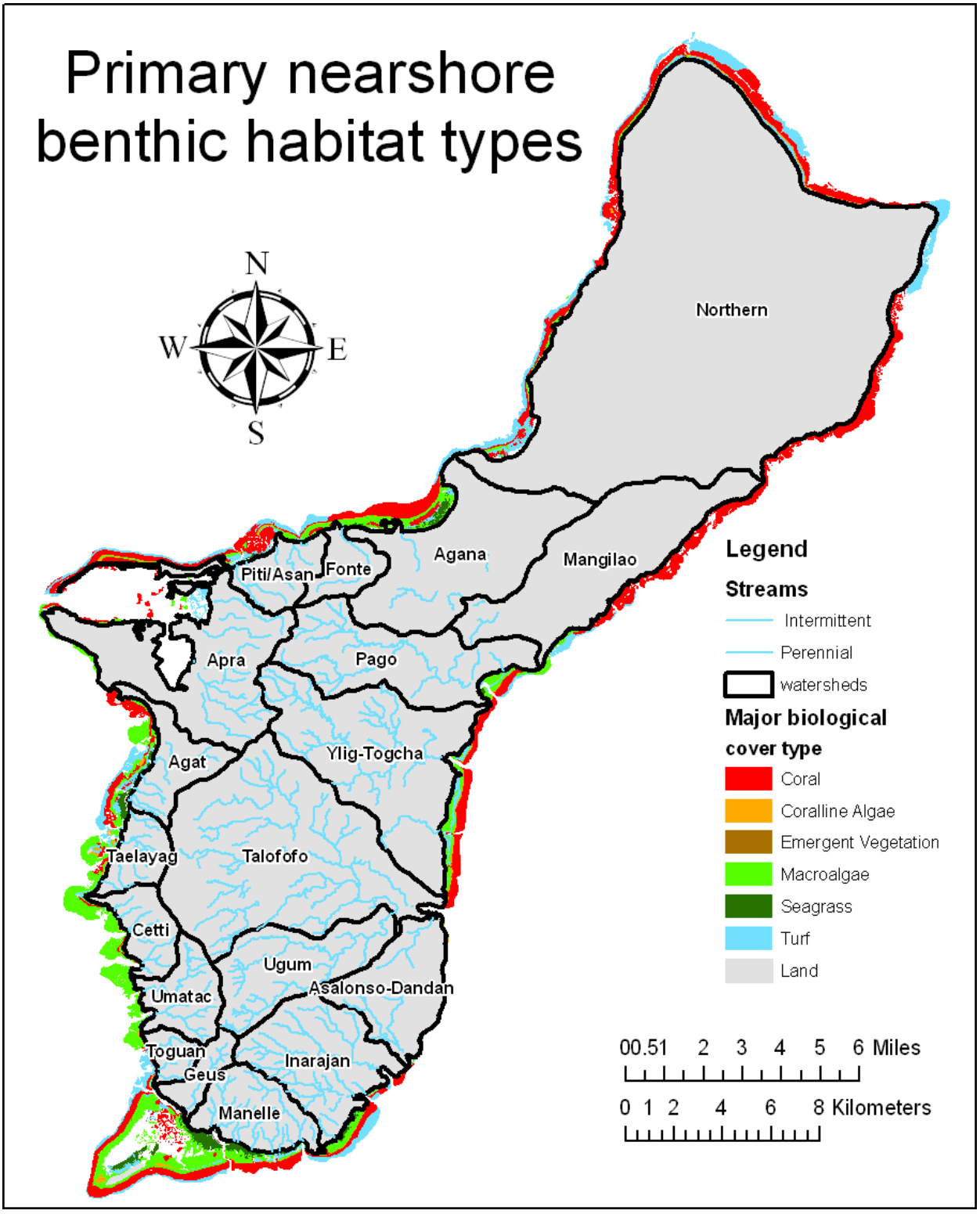

Figure 18. Primary nearshore benthic habitat types around Guam.[39]

[39] Source: Burdick (2009).

Guam Wildlife Action Plan

The 2008 Farm Bill and national guidance require that the GFAP evaluate commonalities with the state wildlife action plan. The Guam Department of Agriculture - Division of Aquatic and Wildlife Resources', Guam Wildlife Action Plan (GWAP, formerly, Comprehensive Wildlife Action Plan), updated January 10, 2019, identified 99 Species of Greatest Conservation Need (SOGCN) among terrestrial, aquatic and marine organisms (76 species and 20 family groups). Species, subspecies and groups were identified based upon the evaluation of each species' biological importance and vulnerability to extinction, and not decided solely upon ESA candidacy or listing.

The Wildlife Action Plan identifies limestone forests, scrub (secondary forests), and ravine forests as important for all of Guam's native avian, invertebrate, reptilian and mammalian species. Limestone forests are found on the northern limestone plateau and on large limestone outcroppings in southern Guam. These habitats are vital for almost all of Guam's native forest birds, snails, insects, lizards, and two fruit bat species. Typhoons, loss of pollinators, loss of habitat due to development and wildfires, and introduction of aggressive invasive plant species are all factors that lower forest resilience that can ultimately support these essential habitats.

The scrub forest is described as a degraded, yet diverse, brush-type forest, generally with an open canopy under 10 meters high and a dense understory. The plant species are similar to those in more mature limestone forests but are at an earlier stage of development. In northern Guam, this habitat is often dominated by *Vitex parviflora*, an introduced species from the Philippines. While native plants can be found as understory within Vitex stands, Vitex trees shed their canopy during the dry season, leaving an open canopy that promotes invasive weeds. The same factors impacting limestone forests are changing the structure of scrub forest (feral deer and pigs, invasive plant species, development and typhoons). In the absence of deer, pigs, and invasive plants, scrub forest could be restored to support primary limestone forest habitat.

Ravine forests of southern Guam are highly degraded and contain many non-native species including *Pimenta racemosa* and palma brava (*Heterospathe elata*). The ravine forests have been reduced in quality and quantity by damage from deer, pigs, fire, and introduced plant species.

The goal of the Guam Wildlife Action Plan to promote the recovery and sustainable use of Guam's native aquatic and terrestrial species, especially those of greatest conservation need, aligns with the mission of Guam Forestry. Rehabilitation of native forests is a necessary step in the management and recovery of species of concern.

Issues & Threats to Forest Ecosystems

Approach

As described under the Conditions and Trends of Forest Resources section, vegetative cover on Guam can be classified coarsely as Forest, Non-Forest (savanna and grasslands), Developed and Bare Ground. Because of the high degree of loss and conversion of forests and the mosaic of cover types on the landscape, it is important to evaluate issues and threats at the landscape scale, rather than focus only on the current forest cover. For example, the threat of fire to existing forests occurs on the edge of forest in the grasslands and savannas. For this reason, the threats to forest ecosystems should focus not only within forest boundaries, but across all landscape cover types to determine the best actions for management to prevent further impacts to forests.

The identification of issues and threats followed a two-step process. The first step was a Stakeholder process that identified six major related issues developed for Guam. The second step involved fine-tuning the strategies and updating maps (vegetation, fire risks and forest stewardship priority maps).

Step 1: The Stakeholder Process

The Stakeholder process included reviewing the 2010-2015 Statewide Forest Resource Assessment and Resource Strategy (SWARS) with the FAP Advisory Council and incorporated revisions to the six issues and strategies. The original SWARS data were incorporated within this update along with updated information, where available. Stakeholders considered eleven environmental attributes throughout the process: 1) Wildfire Risk, 2) Proximity to Protected and Managed Areas, 3) Public Water Supply/Priority Watersheds, 4) Wetlands, 5) Riparian Areas, 6) Slope, 7) Threat of Development, 8) Native Forests, 9) Threatened & Endangered Species, 10) Population at risk of fire, and 11) Private Forest Lands.

The outcome of this FAP is a merging of the original SWARS and current available data in an effort to determine the best course for continued, repeatable data collection and analysis to develop robust, science-driven management at the island-wide scale. Therefore, the new risk models looked at grasslands, including small areas of crops and pasture with slopes greater than or equal to 50%. For specific urban area risks the same 300 and 500 ft buffers as the SWARS method was used and the urban layer was a combination of impervious and developed/open space layers from the 2014 vegetation map (Figure 5).

Step 2: Fine-Scale Assessment

The underlying data sources used for the Stakeholder Process were evaluated for their utility in quantifying and describing threats on the landscape. This involved a scientific approach to determining (at fine scales) potential threats to trees and forests in the rural and urban areas, fire behavior potentials, and mechanisms for addressing stakeholder issues and threats. This approach also expanded to a watershed-science based approach to quantify erosion and sediment delivery, with prioritized areas on the landscape for active forestry and reforestation management. Base information included the fine-scale GFAP vegetation map, LiDAR surface elevation models, soils mapping, and hydrology datasets.

Stakeholder Identification of Issues

Guam Forestry, in coordination with the Guam Bureau of Statistics and Plans (BSP), completed the spatial analysis involving stakeholder ranking of environmental attributes. Six issues were identified by the GFAP Advisory Council:

1. **Wildfire and Public Safety**: The threat of wildland fire on human life and infrastructure.
2. **Water Quality and Water Supply**: The threat to water quality and quantity from human development and forest degradation.
3. **Deforestation of Native and Old Forests**: The threat posed to unique forest environments on Guam.
4. **Urban Forest Sustainability, Population Growth and Urbanization:** The threat posed to Guam's urban forest resources by development and other stressors.
5. **Degraded Lands**: Identification of threats to ecosystem health posed by lands currently identified as being in a degraded condition.
6. **Invasive species and Forest Health**

The following sections detail each of the issues above, summarizing the stakeholder issue review and fine-scale assessment outcomes. Beginning on page 90, a *Synthesis of Issues* section describes how the stakeholder issues are related to on-the-ground threats, and displays prioritized areas where single treatments meet multiple objectives.

Issue 1. Wildfire and Public Safety

Introduction

Wildfire is a primary disturbance that affects forest and watershed health and is a keystone issue that is linked with other identified stakeholder issues. Fire is an anthropogenic disturbance that directly interferes with the establishment and expansion of native forests, threatens standing forests, opens corridors for invasive species intrusions, accelerates erosion, and contributes to the decline of the coral reef system. Hence, the issue of "wildfire and public safety" includes other stakeholders' issues (i.e... *Issue 2. Water Quality and Water Supply, Issue 3. Deforestation of Native and Old Forests*, *Issue 4. Urban Forest Sustainability, Population Growth and Urbanization, Issue 5. Degraded Lands and Issue 6. Invasive Species and Forest Health*).

A fire risk assessment[40] conducted in 2004 identified the key vegetation types and topographic influences that would likely contribute to hazardous burn conditions in a given climate scenario. In general, fires are more difficult to suppress when flame lengths exceed 3-6-ft, and when they occur in inaccessible terrain. Flame lengths and rates of spread increase proportionally with slope. The fire assessment suggested management actions such as reforestation or afforestation to change fuels structure, and establishment of fuel breaks on grasslands on steep slopes. These management strategies are synergistic, with breaks helping to establish new plantings and older plantings, in turn, shading out grasses that fuel fires.

A wildfire mapping effort commenced in 2015 which has resulted in the production of annual wildfire summary maps. The 2010 SWARS document noted that previous assessment reports lacked sufficient spatial data, detailing specific land areas for fuels treatments to improve fire protection. The current wildfire mapping effort has provided additional data, to include the mapping of installed and proposed green belts and firebreaks.

Since wildfire is prevalent and a threat on multiple levels (safety, forests, water quality) in wildland and urban areas, a more detailed potential fire behavior map was produced for this assessment using the GFAP vegetation map and LiDAR-derived ground surface information. The output is designed to identify specific sites of hazardous fire behavior potentials that can be prioritized for treatments addressing risk to wildfire in watersheds and communities, as intended by the Farm Bill and USFS agency guidance.

[40] (Neill and Rea 2004)

The results of the fire behavior risk assessment are summarized below.

Potential Fire Risk

Fire behavior risk was calculated to "scale" the potential risk factors combining vegetation types and slope. These scales were divided into four generalized risk assessment categories (Table 12). These risk codes correspond to areas that would have potential high rates of spread and long flame lengths.

Table 12. Generalized criteria in defining fire behavior risk associated with vegetation/cover types and slope.

Fire Behavior Risk	Description (any combination)	Risk Code
Low	Forest, bare soils, water & urban development, <50% slopes	0
Moderate	Open areas near development, secondary or patch forest, 50 - 100% slopes	1
High	Long leaf grass or savanna types, 100 - 200% slopes; short grass types with >200% slopes	2
Extreme	Long leaf grass or savanna types, extreme slopes >200%	3

Potential fire behavior based on slope and fuel structures is depicted on the map (Figure 19) and rated into four categories – Low, Moderate, High and Extreme Fire Risk. These fire risks are further categorized as risks to forest fragments and urban environments in the following sections.

Fire Risk to Forest Fragments

Fire risk to forests and urban environments was determined by calculating a 300-ft buffer distance from all forest edges. These buffers were chosen as areas most likely to have "edge effects" for fire risk to standing forests. The total area of fire behavior risks (Codes 0-3) was calculated within each zone for all watersheds (Table 13). Figure 19 displays the forest fragments at risk for Guam. The yellow color highlights areas of fire risk; their proximity to forest edges identifies these areas as high priority for fuel breaks and conversion to forest.

At watershed scales, the eastern watershed management areas contribute the largest number of acres that pose a moderate or higher fire risk within this forest edge interface zone (8,187 acres), mostly relegated to the central uplands in Talofofo, Ylig and Pago, with upper reaches of Apra in the western watershed management area. Though smaller in land area, the western watersheds all exhibit approximately one-quarter of the land area having moderate or higher fire risk to standing forests, including the Manell (Merizo) watershed, which abuts a marine preserve at the outlet of the watershed. Overall, priority areas pose the highest concentrated direct risk to forests from fires that are likely to exhibit fire behavior that is difficult and potentially dangerous to suppress (Figure 19).

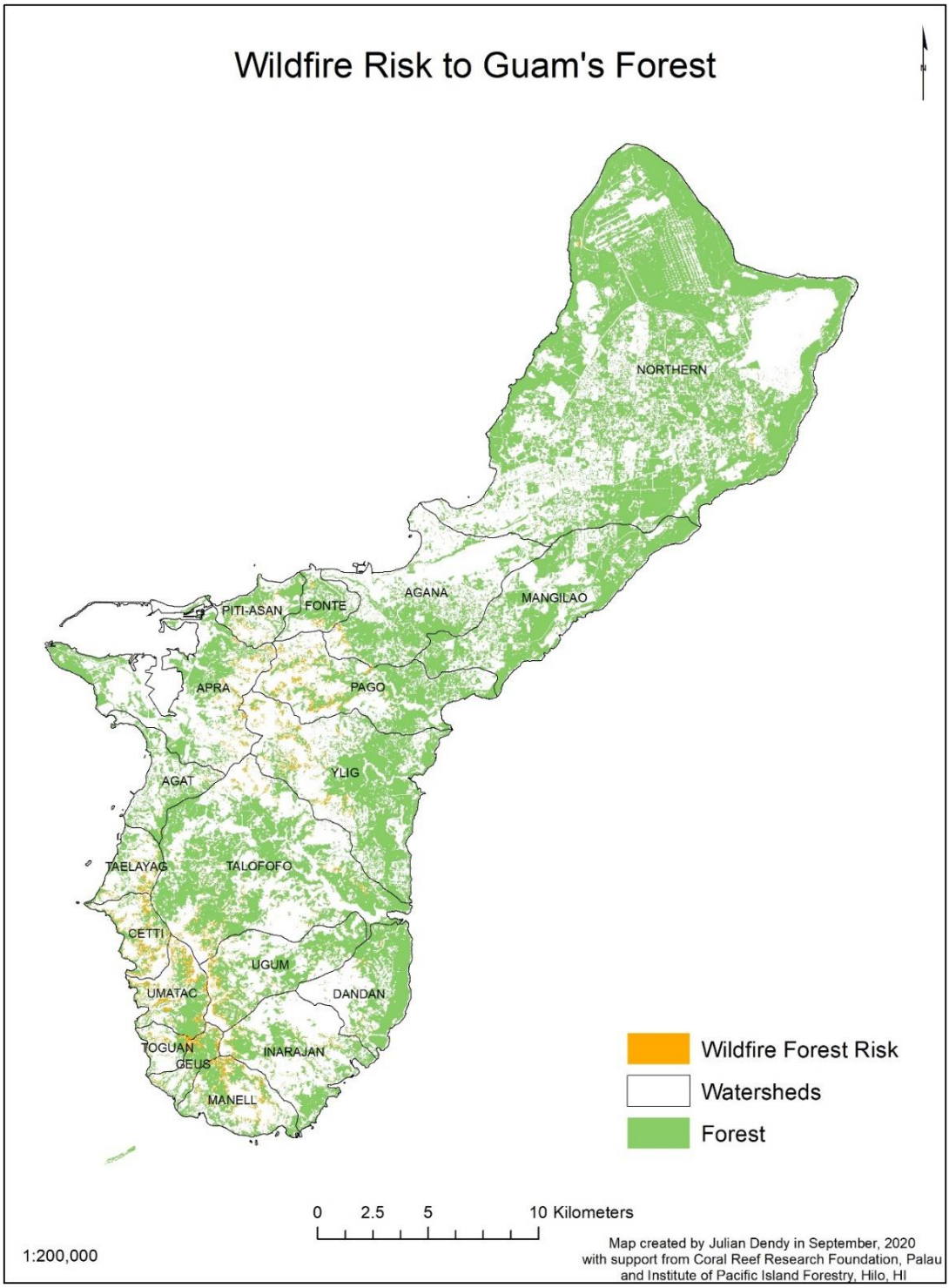

Figure 19. Priority areas for fuels treatments to reduce risk of fire damage to standing forests.

Figure 19 prioritizes the areas for fuels treatments to reduce risk of fire damage to standing forests. Areas were prioritized on the basis of potentially long flame lengths and/or fast rates of spread near forest edges (300-ft). Priorities increase with increased risk. The data are summarized in Table 14 where data values are expressed in acres and percentages of each watershed's total area within non-forest fuel types.

Table 13. The priority areas summarized by watershed for risk of severe fires in 300 ft perimeter of forest fragments, SWARS 2010.

Region	Watershed	Watershed Acres	Low		Moderate		High		Extreme	
			Acres	%	Acres	%	Acres	%	Acres	%
Eastern	Pago	6,683	2,456	37%	1,045	16%	471	7%	25	0%
	Ylig-Togcha	10,067	4,066	40%	1,212	12%	480	5%	18	0%
	Talofofo	15,016	5,860	39%	1,806	12%	756	5%	43	0%
	Ugum	4,851	2,037	42%	726	15%	388	8%	28	1%
	Asalonso- Dandan	4,183	1,972	47%	174	4%	54	1%	3	0%
	Inarajan	5,564	3,155	57%	750	13%	200	4%	8	0%
Western	Manell	3,107	1,139	37%	681	22%	278	9%	18	1%
	Geus	1,120	284	25%	155	14%	162	14%	24	2%
	Toguan	903	427	47%	193	21%	75	8%	5	1%
	Umatac	2,447	673	28%	453	19%	374	15%	55	2%
	Cetti	1,928	696	36%	479	25%	314	16%	18	1%
	Taelayag	1,639	823	50%	309	19%	123	8%	3	0%
	Agat	2,511	1,385	55%	198	8%	39	2%	1	0%
	Apra	8,283	4,415	53%	864	10%	404	5%	11	0%
	Piti/Asan	1,993	894	45%	334	17%	126	6%	3	0%
	Fonte	1,575	678	43%	118	7%	64	4%	6	0%
Northern	Agana	8,717	5,459	63%	275	3%	72	1%	4	0%
	Mangilao	8,772	3,709	42%	106	1%	24	0%	6	0%
	Northern	44,971	22,373	50%	455	1%	140	0%	31	0%

Fire Risk to Communities: Wildland Urban Interface

Similar to assessing fire risk to forest fragments, urban areas, including highly developed and open space areas, were evaluated within 500-ft buffer areas known as the *Wildland Urban Interface* (WUI) for potential fire behavior fuel types.[41] The WUI provides areas for increasing Urban Forestry objectives and reducing hazardous fuels.

[41] Under the USFS WUI definitions, the entire island of Guam would be categorized as within WUI boundaries. (USFS, Fire & Aviation Management)

Figure 20 shows the prioritized areas having potential fire behavior risk in urban zones and associated buffer areas. The areas in yellow are the priority areas that require fuels treatment or conversion to forests.

The percent of each watershed that is mapped as falling within the WUI and Buffer is listed in Table 15. The percent of the watershed in these urban and buffer zones varies from 12% at the low end for Ugum to 95% at the extreme end for the Agana watershed.

Though urban environments are dominant in the northern watersheds, the majority of the fire risk is within the WUI is concentrated in the western and eastern watershed regional groups (Table 16). Areas targeted as having moderate or higher fire behavior risks represent priority areas for converting fuel types to forest, or for creating fire breaks (reduction in fuels). This is especially true along the road areas in the western and eastern watershed regions, as they provide the highest access for arson starts and cover a broad geographic area (Cross Island Road and Highway 2 from Agat to Merizo).

Table 14. Combined watershed risk to forest and urban areas using the 2014 Vegetation Map.

Watershed	Watershed Acres	Acres of Forest Risk	% at Risk to Forest	Acres of Urban Risk	% at Risk to Urban
Agana	8720	37	0.4%	40	0.5%
Agat	2524	21	0.8%	13	0.5%
Apra	8302	182	2.2%	80	1.0%
Cetti	1930	245	12.7%	37	1.9%
Dandan	4183	26	0.6%	5	0.1%
Fonte	1575	27	1.7%	12	0.7%
Geus	1120	121	10.8%	28	2.5%
Inarajan	5566	123	2.2%	20	0.4%
Manell	3119	241	7.7%	24	0.8%
Mangilao	8772	6	0.1%	5	0.1%
Northern	44972	33	0.1%	25	0.1%
Pago	6683	266	4.0%	58	0.9%
Piti-Asan	1993	70	3.5%	53	2.6%
Taeyalag	1648	102	6.2%	9	0.5%
Talofofo	15016	281	1.9%	87	0.6%
Toguan	903	64	7.1%	19	2.1%
Ugum	4851	180	3.7%	3	0.1%
Umatac	2447	314	12.8%	83	3.4%
Ylig	10067	243	2.4%	40	0.4%

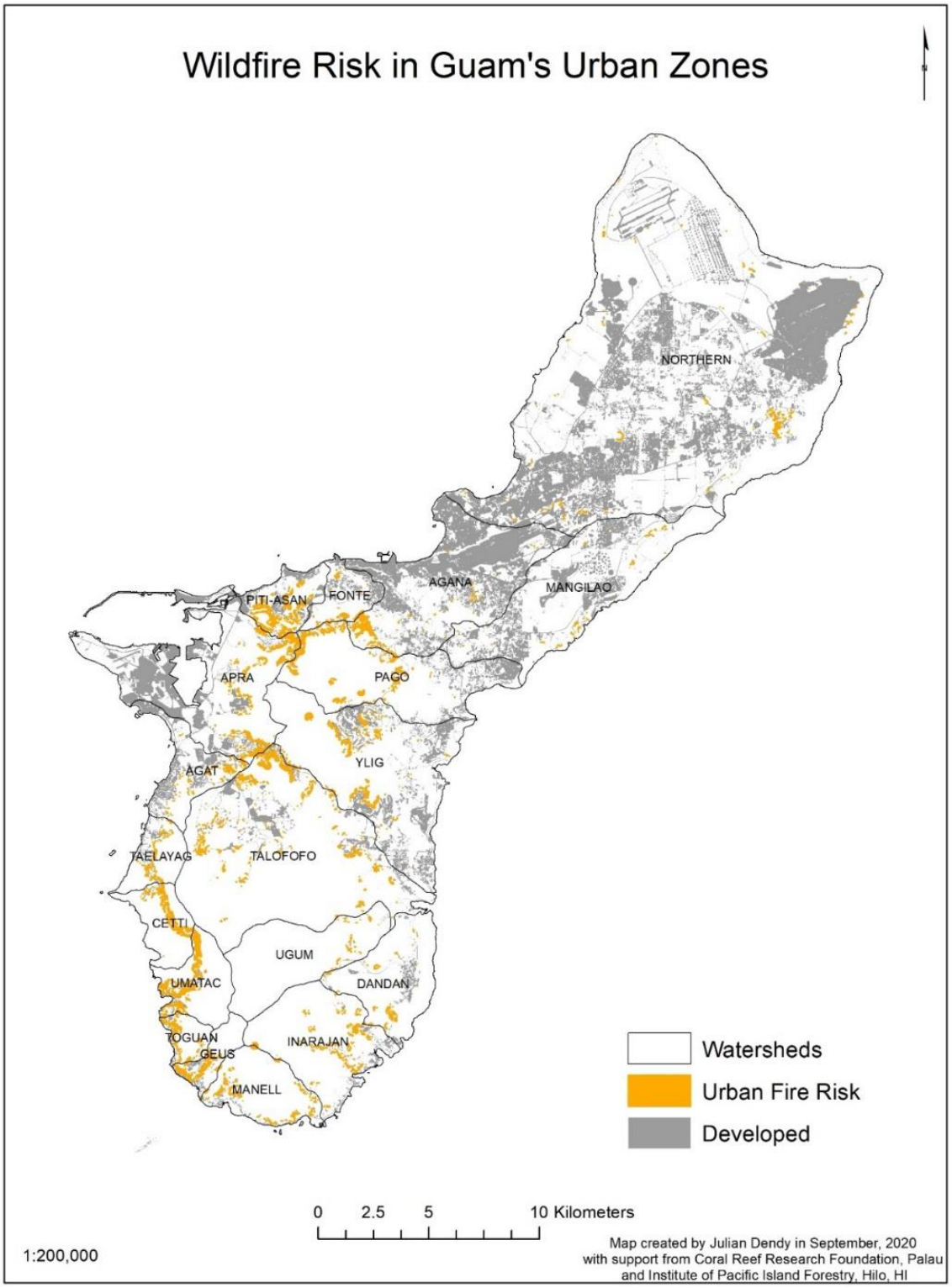

Figure 20. Wildfire risk in Guam's urban zones.

Table 15. Urban areas and the 500 ft WUI areas, expressed as total acres and proportion of the watershed.

Region	Watershed	Watershed Acres	Area within the WUI and Buffer (acres)	Percent of Watershed
Eastern	Pago	6,683	3,746	56%
	Ylig-Togcha	10,067	6,558	65%
	Talofofo	15,016	6,084	41%
	Ugum	4,851	600	12%
	Asalonso-Dandan	4,183	2,319	55%
	Inarajan	5,564	1,698	31%
Western	Manell	3,107	999	32%
	Geus	1,120	526	47%
	Toguan	903	555	61%
	Umatac	2,447	773	32%
	Cetti	1,928	429	22%
	Taelayag	1,639	646	39%
	Agat	2,511	2,121	84%
	Apra	8,283	6,202	75%
	Piti/Asan	1,993	1,599	80%
	Fonte	1,575	1,265	80%
Northern	Agana	8,717	8,316	95%
	Mangilao	8,772	7,636	87%
	Northern	44,971	36,205	81%

Table 16. Fire behavior risk priority areas within the WUI (including open spaces) and a 500 ft buffer surrounding them.

Group	Watershed	Watershed Acres	Low		Moderate		High		Extreme	
			Acres	%	Acres	%	Acres	%	Acres	%
Eastern	Pago	6,683	3,286	49%	333	5%	118	2%	8	0%
Eastern	Ylig-Togcha	10,067	5,969	59%	442	4%	139	1%	8	0%
Eastern	Talofofo	15,016	5,320	35%	601	4%	158	1%	6	0%
Eastern	Ugum	4,851	537	11%	50	1%	12	0%	1	0%
Eastern	Asalonso-Dandan	4,183	2,217	53%	78	2%	23	1%	1	0%
Eastern	Inarajan	5,564	1,484	27%	177	3%	36	1%	1	0%
Western	Manell	3,107	855	28%	109	4%	34	1%	2	0%
Western	Geus	1,120	399	36%	92	8%	33	3%	2	0%
Western	Toguan	903	389	43%	131	14%	35	4%	0	0%
Western	Umatac	2,447	517	21%	176	7%	77	3%	3	0%
Western	Cetti	1,928	247	13%	109	6%	69	4%	4	0%
Western	Taelayag	1,639	564	34%	62	4%	18	1%	1	0%
Western	Agat	2,511	1,954	78%	140	6%	25	1%	1	0%
Western	Apra	8,283	5,727	69%	344	4%	126	2%	5	0%
Western	Piti/Asan	1,993	1,287	65%	222	11%	87	4%	3	0%
Western	Fonte	1,575	1,149	73%	79	5%	34	2%	3	0%
Northern	Agana	8,717	7,969	91%	273	3%	71	1%	4	0%
Northern	Mangilao	8,772	7,526	86%	89	1%	17	0%	4	0%
Northern	Northern	44,971	35,785	80%	351	1%	64	0%	6	0%

Fire Risk Summary

Treatments in the wildland urban interface (installation/maintenance of fuel breaks, green belts, planting native trees to shade out invasive grasses, and removal of ladder fuels) readily correspond with Urban and Community Forestry. Forest Stewardship and Forest Health program objectives as well as Cooperative Fire for fuels treatment operations. Converting non-forest high-risk areas to forested areas will help slow the rate of spread of fire and ultimately fragment fire-prone areas, especially along the major road networks. Immediate edge effects (wildland urban interface areas, roads, community boundaries, etc.) that contribute to risk can be treated using direct fuel break treatments (mowing) around structures and residences within the wildland urban interface to minimize spread to other high-risk areas. A program designed to *isolate*, *contain* and *prevent* fires in the wildland urban interface will offer the highest preventative protections at lowest overall cost. A community-assessment of fire resources, risk areas, and community involvement in a program such as FireWise[42] can assist Guam Forestry and stakeholders with strategies to address urban fire risk through preventative action and outreach.

[42] http://www.firewise.org/ (National Fire Protection Program, NFPA)

Issue 2. Water Quality and Water Supply

Water quality is monitored and regulated by Guam EPA programs. Guam Forestry has a critical role in water quality programs in providing surface conditions that allow for the safe capture and storage of water within key watersheds (surface and groundwater resources). Movement of sediment from erosion into waterways is one of the most pervasive problems associated with poor land cover, which degrades surface waters, domestic water supplies, and fragile reef systems. Guam Forestry programs can reduce erosion through forest stewardship, fire management, and restoration activities to protect water quality and domestic water supplies (firebreaks, greenbelts or tree plantings in areas prone to erosion and a source of soil delivery to streams). Further, Guam Forestry can assist in the protection of groundwater resources through avoiding deforestation and degradation in the northern watershed zone through implementation of S&PF programs (e.g., Stewardship, Legacy, Urban Forestry and Forest Health). This section describes the water resources on Guam, the stakeholder evaluation of water quality and water supply, and the assessment of sediment source and transport by watershed area.

Surface and Groundwater Resources

The climate of Guam is characterized by a dry season that runs from December through June, and a rainy season from July through November. Annual rainfall is high, averaging 90 to 110 inches (229 cm to 280 cm) of precipitation (Figure 27). Temperatures are warm all year, with the coolest least humid period being December through February.[43]

Water resources on the island of Guam vary spatially due to the distinctive geologies of northern and southern Guam. The volcanic-dominated geology of the south has a relatively low permeability, and the hydrologic regime is dominated by surface water processes (e.g., streams and lake impoundments). In contrast, the limestone-dominated geology of the northern watersheds is highly permeable, and groundwater recharge processes dominate.

[43] (Daly and Halbleib, 2006)

Stakeholder Evaluation of Water Quality and Water Supply Issue

The stakeholder evaluation of this issue relies on the estimate of the threat posed by human development and forest degradation. Five environmental attribute layers were identified as being relevant to this issue and are discussed in the Appendix 2 of the SWARS 2010 document. The dominant issue rating was heavily dependent on whether the watershed was rated as a public water supply priority watershed or as an aquifer (Figure 21). In the Northern region, the priority areas are zones of contribution for groundwater resources; in Southern Guam, three watersheds were prioritized for surface water. As such, the Talofofo, Asalonso- Dandan and Ugum watersheds in the south were rated as high priority, as were the portions of the northern watersheds that overlay the primary aquifer.

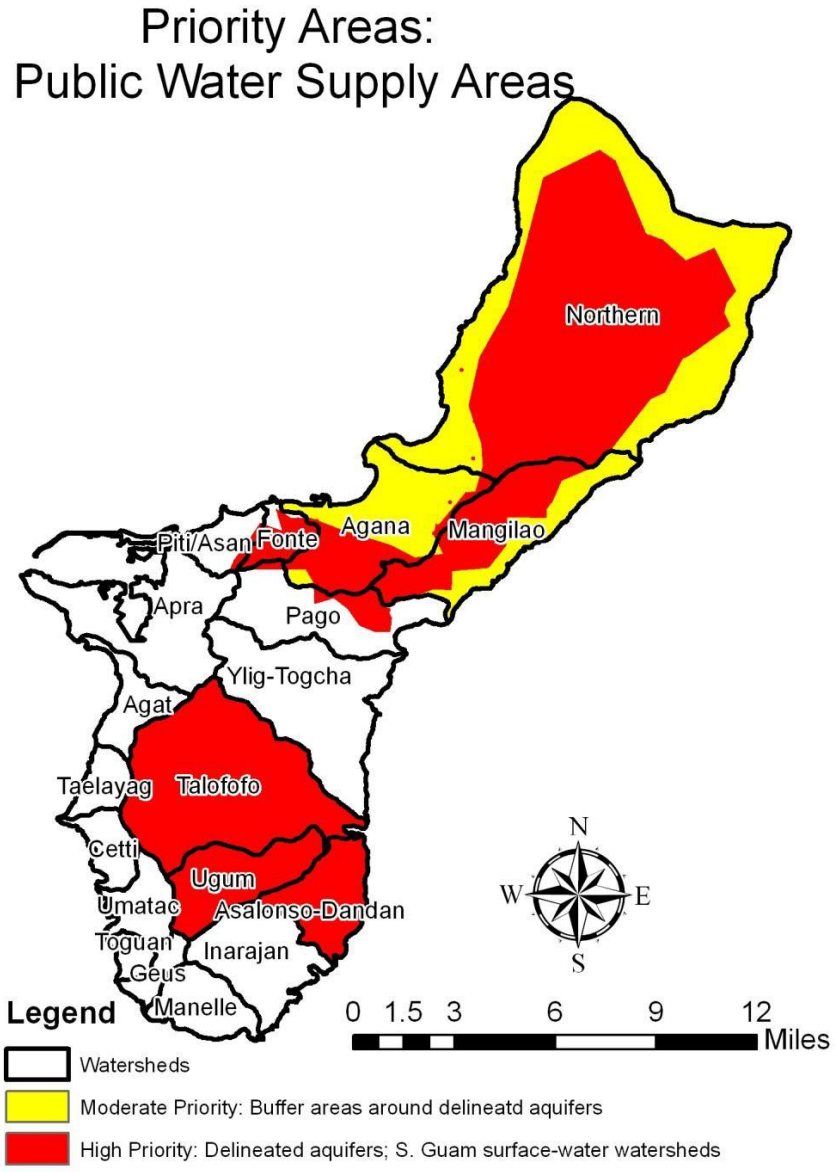

Figure 21. The prioritized areas for sourcing public water supplies.

Water Quality Priorities: Soil Erosion and Sedimentation

Soil erosion is an important issue in Guam, particularly in the southern half of the island. The combination of steep slopes, heavily weathered volcanic soils, and frequent and often intense rainfall provides conditions for erosion of soils in exposed cover types (low canopy grasses, exposed soils, road fill, etc.). Increasing population in the past 25 years has led to changes in vegetation, road construction, and urbanization that increase erosion. Soil erosion on Guam results in loss of soil productivity, degradation of water quality in streams and drinking water sources, and degradation of coral reefs and fisheries resources around the island.

Land uses that contribute to increased erosion include those that remove ground cover and expose soil to erosive forces or land uses that reduce infiltration and increase surface runoff. Prevalent land uses associated with increased runoff and/or erosion include:

- Burning and removal of native vegetation (removes ground cover, increases runoff)
- Road construction and use (increases and channelizes runoff, removes ground cover if road is unpaved, focuses high-energy runoff directly to streams at crossings)
- Off-road vehicle uses (disturbs soil, rutting leads to rills and gully erosion)
- Construction sites/urbanization (removes ground cover during construction, increases runoff)

Due to the high infiltration rates and low erosion potential of the limestone-based soils on the northern half of the island, there are no permanent streams and surface runoff is limited. As a result, erosion hazard is minimal and is not a soil erosion high priority area. However, increasing impermeable surfaces and changing landcover have resulted in increasing surface runoff, nuisance flooding, and erosion issues, particularly in heavily developed areas and low-lying coastal areas. This may be an issue for future research and investigation as development continues to increase in northern Guam.

The low infiltration rates, high erosion potential, and steep slopes in southern Guam result in a high potential for soil erosion and delivery of eroded sediments to streams, which flags this area as a high priority zone for erosion and sedimentation. To prioritize site-specific areas for potential treatments, the Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT) GIS model[44] was chosen to characterize relative erosion hazard areas in southern Guam.

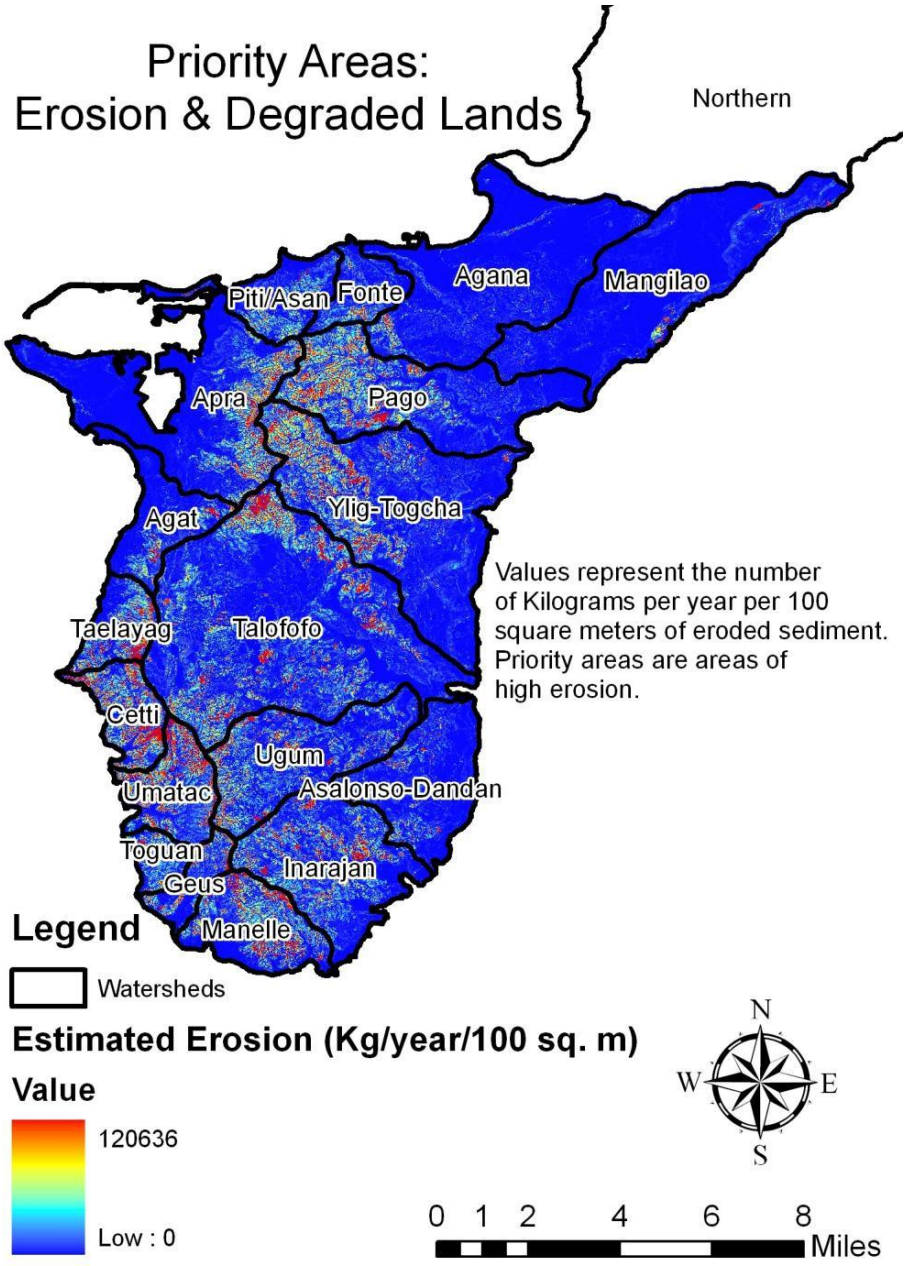

Figure 22. Priority areas for degraded lands, expressed areas that are undergoing erosion, 2010 SWARS.

[44] (Eslinger et al., 2005)

This model estimates surface and rill erosion and does not account for mass wasting, gully erosion, or streambank erosion. However, the same factors affecting surface and rill erosion (slope gradient, vegetation cover, soil permeability) also contribute to mass wasting and gully erosion.

Loss of soil and degradation of soil productivity can affect all areas of the landscape. The N-SPECT output map showed average annual erosion rates, which provide an estimate of the relative risk of soil/productivity loss (also identifies priority areas for *Issue 6. Degraded Lands*). Areas with the highest erosion risk occur in the headwaters of most of the watersheds in southern Guam (Figure 25). In general, these areas have steeper slopes, sparser vegetation, and higher rainfall rates.

Fire plays a large role in altering the native forest vegetation cover in Guam. Due to the moist conditions, fire is not a prevalent natural process. However, poachers intentionally light fires to improve hunting success as animals are drawn to new shoots that sprout following the fire. Human-induced fires have affected Guam for several thousand years. Intentionally lit fires continue today, and the resulting altered vegetation cover of savanna and grasslands are adapted to the current fire regime. These altered vegetation types result in an increase of erosion following a fire; as much as 4-5 times more sediment can be eroded from burned land as from savanna; savanna/grasslands produce more sediment than heavily forested areas.

Erosion of the upper soil horizons is a particular issue on the volcanic soils prevalent in southern Guam because the underlying material is saprolite. Saprolite is clay-rich, decomposed rock that has low pH, low fertility, and a stiff structure. Once the upper soil horizons are eroded and the underlying saprolite is exposed, vegetation generally does not establish well and will not thrive. These un-vegetated areas can remain bare for long periods of time and are locally referred to as badlands.

Eroded sediment that reaches streams degrades water quality, aquatic habitat, and downstream reef communities. Sediment that is eroded far from streams has a lower probability of reaching the stream because much of it is caught in small topographic depressions or behind vegetation or other roughness elements. An estimate of the risk of eroded sediment reaching streams was made based on the N-SPECT model results and a linearly decreasing delivery assumption (i.e., less sediment delivers the farther away erosion is from a stream) within a 1,000-foot buffer around mapped streams. The resulting map shows the risk of erosion *and* delivery of sediment to steams across the southern half of Guam (Figure 23).

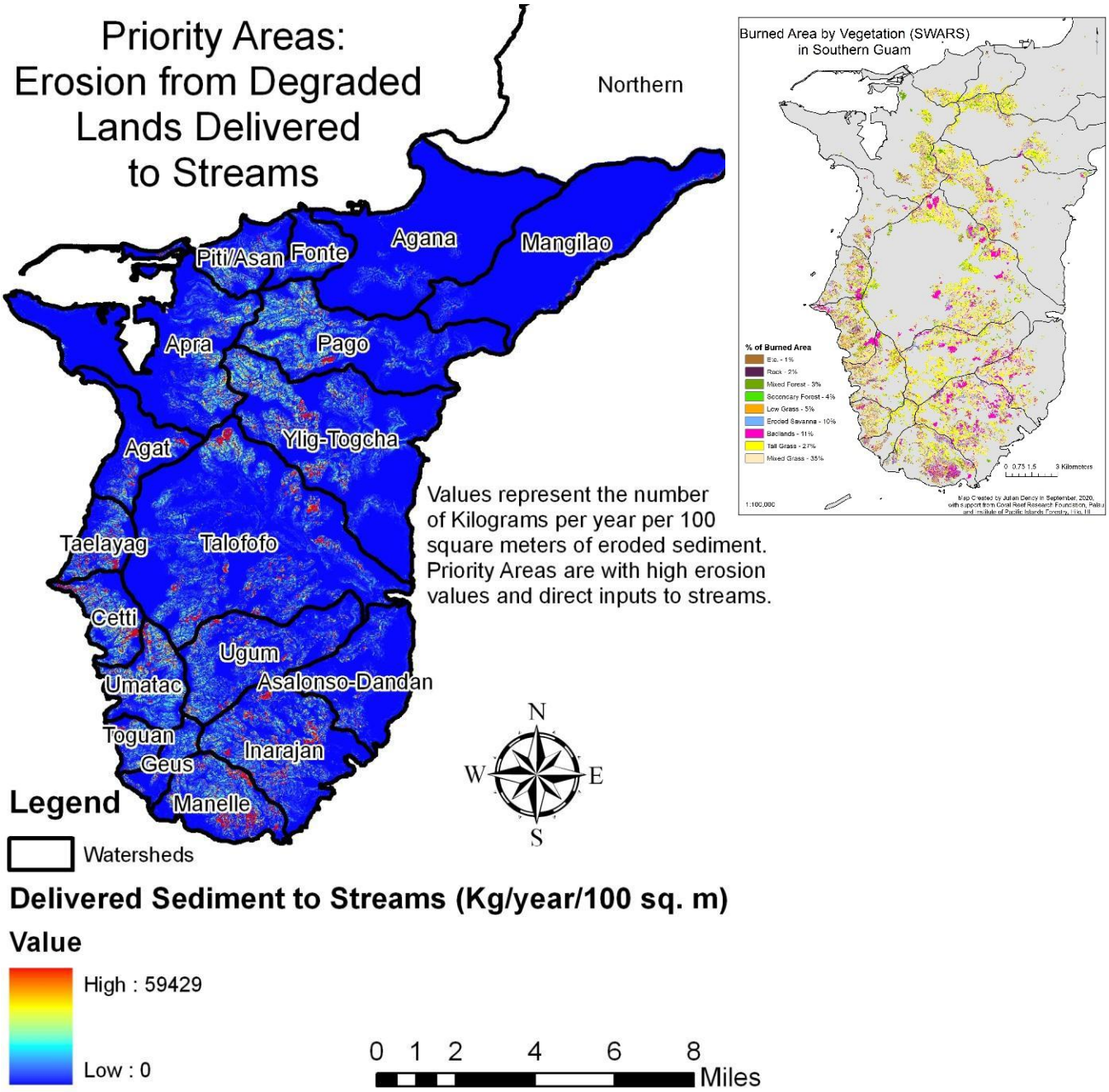

Figure 23. The priority areas for erosion and degradation that are delivering sediment to streams and other waterways.

The estimated sediment delivered to streams in each watershed is shown in Table 17. Watersheds with the highest relative sediment yield are those on the steeper west and southern coast; the Cetti, Manell (Merizo), Taelayag, and Umatac.

Table 17. Estimated delivered sediment yield by watershed. The data are summarized in Table 15.

Watershed	Estimated Delivered Sediment Yield (average tons/yr)	Watershed Area (sq mi)	Delivered Sediment Yield (tons/acre/yr)
Agana	5,238	13.62	0.6
Agat	15,785	3.92	6.3
Apra	40,330	12.94	4.9
Asalonso-Dandan	16,082	6.54	3.8
Cetti	43,395	3.01	22.5
Fonte	4,140	2.46	2.6
Geus	8,822	1.75	7.9
Inalajan	64,601	8.69	11.6
Manell	63,147	4.86	20.3
Mangilao	12,983	13.71	1.5
Pago	55,427	10.44	8.3
Piti/Asan	13,609	3.11	6.8
Taelayag	25,376	2.56	15.5
Talofofo	103,149	23.46	6.9
Toguan	11,736	1.41	13.0
Ugum	39,076	.58	8.1
Umatac	49,771	3.82	20.3
Ylig-Togcha	81,928	15.73	8.1

Erosion on Guam, particularly the southern half of the island, has resulted in degraded soil productivity, water quality, aquatic habitat, and reef communities. Based on existing data and studies, areas with the highest risk for erosion and delivery of eroded sediment to streams/reefs have been identified. N-SPECT, or a similar erosion prediction tool (e.g., DHSVM[45]) can be used to determine the relative decrease in erosion under different erosion control or re-vegetation effort scenarios and to help to select locations where improvements would be most effective.

Groundwater Infiltration

In northern Guam, the primary influence of water quality and quantity is related to the zone of contribution in the limestone aquifer (Figure 21). Principle activities that limit water absorption are roads, development, increases in impervious surfaces, and changes in forest cover that increase overland flow (and decrease absorption); these processes affect the *quantity* of water that is likely to be absorbed. Point source pollution, runoff from roads, and changes from native forest to industrial uses alters the *quality* of the water. In the northern region, Guam Forestry can provide tree ordinances along roads and developments to filter road and impervious surface runoff as well as provide greenspace to increase absorption (avoid conversion to impervious surfaces).

[45] Distributed Hydrology, Soils and Vegetation Model (DHSVM)

Water Quality and Erosion Priority Summary

The Stakeholder evaluation stressed the importance of protecting public water supplies and priority watersheds. Urban development and development associated with the military buildup are a threat to public water supplies on the island. Sediment modeling demonstrates the relationship between the altered vegetation types, fire frequency and the increase in erosion following a fire. Areas that show moderate to high sediment *delivery* rates are highlighted as priority areas in the south of the island. In the north of the island the development of greenspace ordinances in urban (or scheduled to be urban areas) represent high priority areas (see priorities in *Issue 3. Deforestation of Native and Old Forests, Issue 4. Urban Forest Sustainability, Population Growth and Urbanization).*

Forest management strategies that direct resources toward reestablishing native forests, preventing and reducing fire frequency, and providing rehabilitation of degraded landscapes will improve water quality and assure safe water supplies for the future.

Issue 3. Deforestation of Native and Old Forests

The evaluation of Deforestation of Native Forests (especially old forests) is an estimate of the threat posed to unique forest environments on Guam. Figure 24 displays a hybrid of the stakeholder-driven identification of native forests coupled with the tree crown map associated with the GFAP vegetation layer.[46] These forests have not been surveyed for forest structure, composition, and overall health, though the GFAP process has identified these areas as priority areas for conservation and gathering of ground-truth information through inventory surveys.

The stakeholder evaluation was qualitative in nature and identified potential deforestation threats to native and old growth stands in the headwater portions of southern Guam watersheds, and the coastal fringe in northern Guam. Some of these areas also have a high likelihood of development associated with the proposed military buildup.

Avoiding deforestation is highly dependent upon willing stakeholders and the capacity of land management agencies to administer and facilitate local conservation and conservation groups. Figure 24 represents the priority areas (all trees) for Guam for potential evaluation and conservation projects. Private lands provide opportunities for identifying potential Forest Legacy and Community Forests and Open Space projects and participants, as well as Forest Stewardship, Cooperative Fire and Forest Health projects for improving forest conditions, expanding forests and fuels conversion projects to minimize risk to forests. (The Forest Legacy Program may enable the Territorial government to purchase private forest lands in fee simple, or to pay for a conservation easement under which the Territorial government would monitor the private landowner's conservation of the forest. The Community Forests and Open Space program may enable a local government or land trust to purchase private forest land in fee simple.) In addition, the existing forest fragments can be coupled with areas delivering sediment to streams. Avoiding deforestation (and planting trees, and improving forest health) is extremely relevant to all Stakeholder Issues on Guam. Coordinating stakeholders that are willing to implement conservation (and enhancement projects) is paramount to the success of the project for further discussion on ownership and forest cover).

Figure 24 identifies key landowner types—the critical data gap is to inventory these lands and identify native forest reserves and potential candidate sites for conservation and enhancement programs. Native forest tree ordinances would enhance conservation efforts.

[46] (Mafnas 2010)

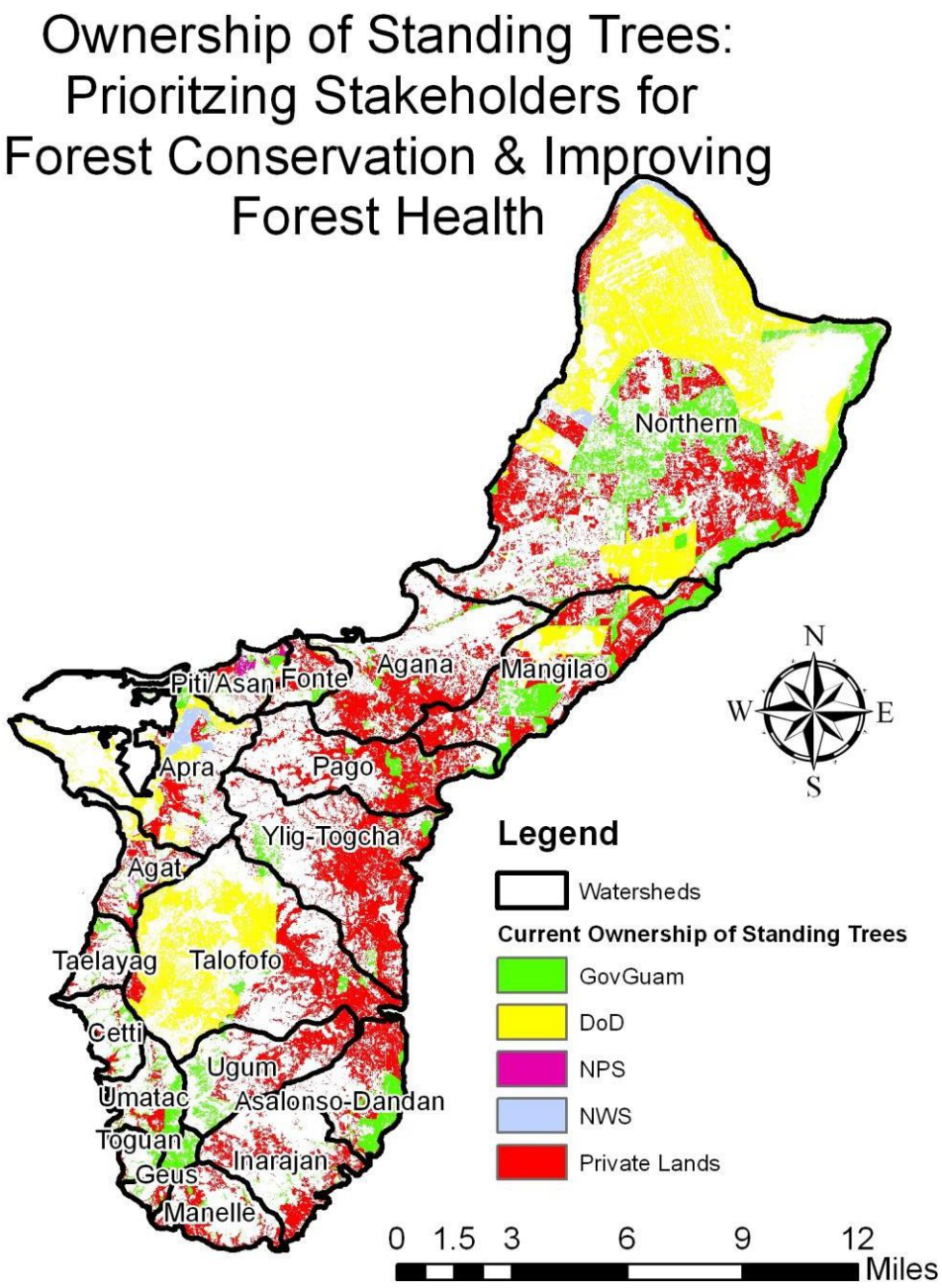

Figure 24. Tree crown map with forest fragments identified by current ownership, 2010 SWARS.

Primary Effects of the Buildup

The primary threat from the military buildup is the direct displacement of currently forested landscapes. This effect was measured as the potential displacement of trees within the major areas of development identified in the Guam buildup SEIS. For this analysis, the proposed areas considered were limited to the USMC Main Cantonment & Housing compounds ("Housing"), the proposed Andersen South Training grounds and associated firing ranges at Northwest Field on Andersen Air Force Base. These areas represent the largest areas currently proposed for construction.

In total, approximately 1,000 forested acres have been cleared to support the buildup, including about 80 acres of high-quality native limestone forest. Additional forest areas or fragments may be cleared outside the installation boundaries to accommodate roadways, transmission lines, and other infrastructure related to the buildup, as well as private development associated with the activities. The high demand for raw materials may drive the creation of new quarries, potentially leading to clearing of remnant stands of native limestone forest that are growing on areas valued for mining aggregate.

In addition to the direct effects, secondary effects are anticipated with changes to land use. Increased access to the forest can cause a range of disturbances, including increasing fire frequency (barbeques, increased off-road vehicle use, military operations), spread of invasive species (direct establishment or importation of new species from increased off-island transportation of goods and transport of existing invasive species to other parts of the island via road networks), and compaction or other physical damage to soils (increasing erosion and reducing forest health). Another secondary effect is the increased risk to disturbances as smaller forest fragments are more vulnerable to wind throw, flood damage, fire mortality, compaction, firewood harvest, and invasive species.

Issue 4. Urban Forest Sustainability, Population Growth and Urbanization

This issue focuses on the establishment and use of urban forests in planning within an urban intermix zone, rather than on the direct threats of development to forests. This issue was evaluated using two methods. The first was by the GFAP Advisory Council using qualitative measures of threat of development as identified from the *PIC Veg layer*. The second involved a fine-scale assessment of the current urban forest conditions using the GFAP vegetation map.

Stakeholder Evaluation of Urban Forest Sustainability

The GFAP Advisory Council identified that the threat to Guam's urban forest resources was primarily associated with development and the lack of ordinances to protect urban forest resources. The environmental attribute layer used to evaluate this issue was a measure of the proximity to areas of existing development, and private ownership.

The threats and priorities for urban forestry, as evaluated by the GFAP Advisory Council is depicted in Figure 25. The shades of red on the map show where existing development is heaviest and therefore where the continued threat to urban forests will occur Stakeholder evaluation shows wide-spread threats to urban forest sustainability, with heavy emphasis following road networks.

Stakeholder Evaluation of Threats of Development to Forests

The threat of population growth was evaluated by the GFAP Advisory Council and by a specific evaluation of the effect of military expansion on forest resources (previous section). The GFAP Advisory Council evaluated the threats of population increase based on the current distribution of cities and towns, with the threats of increased impervious surfaces (from roads, buildings, etc.). Population growth was assessed as having the highest threats and urban development within the northern watersheds. These are also the areas with the highest likelihood of development associated with the proposed military buildup.

This section discusses in quantitative and qualitative detail the threats to forests and urbanization in the next 10 years.

Threats of Development

There are a range of other secondary effects of development that can cause harm to forests, decrease their productivity, and limit their resilience to natural disturbances. Though not directly quantified in terms of acres, the major secondary threats to development include:

- **Military Buildup: Roads, Shopping Centers, Other Infrastructure.** Inherent with the projected population increases for Guam, there will likely be a need over the next 5 years to increase roads and transportation networks and increase business services for families and residents (military or civilian). These needs would likely expand other areas into potentially forested zones within and beyond the 500 ft urban intermix zone. New areas for development would directly displace trees and forest fragments. These areas will likely increase fire ignition points and complicate the fire risks to forests and urban zones on the island.
- **Edge Effects and Degradation around Developments.** Forest fragments, and their resilience to disturbance, are related to the amount of forest edge associated with the environment.[47] Increases in forest edge increases wind-driven disturbance (windthrow), invasive species establishment, and fire edge effects. All of these factors contribute to mechanisms that increase edge size (decrease fragment size), resulting in long-term disturbances related to the initial development.

[47] (Laurance and Bierregaard 1997)

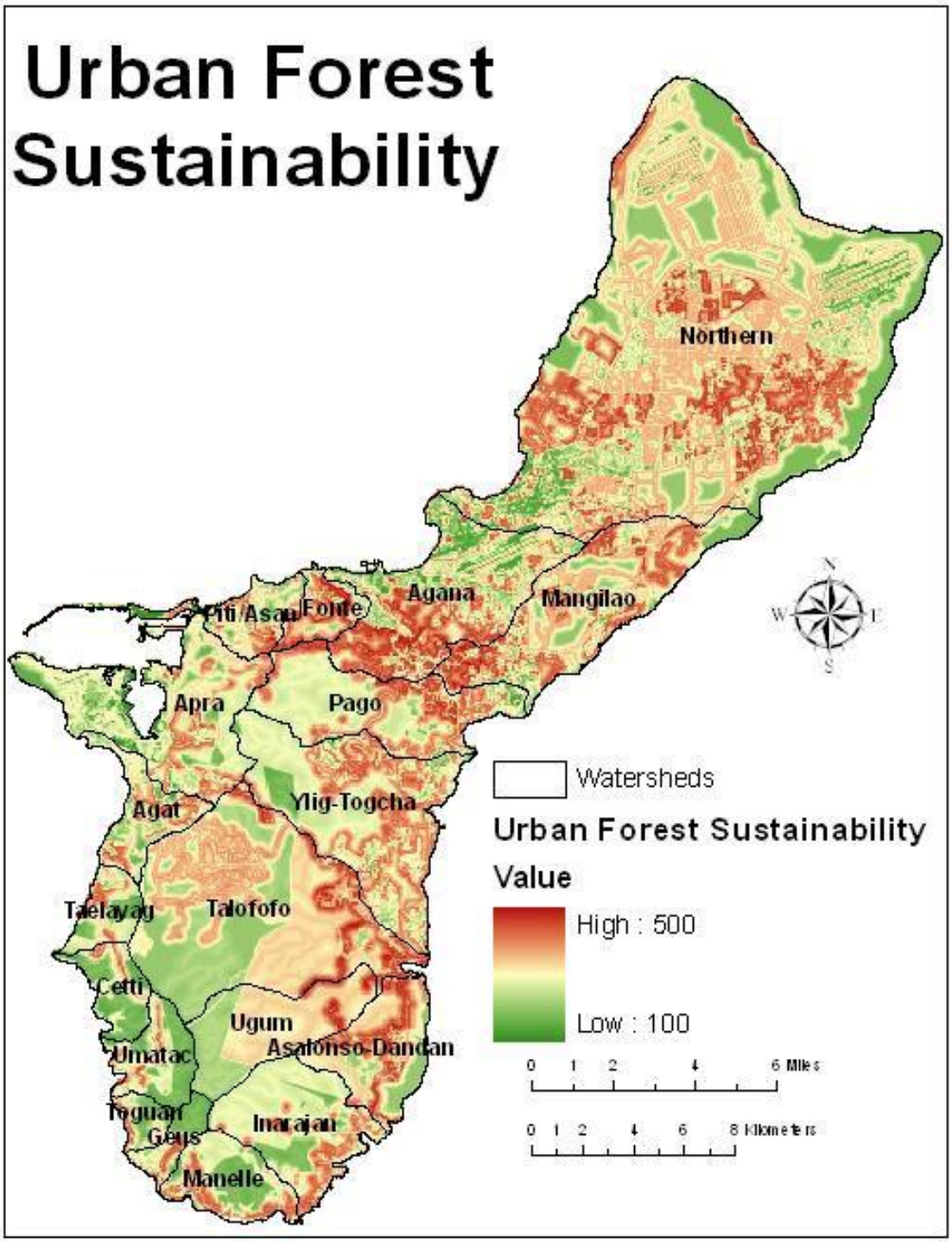

Figure 25. Priority areas identified by stakeholders for urban forest sustainability, 2010 SWARS.

Summary

The Stakeholder-developed map (Figure 25) highlighted the urban zones where the perceived threat of continued degradation through development is expected to occur. Specific priority areas have been identified that can be used for two major priority actions: (i) conserve, protect, maintain and monitor standing trees, and (ii) identify additional areas on all urban lands and engage private landowners to participate in urban forestry projects on non-forested lands. Inherent in both these actions is a continued focus on outreach and education to promote good arboriculture practices, making more people likely to understand how to better manage urban trees.

Strategy considerations should include estimating the *potential* for forest growth, specifically targeting areas where trees can provide multiple benefits, including recreation, abatement of sediment, reduction of hazardous fuels, urban habitat, and open space aesthetic values. Overall, the non-forest acres presented in Appendix 2 identify the *potential* areas for planting trees in the urban environment. Ground-truthing is needed to evaluate areas that have the highest value for the planting project, selecting stakeholder groups that will be most likely to maintain the plantings and ensure successful implementation.

A current implementation gap is incorporation of planting requirements into urban development plans. Potential for planting trees could include roadways, parks, greenways, edges of ponding basins and "functional areas" to offset runoff (e.g., bioswales to capture stormwater). Additionally, Guam does not currently have a tree ordinance that defines Best Management Practices (BMPs) or other regulatory considerations to address road runoff, sediment abatement, and parks and open space. This is a programmatic action that should be considered for implementing Urban and Community Forestry programs that would continue to meet multiple stakeholder objectives.

An important strategy as part of the Urban and Community Forestry program is to work with the DoD during the proposed expansion phase for new developments. Additionally, continuing to develop and establish partnerships with government, nongovernment, nonprofit organizations, and the private sector to expand the footprint of currently managed, abandoned and potential new urban green spaces. The use of tree ordinances that focus on *retaining standing forest* rather than *replacing* lost trees would help to increase the use of native species in urban forestry planning.

Issue 5. Degraded Lands

The GFAP Advisory Council identified areas that are considered a threat to future ecosystem health, with lands that have limited vegetative cover or are barren areas. The Degraded Lands map was developed from several environmental attribute layers during the Stakeholder evaluation period from the 2010 SWARS assessing – fire risk, proximity to protected and managed areas, riparian areas, wetlands, public water supply/priority watersheds and threats associated with development and slope. Threats are concentrated primarily in the headwaters and higher elevation areas of the Cetti, Piti/Asan, Ugum and Talofofo watersheds (Figure 26).

This issue overlaps with many of the other issues described in the assessment. In particular, the rate of potential recovery from degraded lands status is dependent upon the ability to successfully be reforested, while maintaining a fire-free environment for several years following planting. Because degraded lands have larger areas of exposed soils and can contribute to higher amounts of eroded sediment to streams and reefs, prioritization of degraded lands is similar to the prioritization of high-risk fire-prone areas that are within a delivery distance to streams.

The priority areas and rational discussed in *Issue 2. Water Quality and Water Supply*, specifically the *Water Quality Priorities: Soil Erosion and Sedimentation* beginning on page 65, is especially relevant to this Stakeholder Issue. Priority Areas for degraded lands are mapped for sites to plant having high erosion (Figure 26), with higher priorities set for those eroding areas where sediment is being delivered to streams (Figure 23).

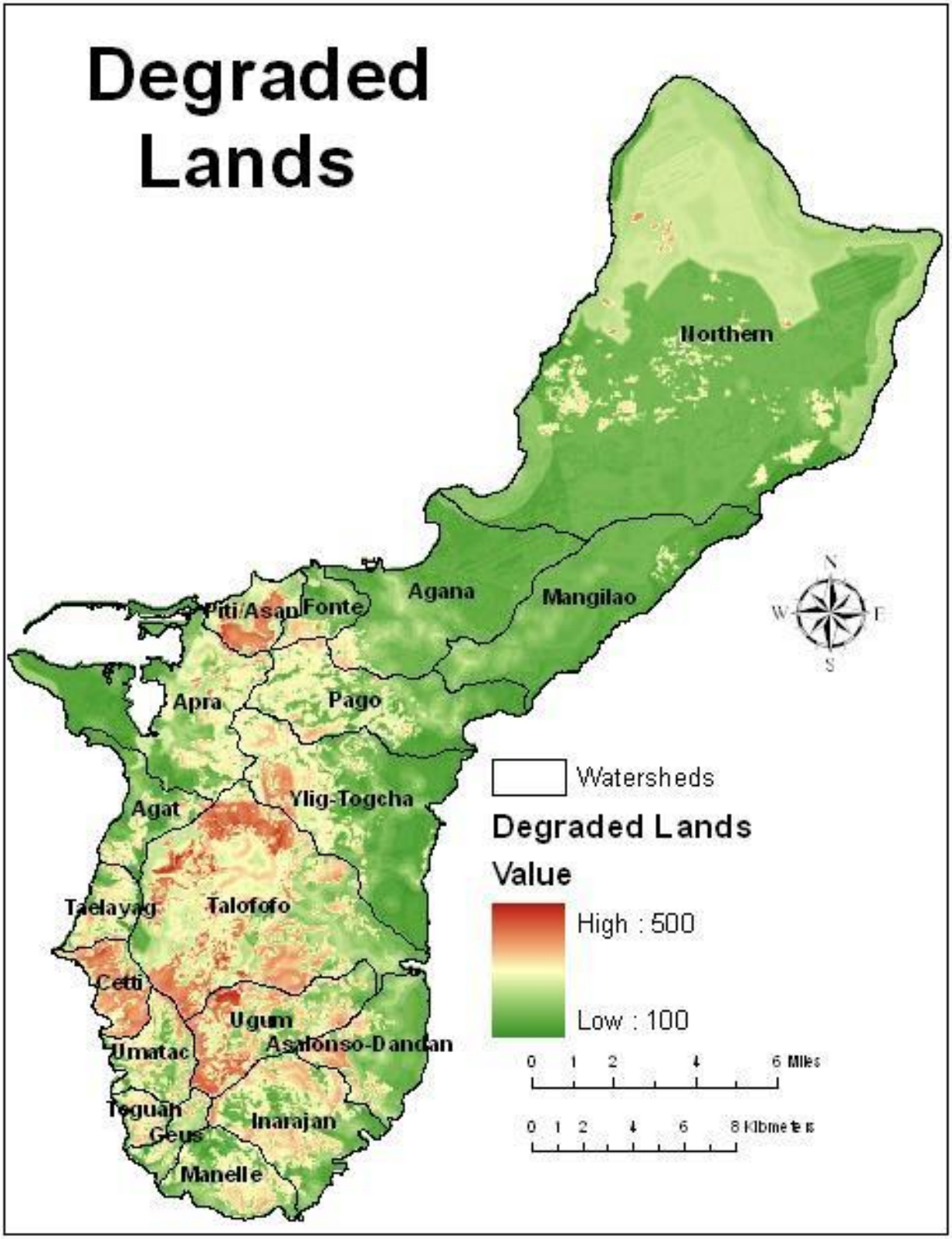

Figure 26. Perceived prioritized degraded lands issue map developed by stakeholder evaluations, 2010 SWARS.

Issue 6. Invasive Species and Forest Health

"Forest health"[48] is defined as a descriptor for forest conditions and trends, including the resilience of forested environments to a range of biotic (living) and abiotic (non-living) disturbances. This section begins with quantitative discussion on the current structure of forests, an analysis of available trend information in forest cover, and a qualitative discussion on a range of abiotic and biotic disturbance regimes and their known status and effects on the forests of Guam. The information presented in this section is drawn from a forest inventory analysis (FIA) conducted by the U.S. Forest Service in 2013.[49] Forty-eight plots spaced uniformly at 1.9-mile intervals in a hexagonal grid were sampled over the entire island (Figure 11). In addition, 67 plots were sampled by the Micronesia Challenge (MC) in 2013 using similar methodology, but with a focus on protected conservation areas in northern Guam and in ravine forests in southwestern Guam.[50]

Disturbances Affecting Forests Health

Approximately 1/2 or 49% of island trees exhibit damage from a wide range of causes which include animals, insects, weeds, fire, disease, and storms (Table 19).

Table 18. Estimated forest area and SE (acres) and % of total forest area and SE affected by disturbance in Guam forests.[51]

Disturbance	Estimated Area (acres?)	SE (acres?)	% Total Forest Area	SE
Animal damage	20,778	4,167	30	5.9
Insect damage	11,040	3,494	16	4.9
Vegetation suppression	2,408	1,790	3	2.6
Fire	3,633	2,044	5	2.9
Tree disease	256	616	0	0.4
Any disturbance	34,205	4,882	49	6.4
Undisturbed	35,380	5,007	51	6.4

[48] "Forest Health" (in sentence capitals) is used here as being analogous to overall condition. "Forest Health" (capital letters) refer to the specific S&PF program and activities that it funds.

[49] (Lazaro *et al*. 2020)
[50] (Micronesia Challenge 2019)
[51] (Micronesia Challenge, 2019)

Abiotic Disturbances Affecting Forest Health

There are a number of abiotic or non-living threats to island forests in the form of storms, droughts, urban development, and fire. Guam's climate is uniformly warm and humid throughout the year, with two distinct seasons. There is a dry season between December and May and a wet or rainy season from June to November (Figure 27).

Storms may have a devastating impact on the island landscape. Frequent tropical storms and typhoons (Table 20), especially during the weather phenomenon "El Nino" may cause dramatic damage to forests and are most prevalent during the wet season months of September to November (Figure 27).

Abiotic factors, such as drought, can increase a tree's susceptibility to disease and insect attack.[52] Short term droughts frequently occur during the dry season and may be exacerbated by conditions typical of an El Niño weather pattern following active typhoon seasons. Droughts may reduce tree growth and increase tree mortality. Storm damage may cause defoliation, toppling of trees, limb breakage, and damage due to saltwater spray and inundation. These forms of damage provide niches and enhanced opportunity for exotic "pioneer" species to become established in a forest. These "pioneers" are often aggressive non-native or invasive plants that rapidly outcompete native plants. Winds from tropical storms or typhoons may also spread insect pests and weed seeds.

[52] (Szczepaniec and Finke, 2019)

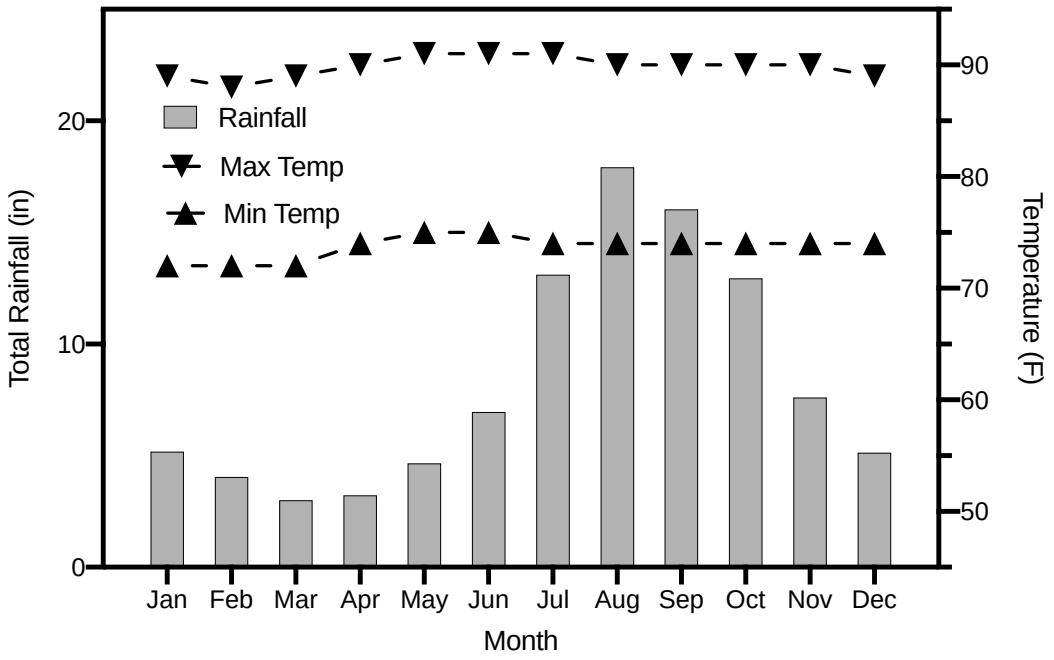

Figure 27. Yearly weather averages for Guam 2000 – 2019.[53]

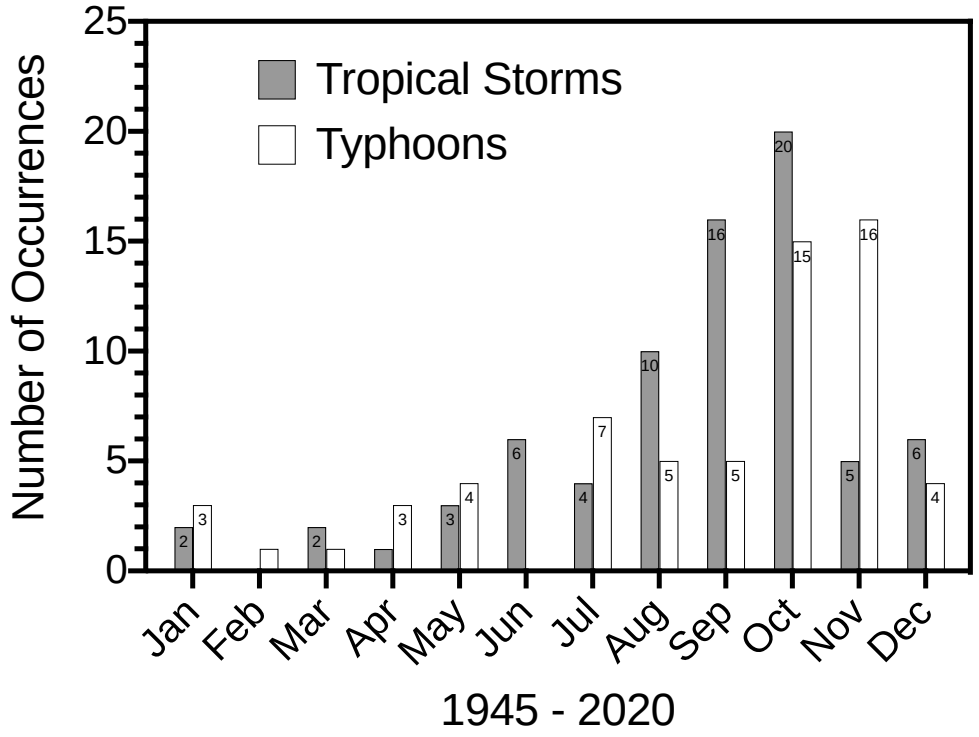

Figure 28. Number of tropical storms and typhoons within 120 nautical miles of Guam between 1945 – 2020.[54]

[53] (NOAA, 2020a)
[54] (NOAA 2020b)

Table 19. Total number and mean number/year of tropical storms (36 mph - 74 mph) and typhoons (>74 mph) by closest approach to Guam between 1945 and 2020.[55]

Closest Approach to Guam	Total Number of Tropical Storms	Number of Tropical Storms/Year	Total Number of Typhoons	Number of Typhoons/Year
Within 180 Nautical Miles	135	1.85	103	1.37
Within 120 Nautical Miles	78	1.04	64	0.85
Within 60 Nautical Miles (Direct hit)	35	0.47	26	0.35

The small size, as measured by DBH, and the lack of height in island trees is probably due to the negative impacts of droughts and storms on Guam's forests. Guam has an urbanizing environment as described in a previous section. The land development related to this urbanization has a major impact on forests in the direct removal of trees and the fragmentation and degradation of forest. Fire is a major disturbance affecting forest health and is addressed in other sections of this plan.

Biotic Disturbances Affecting Forest Health

Invasive Plants

Invasive plants are a serious threat to Guam's forests (Table 21). Regionally, there is the Pacific Islands Ecosystems at Risk project or PIER[56] which has an interactive online database that lists 495 plant species that are profiled as invasive or potentially invasive that occur in Guam. It includes those plants of environmental concern (including those that are probably of threat only to islands with high elevations) as well as agricultural and pioneer (ruderal) weeds. There are current efforts by Guam Forestry, UOG, and the Guam Invasive Species Advisory Committee (GISAC) to identify the "highest priority" (top 10 – 20 species) that are the most prolific within

[55] (NOAA, 2020b)
[56] (PIER, 2020)

native forests and have the capacity to radically affect forest health and function in a short period of time.

In general, priority species are controlled using mechanical, chemical and biological methods. Weeds of widespread importance in the western Pacific that are currently under control actions include cogon grass (*Imperata cylindrica*), mile-a-minute vine (*Mikania micrantha*), Siam weed (*Chromolaena odorata*), Koster's curse (*Clidemia hirta*), giant sensitive plant (*Mimosa diplotricha*), and root beer plant (*Piper auritum*). Trees such as Molucca albizia (*Falcataria moluccana*), African tulip (*Spathodea campanulata*) and vitex (*Vitex parviflora*) grow at rapid rates and hinder growth and establishment of native forests.

Quantitative data on invasive plant distribution is sparse, as is a unified island-scale strategy for invasive species detection and management on Guam. A coordinated effort with Guam Forestry and stakeholders, including GISAC, UOG, APHIS, and CAPS (Cooperative Agricultural Pest Survey), is needed to centralize information and strategies to address invasive species information. There is currently no clear island-scale strategy for invasive weed species management on Guam, though stakeholders have been engaged through the GFAP process to develop a strategy for addressing invasive plants (see *Strategy 4: Implement a Forest Health Program: Unify Interagency Efforts to Control Invasive Species*). Refinement of the priority species, their effects, distribution, and magnitude of disturbance requires focused effort, local capacity, leadership, and targeted funding to pursue.

Table 20. All invasive plant species by occurrence (# and % of all subplots present), average % cover and estimated acreage of forest covered (with SE) in the MC invasive subplots on Guam.[57]

Scientific Name	# of Subplots	% Occurrence	Average % Cover	Acres of Forest	SE
Vitex parviflora	114	32	40	9,269	1,887
Leucaena leucocephala	105	29	21	6,860	1,408
Heterospathe elata	18	5	29	2,735	1,270
Antigonon leptopus	13	4	27	1,850	839
Averrhoa bilimbi	25	7	18	1,285	624
Epipremnum pinnatum	12	3	21	1,225	294
Mikania micrantha	108	30	4	1,113	504
Panicum maximum	15	4	26	565	247
Bidens alba	25	7	6	513	205
Pennisetum polystachion	26	7	8	506	229
Chromolaena odorata	122	34	3	424	118
Adenanthera pavonina	2	1	35	357	203
Syngonium podophyllum	7	2	8	295	144
Spathodea campanulata	5	1	9	223	111
Tradescantia spathacea	1	0	30	145	120
Mucuna pruriens	9	3	4	113	59
Stachytarpheta jamaicensis	22	6	2	86	39
Euphorbia cyathophora	14	4	1	85	28
Arundina graminifolia	9	3	2	76	41
Imperata cylindrica	4	1	6	17	25
Lantana camara	4	1	6	17	25
Momordica charantia	1	0	1	1	2
Mimosa diplotricha	1	0	1	1	2

Feral Ungulates

Feral pigs (*Sus scrofa)* and Philippine deer (*Rusa mariana)* are present throughout Guam and inflict tremendous damage on forest stands. Pigs eat young seedlings and seeds, damage roots, and may gouge the trunks of some trees, including cycads. Pigs also spread invasive species, including *Annona reticulata*, *Averrhoa bilimbi*, and *Annona muricata*, which can form dense stands that exclude most native tree and understory species. Deer also damage adult trees by browsing, and through rubbings that effectively girdle small trees. Seedlings and seeds are consumed in their entirety, leaving many areas devoid of young trees and dramatically reducing biodiversity.

[57] (Micronesia Challenge 2019)

Asian Cycad Scale

The Asian cycad scale (*Aulacaspis yasumatsui*) was detected in 2003 on the common ornamental king sago palm (*Cycas revoluta*) in Tumon Bay and rapidly spread to other *C. revoluta* within urban areas. The scale also readily infests a cycad endemic to Guam, *Cycas micronesica*, that is a co-dominant species of the native karst-limestone and riparian forests. In 2005, the cycad blue butterfly, *Chilades pandava*, was detected on Guam after having been previously collected on Saipan. *C. pandava* caterpillars further decreases the resilience of native cycads by feeding on young emergent leaves, thus reducing overall leaf area and lowering the tree's resistance to scale infestations. Mortality rates of native cycad between 2004 and 2007 were estimated to be approximately 9% per year on permanent transects,[58] suggesting the threat of extirpation of *C. micronesica* within the next few decades. Native *Cycas micronesica* was placed on the IUCN Red List of Threatened Species in 2006[59] and were listed as threatened by the U.S. Fish and Wildlife Service in 2015.

In response to the outbreak of Asian cycad scale and its associated high mortality rates, a coccinellid beetle, *Rhyzobius lophanthae*, was introduced as a biocontrol agent from Maui, Hawaii. While initial results with *R. lophanthae* appeared promising, a subsequent decline in beetle populations coupled with high seedling mortality due to the beetles' failure to forage for scales on small, immature plants, has limited its effectiveness. Other efforts to introduce parasitoid wasps onto Asian cycad scale have not proven successful.

Coconut rhinoceros beetle

The coconut rhinoceros beetle (CRB), *Oryctes rhinoceros* L., was detected at Tumon Bay and Fai Fai beach in September 2007. CRB is native to southeast Asia and was thought to be accidentally introduced via cargo deliveries to Guam as early as 2005. CRB is a serious pest that affects palms, including coconut, *Cocos nucifera*, betelnut, *Areca catechu*, and native *Pandanus* spp. Past outbreaks of CRB in the Pacific have caused widespread damage. Nearly 50% of palms in Palau were killed soon after its introduction there in 1942. Its presence on Guam, and more recently on Rota in the Commonwealth of the Northern Mariana Islands (CNMI), poses a direct threat to other

[58] (Marler and Lawrence 2010)

[59] (IUCN, 2020)

islands within Micronesia that rely on coconuts and related plants, as a major source of food and fiber.

Palms in urban settings and large stands of coconut and beetle nut palms found in Guam's forests are threatened by CRB. Habitat for this large scarab beetle is plentiful. Larvae live in litter and debris, of which there is an abundance due to high levels of dead and dying coconut palms generated from typhoons and tropical storms. Potential native vertebrate predators of beetles, including birds, have been largely reduced or extirpated on Guam by the brown tree snake and development activities.

An interagency incident command team has been in place since the initial stages of CRB infestation on Guam with a cooperative eradication program between the USDA's APHIS, the U.S. Forest Service, the Guam Department of Agriculture, and the University of Guam. Monitoring traps are positioned along roadsides throughout Guam, with a focus on the urban centers. CRB has also been observed on other hosts such as fan palms, which is an indication of further CRB spread.

In many countries, two diseases have been used as biocontrol agents – one fungal, *Metarhizium anisopliae*, and one viral, *Oryctes* sp., which may prove to be an important component in an Integrated Pest Management (IPM) strategy on Guam. Managing CRB spread on Guam is of imperative concern for subsistence communities that are reliant on coconut for a major food source elsewhere in Micronesia. Guam's importance as a central hub for travel and exchange of goods and services allows for potential vectors of spread to other islands that do not have CRB.

Little fire ant

Little fire ant (LFA) has been placed in the top 100 of worst invasive species worldwide. It quickly spreads by human intervention throughout forest and residential areas. In the areas it infests, native populations of insects and other animals are decimated and often eliminated, creating an ecological desert. LFA may move indoors infesting homes and pose significant health threats to those with allergies to insect venom, which may require hospitalization in severe cases. Areas such as parks, or private gardens or orchards may be rendered unusable due to the presence of the ants, which sting anybody venturing into infested areas. Animals in LFA-infested areas may become agitated due to repeated stings, and stings on animal eyes may result in irreversible blindness due to corneal damage. Populations of pestiferous insects, primarily among the Hemiptera such as aphids,

mealybugs, and whiteflies, may be enhanced by the well-developed attendance behavior of LFA, which may in turn result in crop and ornamental damage due to increased vectoring of plant diseases as well as direct feeding damage to plants.

Past and ongoing projects funded by the USDA Forest Service and USDA APHIS to combat LFA have allowed the University of Guam to modify techniques developed by the University of Hawaii-Hilo Ant Lab under the direction of Dr. Cas Vanderwoude, that have proven effective on Guam. In addition, USDA APHIS has provided funds for LFA surveillance on Guam and in the CNMI, resulting in a small core of trained personnel at the University of Guam and in local and federal government agencies with expertise in identifying and treating LFA. We estimate that well over 50 sites on Guam are infested with LFA, ranging from federal DOD lands at Andersen South (AAFB), National Park Service Lands, Guam public lands, and private and commercial lands throughout the island.

Little fire ant (LFA), *Wasmannia auropunctata*, was detected in November 2011 at a single forested site near a green waste landfill in northern Guam. Subsequent LFA surveys throughout Guam and the adjacent islands of Saipan, Tinian, and Rota suggest that it is presently established on over 50 sites on Guam alone. These sites include the original detection site on about 5 ha of karst-limestone forest surrounding an active green waste hardfill near Yigo in northern Guam, watersheds in southern Guam, and numerous forested areas, small farms and residential areas throughout the island. Previous LFA infestations in the Pacific Basin include those of the five major islands of Hawaii, New Caledonia, and Northern Queensland, Australia. These LFA-infested regions all have air and sea connections to Micronesia. The devastating effects of LFA on agriculture and forest ecosystems observed in LFA-infested areas in Hawaii, Australia, New Caledonia, American Samoa, and Yap, are being repeated on Guam and potentially may occur on any other Micronesian island infested by LFA. LFA spread to and throughout Guam is most likely due to human transport of infested plant material.

Technology has been developed in Hawaii at the University of Hawaii-Hilo, in New Caledonia, and Australia to eradicate or manage LFA infestations. These techniques have been successfully adapted for use in LFA-infested areas on Guam. Past approaches to LFA management focused on the application of appropriate environmentally safe insecticides applied in a manner where LFA workers will carry the toxicant back to the many reproductive queens in the colony. These queens ingest the toxicant, die and over time the entire colony is destroyed. Any strategy adapted from outside of the humid tropical islands of Micronesia must be adapted to the unique conditions of Guam to be effective. The most promising strategy for LFA control is the application of ant specific

toxicants using handheld applicators. Granular bait formulations of insecticides are applied to control ground dwelling LFA colonies, while a sticky gelatinous bait matrix containing insecticide is squirted onto the trunks and crowns of trees within LFA- infested areas. The ants feed on the baits ingesting the insecticide in sub lethal doses which are then transported by workers to the main colony and to the reproductive queens. Upon ingesting the bait and the insecticide, both workers and reproductive queens across the entire habitat spectrum occupied by LFA are eventually intoxicated and die. This system has been used successfully in Hawaii to eradicate LFA from small areas of tropical forest and farmland and has proven effective in Guam's forests as well. Similar applications to include the use of drone technology are being applied locally.

Casuarina Dieback

Casuarina equisetifolia, gago or ironwood, is a hardy, pioneer, salt-resistant tree that occurs on both limestone and volcanic soils. Its ability to fix free nitrogen allows it to thrive on coastal sands where few other plants can survive. Native to the Marianas, including Guam, ironwood is widely used and propagated for windbreaks, reforestation and erosion protection programs on southern Guam's volcanic soils. Although normally a hardy species, widespread dieback of ironwood is occurring on Guam. The health and survival rate of ironwood trees on Guam have been declining due to fungi and bacteria and a series of severe typhoons during 2002. Typhoons Chata'an[60] and Pongsona[61] caused widespread limb breakage and defoliation. The USFS FIA program estimated that Guam had 116,000 ironwood trees 5 inches in diameter and greater during a 2002 forest inventory and that trees were generally healthy. Today, tens of thousands of these trees are dying on Guam. The decline is exacerbated with frequent fires in the savanna grass areas.

Casuarina dieback is most likely due to a bacterial wilt, *Ralstonia solanacearum.*[62] A complex of biotic and abiotic factors also can contribute to tree decline. Possible biotic factors include fungi of the genera *Ganoderma*, *Pestalotia*, *Botryosphaeria*, and *Fusarium*, as well as several yet unidentified fungi and bacteria. Insects, including termites, and a gall-forming eulophid wasp, tentatively identified as belonging to the genus *Selitrichodes* (Eulophidae: *Tetrastichinae*) can also affect tree health.

[60] (July, 2002)
[61] (December, 2002)
[62] (Schlub 2019)

In addition to typhoons, abiotic factors affecting Casuarina include severe drought and proximity to urban developments. The healthiest ironwood trees are in native stands on Cocos Island, 1.6 miles off the southern tip of Guam, and at the Guam National Wildlife Refuge at Ritidian Point on the northern tip of Guam. Casuarina decline appears to be distributed randomly across Guam and is also reported from Rota but not Saipan or the FSM, where it is native, nor on Hawaii where it has been introduced and widely planted.

Synthesis of Issues: Actions Meeting Multiple Objectives

As mentioned in the Stakeholder Issues sections above, each of the 6 Stakeholder Issues are interlaced with each other, so single, targeted management actions can meet multiple objectives identified by stakeholders. Likewise, objectives and funds from multiple S&PF Programs can be applied to single activities on the landscape, and used to increase efficiencies in implementation, maintenance and monitoring.

This section synthesizes the threats and processes and identifies specific locations of planting and treatment activities that are the Highest Priority Areas for Treatment[63] to satisfy the broadest range of threats, over the broadest range of issues, under the broadest range of S&PF Programs and National Themes. This section lists the Highest Priority Areas in the urban zones and around forested areas, and does not preclude the importance of the Priority Areas in prior sections. These areas are in fact a subset of Priority Areas from multiple issues, and represent the framework to conduct the first implementation actions for treatments on the landscape in the next 10 years (Figure 33).

Bringing Broad Stakeholder Issues to Specific Threats

The six issues identified by stakeholders are linked to major island-scale risk factors that meet the three National Themes. The three major drivers include: fragmented forests, risk of severe fire behavior, and population growth associated with the military buildup. Table 22 displays the primary drivers of degradation on Guam and how they are related to the stakeholder issues.

[63] "Highest priority" areas are not the only priorities for treatment. These areas represent the most critical threats and should be considered the first areas to apply treatment.

Table 21. Synthesis of Threats and Major Drivers to Issues Identified by Stakeholders.

	Major Drivers Affecting Stakeholder Issues		
Stakeholder Issues	**Fragmented Forests and Conversion to Grasslands & Savannas**	**Fire Risk**	**Development and Military Build-up**
1. Wildfire and Public Safety	Increases fire risk	Associated with altered veg. cover	Fire risk increases expansion into forests
2. Water Quality and Supply	Reduces water capture & increases sedimentation	Removal of veg. cover increases sedimentation	Construction and development directly impact water quality; increased water supply demand
3. Deforestation of Native and Old Forests	Limited (and unknown) intact forests remaining	Fire threat to remaining intact forest	Direct risk of deforestation by construction of military facilities, as well as private development driven by the buildup
4. Urban Forest Sustainability, Population Growth and Urbanization	Altered forests threatened from invasive plants, insects and disease; Increased population contributes to forest removal and pressure on remaining forests	Direct threat of fire in urban areas; Fire risk increases with increase in Wildland Urban Interface	Increased population – removal of forest canopy in developed areas; direct population increase due to military buildup
5. Degraded Lands	Conversion to non- forest communities increases acreage of degraded lands	Increased fire frequency is a primary cause of degraded lands	Increased development and population are factors for increasing acreage of degraded lands
6. Invasive Species and Forest Health	Increases edge effect and exposure invasive flora/fauna introductions impacts	Opens corridors for invasive species introductions, and increases fragmentation of forest resources.	Increased development exposes vulnerable forest resources to potential threats.

Management options or strategies associated with the stakeholder issues are fundamentally tied to mitigating the threats or risks on natural resources. In many cases, these involve similar treatments (e.g., tree planting); targeting specific areas that meet multiple objectives is a cost-effective method for land management that accomplishes goals of multiple programs and is met with broad stakeholder agreement (and potentially matched funds).

Overall, there is a need to protect forests from fire risk, reduce fragmentation, and degradation: these landscapes have been spatially identified as the Highest Priority Areas. Areas have been

identified that are within a narrow edge to standing forests where fire behavior risk is moderate to high, posing a threat to standing stocks from fires that are difficult to suppress. A program managing wildfire risk to prevent, isolate and control fires requires pro- active treatments, rather than "reactive" treatments (suppression only). Treatments designed to expand and manage forest fragments to make large, contiguous blocks of forests more defensible by incorporating thinning, lifting canopies, removing ladder fuels, regular maintenance to increase forest resilience to fire, decrease fire size, and isolate the opportunity for future fires to exist.

Pro-active fuels treatments (re-establishing native tree cover, fuel breaks, etc.) to prevent, isolate or control fires will also aide in meeting water quality objectives. Burned areas are more susceptible to sediment runoff. Grassland/savanna areas identified as known sediment delivery sites pose additional threats to water quality should these sites burn.

Population growth on Guam is a major consideration and poses potentially severe impacts to natural resources. The military expansion is scheduled to construct housing and training facilities on approximately 1,000 acres. Secondary effects of the military expansion are less quantifiable, and involve the creation of new roads, power lines, increased recreation, increased traffic and potential new secondary civilian developments (housing, shopping centers, etc.). The Cooperative Fire Program has been in regular communication with DoD fire and emergency response departments and DoD environmental with regard to firebreak, greenbelt, and prescribed burn discussions and planning. Prescribe burn has been identified as a potential useful management tool but the use of prescribe burn must be carefully considered for Guam, as the entire island is considered a coastal zone, and impacts from fire are felt immediately within watersheds. Additionally, the Urban and Community Forestry Program is active and will continue to expand engagement opportunities by working with but not be limited to nonprofit organizations, community groups, Government of Guam agency partners such as the Guam Hotels and Restaurants Association, Guam Visitors Bureau, Guam Power Authority, Department of Parks and Recreation, the Urban and Community Forestry Advisory Committee and DoD. Efforts shall include engaging vegetation management businesses and agencies (landscapers, maintenance crews, University of Guam – College of Natural and Applied Sciences and partners) for continued efforts toward developing tree ordinances and other mechanisms to *avoid* deforestation as well as planting additional trees to meet other objectives (water quality, etc.).

All programs will benefit from Readiness and Environmental Protection Integration (REPI) program funding that was awarded to Guam in 2020. Collaborative efforts are underway between DoD and Guam Forestry.

The magnitude and extent of the key threats are summarized in two sections: one for the urban

environment and the other for the forested areas outside of the urban zone. The information is presented in this way to facilitate the relationship between a threat and the S&PF program that best addresses the threat*. In many instances, S&PF Programs that are currently managed separately are combined in the strategy to fully address the issue.*

The following two sections outline a total of 13,098 acres that are the Highest Priority Areas for treating multiple objectives. Approximately 4,178 acres are in the urban areas and 8,920 acres are located around forest fragments. Detailed tables and maps are provided in these sections.

Meeting Multiple Objectives: The Urban Environment Highest Priority Areas

Table 16 summarizes the extent of the urban area by watershed and identifies critical areas that are the Highest Priority for treatment (Figure 33). This does not preclude priorities for other issues, but provides on-the-ground locations for how a single treatment (tree planting) can mitigate multiple threats and meet objectives for multiple stakeholder issues.

These areas focus on the combined effects of wildfire and public safety (Issue #1), water quality and water supply (Issue #2), deforestation of native and old forests (Issue #3), urban forest sustainability, population growth and urbanization (Issue #4), and minimizing degraded lands (Issue #5), invasive species and forest health (Issue #6). Planting trees in these areas are within the Urban, Stewardship, and Cooperative Fire Programs. Monitoring the plantings and expanding forest patches to close the distance between existing fragments also falls within the objectives of Forest Health programs.

A total of 4,178 acres were identified in the urban areas and associated 500 ft. buffer zone for treatment to meet these multiple objectives (Table 23). These acres are mapped in the Priority Area map in Figure 33. The columns in the table describe the following:

- **Watershed Acres**. Total acres in the watershed.
- **Area Classified as Urban Acres**. The mapped areas included in the urban zone. The urban zone included spatial layers (from the PIC Veg layer) identified as: 1) Urban Built-up, primarily mapped impervious surfaces such as buildings, parking lots, and roads, and 2) Areas mapped as Urban Open Space, which are areas within the urban zone that are not identified as forested.
- **Urban Buffer Acres**. This is the total number of acres within the 500 ft. buffer zone mapped around the Urban Zone.
- **Forested Acres within the Urban Buffer:** The area within the within the 500 ft. buffer

that is classified as forested (includes individual trees plus forest fragments).

- **Highest Priority Area for Planting Treatments in the Urban Buffer**: This is the land area that is currently not forested (but potentially will support trees) in the urban zone, where fire risk is moderate or higher and the location was identified as delivering sediment to streams. These are considered the first line of planting for urban forestry, based on an ecosystem threat basis. These acres are mapped in Figure 34.

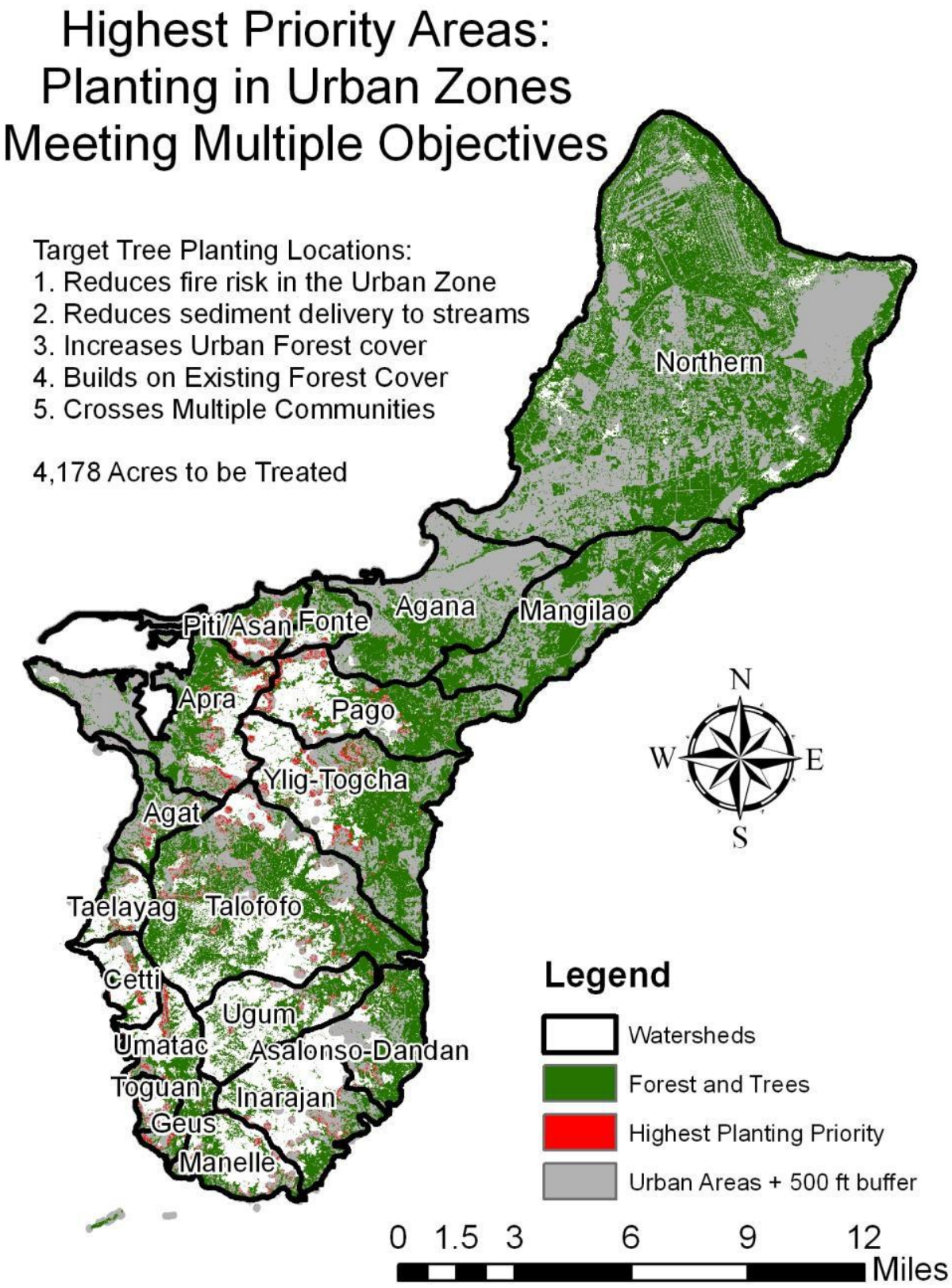

Figure 29. Highest priority areas for planting in urban zones to meet multiple objectives.

Table 22. Highest priority urban planting treatment areas to meet multiple objectives within the urban intermix zone.

Region	Watershed	Watershed Acres	Area classified as Urban (Acres)	Urban Buffer (500 ft. buffer in acres)	Forested Area within the Urban Buffer (acres)	Highest Priority Treatment Areas for Fire Risk and Areas Producing Sediment to Streams
Eastern	Pago	6,683	1,536	2,907	1,371	289
	Ylig-Togcha	10,067	3,038	5,773	2,735	397
	Talofofo	15,016	3,007	5,283	2,276	652
	Ugum	4,851	189	301	111	29
	Asalonso-Dandan	4,183	755	1,477	720	50
	Inarajan	5,564	946	1,502	560	174
Western	Manell	3,107	525	931	406	118
	Geus	1,120	330	498	169	112
	Toguan	903	302	391	90	89
	Umatac	2,447	549	705	156	232
	Cetti	1,928	280	361	81	135
	Taelayag	1,639	428	641	214	78
	Agat	2,511	1,378	2,036	660	145
	Apra	8,283	4,137	5,951	1,813	466
	Piti/Asan	1,993	1,033	1,555	522	282
	Fonte	1,575	669	1,224	556	102
Northern	Agana	8,717	5,679	8,192	2,513	324
	Mangilao	8,772	3,406	6,810	3,400	101
	Northern	44,971	19,987	34,682	14,671	403

Meeting Multiple Objectives: The Forest Environment Highest Priority Areas

Table 24 provides similar information for the forested environment outside of the urban zones. The purpose of this table is to illustrate the extent of forests in the watershed and identify the Highest Priority Treatment areas based on addressing multiple objectives.

The primary objectives met by these priorities cover all of the following: wildfire and public safety (Issue #1), water quality and water supply (Issue #2), deforestation of native and old forests (Issue #3), urban forest sustainability, population growth and urbanization (Issue #4), degraded lands (Issue #5), invasive species and forest health (Issue #6). These cross multiple S&PF programs: Cooperative Fire, Forest Health, Forest Stewardship, Urban and Community Forestry and Forest Legacy.

A total of 8,920 acres have been identified as Highest Priority areas where planting activities can be conducted to meet these multiple objectives (Table 24). Planting in these areas will increase resilience of forest fragments to invasive species, storm events and fire. These acres are mapped in Figure 34 and should be considered the starting place and justification for building planting projects with stakeholders, including willing private landowners.

The columns in Table 24 describe the following information for each watershed:

- **Forested Acres/Watershed Total Acres**: This column illustrates the extent of forested areas within the watershed. "Forest" refers both to contiguous areas of forest types but also to forest fragments.

- **High Priority Area for Fire Treatment to Protect Forests**: These areas are the acres in the 300 ft. buffer around forest fragments that are in need of treatment within each watershed. These acres are the sum of the areas identified as Moderate, High, and Extreme risk for fire. This approach identifies the magnitude of fire prone areas within each watershed.

Sediment delivery is identified in the table in two ways, because both the total delivered sediment and the sediment yield can be used as dimensions of the sediment issue in prioritizing for different objectives:

- **Estimated Delivered Sediment**: This is the estimated annual total sediment delivered at the mouth of the watershed expressed as tons per year. This estimate is influenced by two factors: the number of acres identified as contributing areas, and the total watershed area. For example, a larger watershed with a lower percentage of contributing areas and low erosion rates per acre can produce more total sediment than a smaller watershed with more severe erosion. The total delivered sediment is a critical factor to consider when setting priorities for reduction of sediment to reefs.

- **Delivered Sediment Yield**: The delivered sediment yields as expressed in tons per acre per year provides an indicator of the severity of erosion and sediment delivery in the watershed. Acres targeted for planting will reduce delivered sediment for that acre.

The final column in the summary table represents areas where multiple threats exist, and planting trees will mitigate these risks and threats (Highest Priority Treatment Areas).

- **Highest Priority Treatment Areas to Address Multiple Objectives:** This column identifies the acres where one would get the most benefit for the cost of treatment – the highest priority areas that will meet multiple objectives. These acres combine risks to meet multiple objectives by: (1) being within 300-ft of a forest edge (forest at risk of fire and

fragmentation), (2) delivering sediment to streams, and (3) having moderate - extreme fire behavior risk. The acres represented here are a conservative estimate for actual treatment needed, as actual project implementation will include neighboring areas.

Current efforts toward planting restoration projects to meet some of these objectives are in Cetti Bay, with a 500-acre planting project to mitigate reef damage from Kilo Wharf Expansion Project. These priority area maps will assist in the refinement of planting to target those areas producing the most sediment.

Similar watershed restoration projects can be brokered using these Priority Areas with stakeholders and partners, including the DoD, US EPA, NOAA Fisheries, and the National Park Service.

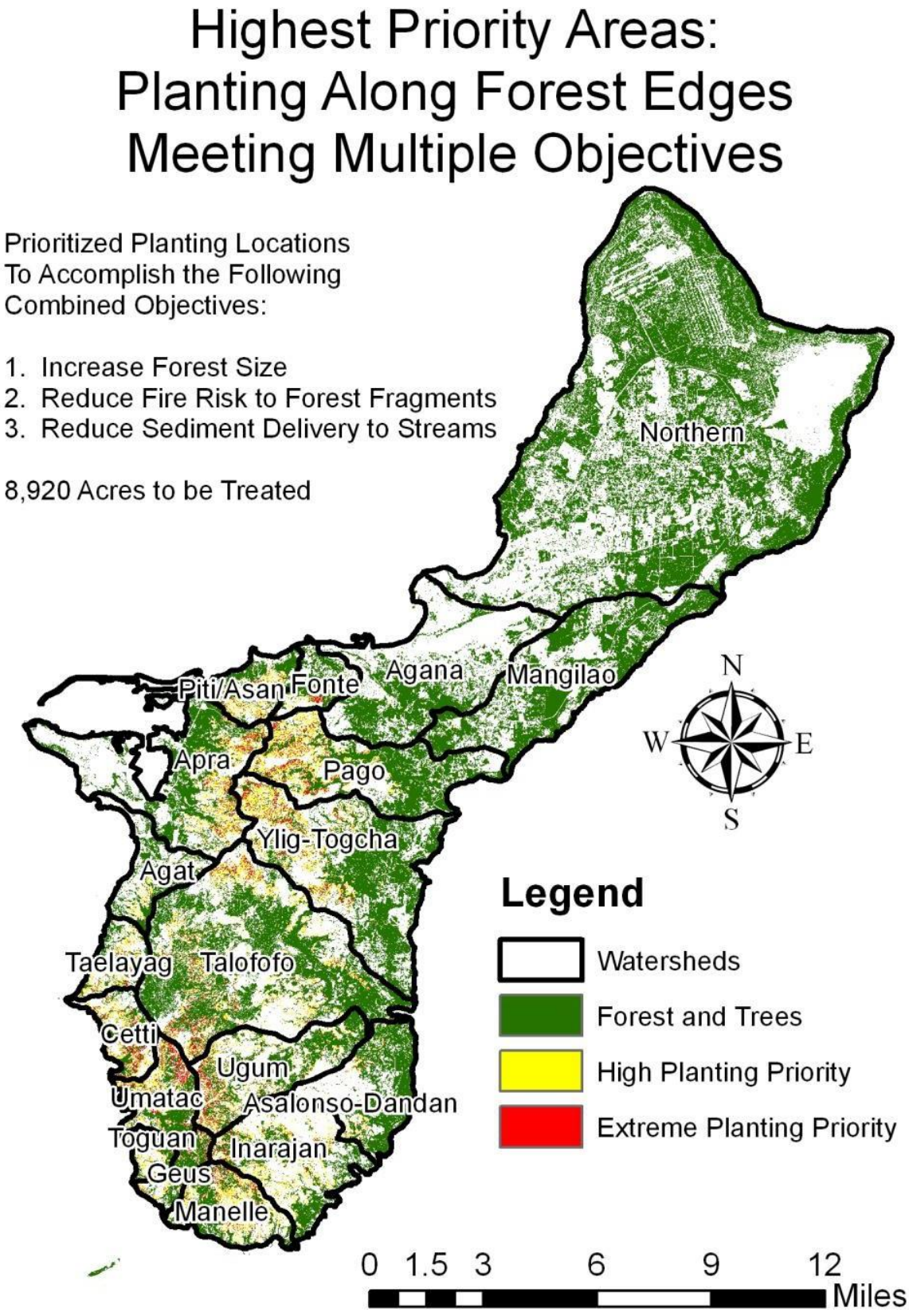

Figure 30. Highest priority areas for planting along forest edges to meet multiple objectives, 2010 SWARS.

Table 23. Highest priority areas for planting, fuels treatment, delivered sediment, and where multiple objectives are met: Increasing forest patch size, reducing fire risk to current forests, and treating areas delivering sediment to streams.

Region	Watershed	Forested Acres/ Total Acres	High Priority Area for Fuels Treatment to Protect Forests (Fire Risk rated Moderate to Extreme in acres)	Estimated Delivered Sediment (tons/yr)	Delivered Sediment Yield (tons/acre/yr)	Highest Priority Treatment Areas – Multiple Objectives (acres)
Eastern	Pago	2,680/6,683	1,541	55,427	8.3	973
	Ylig-Togcha	4,281/10,067	1,710	81,928	8.1	1,101
	Talofofo	6,544/15,016	2,605	103,149	6.9	1,478
	Ugum	1,670/4,851	1,142	39,076	8.1	717
	Asalonso-Dandan	1,968/4,183	231	40,330	4.9	141
	Inarajan	1,440/5,564	958	64,601	11.6	658
Western	Manell	988/3,107	977	63,147	20.3	689
	Geus	493/1,120	341	8,822	7.9	206
	Toguan	201/903	273	11,736	13	192
	Umatac	889/2,447	882	49,771	20.3	584
	Cetti	420/1,928	811	43,395	22.5	478
	Taelayag	378/1,639	435	25,376	15.5	263
	Agat	875/2,511	238	15,785	6.3	142
	Apra	2,556/8,283	1,279	40,330	4.9	803
	Piti/Asan	631/1,993	463	13,609	6.8	317
	Fonte	707/1,575	188	4,140	2.6	79
Northern	Agana	2,897/8,717	351	5,238	0.6	36
	Mangilao	4,916/8,772	136	12,983	1.5	51
	Northern	21,909/44,971	626	Not analyzed	Assumed Low	12

Data Gaps and Recommendations

During the course of the Assessment several data gaps were noted. Addressing these data gaps would improve the technical assessment and conclusions that guide management decisions. The following is a brief summary of the data gaps.

1. **Primary Forests.** No comprehensive forest survey is known to exist to identify patches of native/primary ("pristine" or "old growth") forest remnants. For purposes of the GFAP Vegetation map, forest environments were pooled to have the sole distinction of "Forest" to conduct analyses of tree densities and trees at risk. Further differentiation of forest types, including secondary forest types, is required to improve the GFAP Vegetation Map. A dedicated survey is needed to evaluate contiguous patches of potential primary forest. These primary forests serve as a reservoir of native species for plants, wildlife and all connected biota.

2. **Invasive Species.** Few quantitative data are available with respect to invasive species assemblages, distributions or current condition of the distributed effects on forest health. This is a critical data gap for Guam Forestry in the effective management of a forest health program, including integrated pest management (IPM).

3. **Sediment Modeling.** The Nonpoint Source Pollution and Erosion Comparison Tool, (N-SPECT) was chosen to characterize relative erosion hazard areas in southern Guam. This model estimates surface and rill erosion but does not account for mass wasting, gully erosion, or streambank erosion. Sediment impacts from these processes may play a significant role in impairing water quality. Concentrated effort is needed to evaluate sediment sources and develop a comprehensive model that includes these sources (e.g., monitoring and DHSVM).

Forest Health Conditions. No direct surveys have been conducted to evaluate forests or forest fragments for age or forest health conditions beyond that of the FIA and MC plots. An estimate of the old or primary (pristine) forest was qualitative and delineated without survey information. The GFAP Vegetation Map generated from this assessment provides a map of individual tree crowns, which are to be used as priority areas to survey and identify Forest Status for identifying primary and old forest types. This is a critical data gap in proactive conservation that affects urban development, including urban and community forestry objectives, Forest Legacy, and other programs.

Strategies for Addressing Threats

Introduction

The purpose of this section is to transition the assessment of stakeholder issues and data synthesis into a 10-year strategic plan that achieves the desired outcomes. Specifically, in this section, the following are outlined:

- **Resource Strategies (10 years).** Four major strategies are presented, including a description, action plan of next steps, Forest Service programs that could be leveraged, key stakeholders, resources needed (staff and funding) and an overall timeline with internal performance measures of success.

- **Strategy Implementation Approach.** An outline of how project planning and implementation can be prioritized to take a proactive "vision to outcome" approach. This assures that resources are expended at maximum efficiencies and individual projects fit within the overarching Resource Strategies.

- **Program Capacity Plan.** An assessment of the current resources and programs within Guam Forestry, with a summary of the needed resources and allocation of staff to accomplish the 10-year strategy.

Collectively, this section outlines the overall Guam Forestry Strategy, the relationship with the S&PF programs, and the future program needs.

Guam Forestry Current Program Activity

It is important to evaluate Guam Forestry's accomplishments and challenges to design a feasible 10-year strategy. This section describes the current activities and performance measures associated with each of the S&PF-compatible programs that Guam Forestry has been or is currently engaged in. Following this section, specific strategies are outlined, future plans and goals are described, and the current program capacity is described to evaluate what will be needed to implement each strategy.

The mission of Guam Forestry is to conserve, protect and enhance Guam's vegetative environment and sustain natural resources that are dependent on healthy forests. The agency works with stakeholders to promote healthy and productive forests in

rural and urban areas throughout the island in partnership with the USDA Forest Service and other Federal and GovGuam partners. The Assessment section of this GFAP identified stakeholder inputs and a science-based assessment of priority areas to address stakeholder issues that are affecting Guam Forestry's healthy forest mission.

Guam Forestry's program is currently comprised of five program elements that parallel the USFS S&PF organization. The current activities of Guam Forestry's programs and their performance measures are described below.

Forest Health Protection

The Cooperative Forest Health Management Program (Forest Health Protection) targets enhancement of native forests that have been impacted by the effects of invasive species, forest pests, development, drought and typhoons. Guam Forestry's Forest Health Management Program can use cost-share funds from the USFS for activities such as monitoring and managing outbreaks of invasive pest and plants at the island scale, as well as within conservation areas and plant nurseries. Guam Forestry has a close working relationship with the University of Guam, other staff in Guam Agriculture, and APHIS. Typically, if any outbreaks are identified, Guam Forestry seeks the assistance of UOG on identification of the pests or plants as well as assistance to prioritize species and control methodologies. While exhaustive inventory of insect and disease pests for Guam has not been compiled, detailed information is known for some pests, including CRB, cycad scale and little fire ant, as well as a growing understanding of the mechanisms associated with Casuarina decline.[64] However, more information regarding the distribution and abundance of these pests (and pests not yet evaluated) is needed along with information regarding invasive plants (distribution, abundance, effects of invasion, maps) to develop an effective strategy for Forest Health Protection with stakeholders and partners.

Future plans: Work with partners to increase capacity island-wide and actively participate in Regional programs (e.g., RISC, Micronesia Biosecurity Plan); develop an island-wide strategy for species-based and site-based prevention, detection, eradication, containment and/or control mechanisms for invasive species; secure interagency leadership position to act as an Invasive Species Coordinator to develop and implement the program. Build partnerships on-island and with other agencies (e.g., Global Environment Facility—GEF) to increase on-island capacity and implement the program. See *Strategy 4: Implement a Forest Health Program and Unify Interagency Efforts* to Control Invasive Species. beginning on page 126. Forestry Health priority areas are island-wide, including locations where invasive species occur and in those

[64] Additional details are described in Disturbances Affecting Forest Health section, beginning on page 84.

areas where maintenance or restoration of forest health is needed. These priority areas may or may not overlap directly with areas defined in Figures 33 and 34.

Performance Measures: Number of acres surveyed and treated, species identified, biocontrol projects undertaken, forest health and invasive species-related training opportunities for land managers and outreach and education.

Forest Stewardship Program

Under the Forest Stewardship Program, Guam Forestry provides technical assistance and planting materials to private landowners for establishing forests, managing forests or for agroforestry practices. The FSP supports the Guam Forestry nursery which provides native and non-native plants for erosion control projects and other uses such as establishment of wind breaks and Urban and Community Forestry planting programs.

Currently, the program encourages private landowners to adopt conservation practices on their land by replacing non-native species with desired native plants, and to develop and implement stewardship plans, by educating the public on the importance of protecting and expanding the surrounding forest on their lands, by propagating native plants to accommodate Forest Stewardship plans, and by participating in volunteer planting events.

Performance Measures: Number of acres planted or otherwise treated, number of acres of land under old or new Stewardship Plans being implemented per year, number of new or revised Stewardship Plans written, number of landowners given educational or technical assistance, number of other plans written (e.g., practice plans or landscape-level plans), number of plants planted that survive from previous year.

Reforestation, Nursery and Genetic Resources

Nursery component: Plant nursery operations are directly related to all programs, especially UCF and FSP. The numbers of plants to be propagated are determined by the number of cooperators who signed up for the stewardship program. UCF plants are determined by planting activities from the prior year. For example, Arbor Day activities, plantings in public parks, and specific requests from Government agencies (village Mayors, schools, etc.). These reoccurring activities provide the basis for species selection, number of plants propagated, optimal size of plants for outplanting activities, and other aspects of

nursery operations.

Performance Measures: Total number of plants propagated from the nursery operation.

Reforestation component: The federal Forest Stewardship budget line item includes Rural Forestry Assistance, which authorizes use of FSP grants for reforestation on territorial lands. The Landscape Scale Restoration program includes the authorities of several S&PF programs including Stewardship. Guam's reforestation projects on territorial lands therefore are funded either under FSP or Landscape Scale Restoration, and have been an important part of Guam Forestry's program.

Performance measures: Number of plants planted that survive from previous year; acres successfully treated per grant according to the objectives of any Landscape Scale Restoration proposal (for example, acres of forest replacing acres of grassland).

Urban & Community Forestry

Guam Forestry participates in urban planting in public and private schools, public parks, public rights-of-way, government agencies and private businesses. Guam Forestry coordinates with public and private entities on planting efforts in the urban landscape, Arbor Day activities, and pest eradication efforts. The division assists and advises communities about wildfire risk and treatments in the urban interface zones. Guam Forestry also coordinates with nonprofit and volunteer groups in planting activities and educating the public on the importance of planting trees in the urban setting.

These activities require dedicated staff to increase collaboration with private businesses, village councils, and other agencies to be successful. It is important to increase efforts in this program to ensure that future development falls within guidelines to increase the sustainability of the urban environment. Further, public awareness campaigns for residents of Guam as well as the 1.1 million tourists that visit every year (mostly in Tumon) will increase overall exposure to the importance of balance between built and natural environments.

Performance Measures: Number of plants planted and maintained, number of organizations participated, number of volunteer groups participated, distribution of UCF related material and number of people educated, number of trainings/refreshers provided, number of arborists certified, number of UCF meetings held per year.

Cooperative Fire

Guam Forestry is responsible for firefighting on conservation areas in the initial attack and supports Guam Fire when requested. Guam Forestry's primary responsibilities are within its conservation reserves (GovGuam lands), with significant resources dedicated to the roughly 500-acre Cotal reserve. Primary activities include fuel load reduction, fire break and greenbelt establishment, fire patrol, public education and outreach. Other fire suppression activities occur during fire patrols on GovGuam lands outside the reserve areas or when Guam Fire Department requests assistance. Other activities include Smokey Bear school presentations and public outreach. In the future Guam Forestry would like to establish an Interagency Fire Coordinating Committee.

Performance Measures: Number of fire outbreaks by size and ignition type, number of acres burned, number and acreage of firebreaks established/maintained, number of public outreach activities and number of contacts/participants, number of Community Hazard Mitigation Projects, number of Risk Assessment Plans (e.g., Community Wildfire Protection Plans or equivalent), acres treated for fuels reduction, number of personnel trained, and number of communities assisted.

Resource Strategies: 10 Year Plan

The assessment identified forestry-related issues at island and watershed scales, identified a range of needs to address stakeholder issues and identified a synthesis of the priority acres where multiple objectives can be addressed in each watershed. While this information is important for planning purposes, and for understanding the extent and locations of resource concerns, there is a need to develop *strategies* that describe the approach to the problems within the context of the capacity of Guam Forestry (personnel, infrastructure, and available skills). In addition, a strategy is needed that addresses building program capacity within Guam Forestry to meet the challenges of implementing the strategic plan.

The strategies described below are intended to lay out the road map for Guam Forestry to move forward with assistance from the USFS State & Private Forestry as well as other partner organizations. This section describes four major strategies in detail; further discussion of capacity needs is presented in the *Program Capacity* section.

Strategies are described in the following order to address restoration, conservation of intact forests, reduce impacts to water quality and the reef system, mitigate for the

impact of the military expansion and other development, and address invasive species – all unifying themes developed from stakeholder issues. The four strategies are:

Strategy 1: Implement Highest Priority Plantings in Urban, Rural and Undeveloped Areas that Meet Multiple Objectives.

Strategy 2: Protect, Conserve and Restore Forests on Public, Private, And Other Non- Military Lands

Strategy 3: Improve Fire Prevention, Control, Suppression and Prescribed Fire Activities through Organizing, Training and Equipping Staff and Resources.

Strategy 4: Implement a Forest Health Program and Unify Interagency Efforts to Control Invasive Species

An overview and description of each strategy is organized in the following narrative format:

- **Title**
- **National Themes**
- **Overview**
- **Scale**
- **Maps**
- **Acres Treated**
- **Stakeholder Issues Addressed**
- **Description**
- **Next Steps and Actions**
- **State and Private Forest Programs that Contribute**
- **Key Stakeholders**
- **Resources Needed Including Staff and Project Funding**
- **Performance Measures**

Strategy 1: Implement Highest Priority Plantings in Urban, Rural and Undeveloped Areas that Meet Multiple Objectives.

National Themes Addressed: Theme 1. Conserve Working Forest Lands, Theme 2. Protect Forests from Harm, Theme 3. Protect and Enhance Public Benefits from Trees

Overview: Implement planting projects around forest fragments and in urban zones that have been identified as the GFAP Highest Priority Areas to plant where multiple objectives can be met. These objectives include: (i) expand forest fragments to increase resilience,

(ii) convert hazardous fuels that threaten forest edges, (iii) convert non-forest areas that are delivering sediment to streams to healthy forest to reduce erosion and delivery, (iv) increase overall forest cover.

This strategy focuses on planting projects in the urban areas. This strategy also ties with Strategies 1 and 2, where specific priorities meeting multiple objectives would benefit from plant trees in the urban environment. The purpose of this strategy is to be inclusive of all urban lands on Guam and tie Urban programs into Forest Health and Stewardship program goals.

Scale: Island Scale, to be implemented as local projects

Maps and Tables: Forest lands 2, 6, 7, 8, 9, 19, 22, 23, 24, 30 & Tables 14, 17, 22, 23, and Urban zones: Figure 20, 21, 25, 26, 29 & Table 15, 16, 22

Acres to Be Treated: 13,098 acres (8,920 in Forest Zones, 4,178 in Urban Zones).

Stakeholder Issues Addressed: All stakeholder issues are addressed in this strategy.

- *Issue 1. Wildfire and Public Safety*: Increasing forest continuity, reducing risk of fire to forests and urban communities, fuels conversions, removing ladder fuels, strategies to isolate and contain future fires by installing and maintaining firebreaks and greenbelts.

- *Issue 2. Water Quality and Water Supply*: Converting non-forest types that are producing sediment to stream systems to forests, minimizing erosion processes and direct delivery to waterways, increasing zone of contribution health to filter potential hazards to waterways through improving forest health, and implementing strategic plantings to filter runoff from roads.

  Tree ordinances that focus on zones of contribution or areas that deliver sediment to streams will increase overall efficiencies of gaining benefits from Urban Forestry programs to water quality and supply. Planting programs designed to provide more infiltration of rainwater in parks, near roadways, schools, buildings and other development will increase overall water quality and aide to slow and filter runoff.

- *Issue 3. Deforestation of Native and Old Forests*: Highest Priority planting acres are targeted around suspected native forest sites; plantings at forest edges will increase

diversity and fragment sizes of native forest (i.e., allow to expand) while also meeting other objectives of reducing fire risk, reducing risk of invasive plant and pest establishment, and improving and or maintaining water quality.

- *Issue 4. Urban Forest Sustainability, Population Growth and Urbanization*: Mitigation of secondary threats of development by planting trees along roadways (having considered necessary egress/ingress needs for emergency responders), and increasing forest continuity (increasing resilience).

  Over 4,000 acres are within urban zones to increase current diversity of native trees while reducing community fire riskand mitigating storm runoff. Incorporate the primary planting acres into Tree Ordinance to ensure plantings are met with new developments, and current developments can be enhanced.

  Development of Tree Ordinance in other communities beyond the military buildup (Strategy 4) will increase overall forest cover in urban environments. Model ordinance "pilot" projects will provide adaptive management advice in the development of Tree Ordinances and regulations that work for all of Guam, including the rural towns and villages that are still "urbanized." This is especially important with the large influx of people in the next 5 years that will likely live in smaller communities that will ultimately become larger communities with less green space.

  Planting more native and fruiting trees in the urban zones increases overall urban forest sustainability. Increased attention to the current urban forest landscape and designing treatments to expand these forest fragments (as in Strategies 2 and 3) will increase forest health through monitoring and early detection. Increased public involvement in the value of native trees will increase Forest Health success (through detection of pests like Cycad Scale and CRB) as well as increase volunteer maintenance of planted trees.

- *Issue 5. Degraded Lands*: High priority plantings target sites that are currently eroding and delivering sediment to streams. Conversion to forest is primary treatment for reducing degradation.

Description: The resource assessment illustrated the relationship between the expansion of fire prone grassland/savanna lands, increased fire risk, sediment delivery to streams through hillslope erosion, and the resulting degradation of the reef system. These altered landscapes are extensive in the steep volcanic lands in southern Guam. Areas meeting the criteria of (a) being within 300-ft of forest fragments, (b) having moderate or

higher fire behavior risk, and (c) are in areas that are delivering sediment to streams (and the reef) were identified and mapped. Approximately of 9,000 acres were identified in southern Guam having all three of these criteria. Likewise, an additional 4,000 acres were identified in urban zones that meet multiple criteria described above (Figure 29 and Table 16, final column). Because these areas are so extensive, there is a need for Guam Forestry to communicate the results with stakeholders and lobby their assistance in prioritizing implementation action areas. This involves identifying willing landowners, defining project area boundaries, identifying nursery needs, public outreach components, and implementation staffing (and volunteer coordination). Implementation of this strategy is the next logical step in implementing the GFAP process (e.g., immediate post-GFAP action item.

Efforts in this strategy will likely need to address landowner concerns about fire risk to property and an education/ outreach component that involves the importance of forests to protect other natural resources (clean water, reefs, etc.). Similarly, efforts will include consideration of locally and federally identified species at risk, including both Endangered Species Act listed species and species of special local concern.

Approximately 93% of the resident population has occupied the urban zones and as such, the urban and community forestry program provides the largest needs for interaction with the public, coupled with the poorest environment for growing forests (urban settings, impervious surfaces, compaction, etc.). There is a need to manage all of Guam's urban areas for sustained development from population growth related to the military buildup as well as organic population growth. This involves developing and implementing a tree planting program to increase forest cover in the existing urban environment and to develop protocols and guidelines that ensure future development will incorporate native trees into the design.

To accommodate the large need for preparedness for urban influx in the next five years (and conversion of rural areas to urban zones), there requires a focused effort with attainable goals to implement a UCF program that couples with other objectives and strategies. Goals previously identified in previous UCF plans are still relevant to this strategy. These include:

1. Enhance the environment by planting trees along roadsides, parks, school grounds and areas further inland to satisfy Clean Water Act requirements (as in Strategy 1 and 2).

2. Use more local species, such as *Intsia bijuga* (Ifit), the island's territorial tree

in promoting local culture awareness.

3. Strengthen relationships within the community through a cooperative island-wide tree planting campaign.

4. Provide communities the opportunity to get involved in making Guam a better place to live by promoting tree planting.

5. Involvement with the Guam Visitors Bureau in promoting tourism by greening Tumon and all island communities, through the Tourist Attraction Projects Village Beautification Program.

6. Address storm water problems in urban areas through green infrastructure (e.g., bioswales, plantings near stream crossings, around ponding basins, etc.).

7. Provide technical assistance to organizations, socio-civic clubs, associations and communities.

8. Provide media, technical and educational materials promoting Urban Forestry Practices.

9. Require and maintain International Society of Arboriculture (ISA) standards for Guam.

These actions require dedicated staff to increase collaboration with private businesses, village councils, and other agencies to be successful. It is important to increase efforts in this program to ensure that future development falls within guidelines to increase the sustainability of the urban environment. Further, public awareness campaigns for residents of Guam as well as the 1.1 million tourists that visit every year (mostly in Tumon) will increase overall exposure to the importance of balance between the built and natural environments.

Next Steps and Actions

- Identify willing stakeholder and landowner groups to implement planting projects.
- Identify willing participants and groups to build a Southern Guam Watershed Enhancement Partnership association or similar group to coordinate local priorities, volunteers, education and outreach, and implementation.

- Submit grants for competitive funding to the Forest Service, and seek funding from

other groups (Navy, EPA, NOAA, conservation innovation grants, NRCS, NGO's) to implement the Restoration Plans.

- Meet with State and Federal Agencies to discuss overlapping missions and begin prioritizing landscapes that meet joint objectives such as the Ridge-to-Reef approach to restoring degraded reef systems (marine protected area watersheds, proposed mitigation areas, water systems, etc.). Seek interagency or outside additional funds for large-scale restoration projects to meet the acres required.

- Meet with stakeholders in their communities to inform and facilitate cooperation about reducing fire risk and improving urban forests and open space.

- Follow a structured large-scale restoration implementation processes (e.g. *Step-Down Approach for Landscape Management* on page 126) to identify how activities in priority lands can merge with other activities to increase efficiencies and overall restoration success.

- Develop Tree Ordinances for communities that will promote native trees and assist in protecting, enhancing and expanding the tree canopy in the community.
- Development of guidelines for community and volunteer groups on the use of native and local trees to enhance wildlife habitat, native ecosystems and cultural awareness, and integration of these components into a state implementation plan. Work with GovGuam to incorporate into law.

- Increase monitoring of forest health concerns, particularly CRB, cycad scale and little fire ants, and invasive plants in the urban setting.

- Maintain an early detection program and create materials for local hotels, schools and business custodians and groundskeepers to assist with early detection and monitoring.

- Develop an urban tree inventory database (with Forest Health monitoring, above)

- Develop an inventory of communities, population, acres, and community groups that are potential cooperators for implementing planting and maintenance goals

- Prioritize these communities within watersheds to develop a strategic approach at delivering services where efforts would meet multiple objectives and where

communities have demonstrated an interest improving tree and forest resources with their community.

- Work with Fire personnel (Strategy 3) to address fire risk as part of implementing tree plantings within and along the buffer zones surrounding urban areas.

- Build staff capacity to increase the delivery capability of urban and community forestry services (nursery stock, planting, outreach, education and arborist services) to become prepared for the dramatic increase in population and urban zones associated with military buildup.

- Plan for development of parks and open space both within communities and as regional parks that not only address human needs but have multiple benefits for wildlife, watershed protection and water quality improvement.

- Identify locations for future parks, targeting areas with native forest and species of concern.

State and Private Forest Program Areas that Contribute: Cooperative Fire, Forest Stewardship, Urban and Community Forestry, Forest Health,

Key Stakeholders: Bureau of Statistics & Plans, Guam Fire Department, Guam Environmental Protection, Guam Aquatic and Wildlife Division, Soil and Water Conservation Districts, US Fish and Wildlife Service, National Park Service (Agat and Asan Watersheds), Guam Visitor's Bureau, Guam Hotel and Restaurant Association, private landscape businesses, private businesses in urban zones, Community Councils and Mayors, UCF Committee, GFAP Advisory Committee, Key Private Landowners.

Resources Needed Including Staff and Project Funding: Professional foresters, GIS and spatial analysis technical support, nursery operational funds and staff, funding and staffing to support community meetings, Education & outreach coordination with existing programs, fire assistance (prevention, mitigation, suppression and post fire activities).

Performance Measures: Number of meetings held with communities, number of community groups recruited as cooperators, number of tree ordinances developed, state-wide implementation plan for tree ordinances and development, number of trained personnel added to the program to deliver services to communities, number of acres of open space, parks and regional park areas planned or developed, number of educational material releases and agreements targeting professional cross-over positions (e.g. hotel,

school and business groundskeepers to assist in monitoring as part of their job), number of meetings with GFAP Advisory Council and UCF Committee, number of acres treated included in the Highest Priority Areas, number of outreach or training events, number of S&PF competitive grants submitted per year (target 1 per year for treating Highest Priority Areas).

Strategy 2: Protect, Conserve and Restore Forests on Public, Private, and Other Non- Military Lands

National Themes Addressed: Theme 1. Conserve Working Forest Lands, Theme 2. Protect Forests from Harm, Theme 3. Protect and Enhance Public Benefits from Trees

Overview*:* This strategy emphasizes identification of lands outside of the military boundaries since Guam Forestry has the ability to implement projects in these lands directly. The approach is to identify candidate forest fragments that can be conserved and expanded to increase forest size to increase forest resiliency. These can be done in urban zones as well as in upland environments. Conservation is achieved through three avenues:
(i) reduce stressors to existing forests through enhancement of current stands (e.g., forest health and protection from deforestation); (ii) expansion of current stands to treat external "edge" threats of disturbance (fire, wind, invasive colonization, etc.); and (iii) legal acquisition and conservation of forests now on public lands, through Forest Legacy or Community Forests and Open Space programs.

Candidate sites include those Highest Priority Areas identified in Strategy #1 but are expanded to all forest fragments on Guam and not just those meeting combined threats. Primary activities are planting trees by expanding existing forest edges, fuels treatments, forest health treatments within standing forests, and conservation.

Scale: Watershed-Level and Local Land Parcels

Maps: Threat to Fire Priorities (Figure 19 & Figure 20), Native Forest Conservation and Expansion Priorities (Figure 30), Urban Forest Planting and Conservation Priorities (Figure 29), Reference standing forest classifications by ownership (Figure 24). A subset of these is also in Strategy #1.

Acres to be Treated: Areas overlap. Fire priorities (addresses high-priority fire risk through fuel mitigation on 20,284 acres), Native Forest Conservation Priorities (conserve approximately 25,000 acres), and Urban zones (~35,000 potential planting area in non-

forest and ~30,000 acres for conservation in forest).

Stakeholder Issues Addressed:

- *Issue 1. Wildfire and Public Safety:* Addresses treating hazardous fuels around perimeters of forest fragments and in urban areas.

- *Issue 3. Deforestation of Native and Old Forests*: Conservation of native forests through acquisition and legal protection (including Forest Legacy) and management (including volunteer programs), or through removing disturbance events (fire, off road vehicle use, barbeques, etc.) will prevent deforestation and degradation of native forests.

- *Issue 4. Urban Forest Sustainability, Population Growth and Urbanization*. Increases forest cover by planting in prioritized urban zones to increase forest cover; increases resilience and sustainability of standing stocks and forest fragments by increasing forest size and continuity.

- *Issue 6. Invasive Species and Forest Health.* Improves forest health and potential degradation of forests in urban environments as well as reducing the spread of invasives to other forests on the island. Education and outreach will continue to increase awareness of the importance of Guam's native trees.

Description: This strategy is an extended set from Strategy 1 of areas to be planted or conserved because of direct threat or opportunity for enhancement. In many cases, single areas can meet multiple objectives, though the purpose is to identify areas where activities can be done for potential watershed enhancement projects designed to (i) improve forest health and resilience, (ii) increase urban forest cover, (iii) protect standing forests from fire, (iv) protect native forests from deforestation and degradation. Activities are largely planting opportunities, outreach and education, and forest health treatments and fuels treatments (through converting high risk fuel types to forest and maintaining the conversion through mechanical fuel breaks, protection and suppression efforts). The general goal is to increase forest fragment sizes while increasing forest health in standing forest (especially native forest).

Next Steps and Actions

- Conduct on-site surveys of existing forests on public and private lands in the priority zones (by program or by watershed) to determine the current status of forest health and identify potential needs and prescriptions. Classify forest types by fragment size, targeting the largest fragments, or clusters of forest fragments that are relatively close to one another.

- Identify ground-based opportunities and stakeholder willingness to participate in forest expansion and forest health projects.

- Prioritize potential areas to establish a pool of candidate sites that can be further investigated for purchase/conservation easement.
- Complete the required elements of the Assessment of Need under the Forest Legacy Program to meet the conditions for participation in the Forest Legacy Program.

- Work with landowners to identify their interest in protecting or expanding the candidate forest sites through purchase, easement, or other programs. This effort will include work with the Chamorro Land Trust Commission and Ancestral Lands Commission to facilitate long-term protection of high priority conservation lands under the commissions' jurisdictions.

- Identify a short list of likely landowners that would be willing to participate in a forest protection program.

- Work with the DoD, EPA, and other agency partners to develop long term funding for watershed mitigation and monitoring (especially forest health monitoring).

- Examine viability of "forest credits" for maintaining standing forest and promoting growth (e.g., Office of Ecosystem Services in 2008 Farm Bill).

State and Private Forest Programs that Contribute: Urban and Community Forestry, Forest Stewardship, Forest Legacy, Community Forests and Open Space, Forest Health and Cooperative Fire Protection.

Key Stakeholders: Private landowners, Soil and Water Conservation Districts, Community Councils and Mayors, DoD, EPA, NOAA Fisheries, GovGuam Interagency Partners, UOG

Resources Needed Including Staff and Project Funding:

- Guam Forestry professional foresters & community outreach personnel, including GIS resources and staff and nursery operations to supply needed trees.

- Funding to support staff and meetings for the required outreach to inventory and identify forest health concerns and willing participants/ landowners to design and implement projects

- Staff, contractors or partners to complete the Forest Legacy Assessment of Need including public outreach. There is interest to select the "State Option" for Forest Legacy; stakeholder involvement has begun as part of the GFAP process.

- Identify partners (local governments or land trusts) qualified to acquire and forever conserve land under the Community Forests and Open Space Program.

- Funding for staff, contractors, or partners to build landowner relationships to purchase land, create easements, facilitate land trades, or other mechanisms to assure long-term protection of forests (e.g., Forest Legacy and/or Community Forests and Open Space).
- Fire program support for new plantings and high priority areas: protection, control, suppression and prescribed fire as well as capacity and apparatus for organizing, training and equipping additional fire watch crews.

Performance Measures: Number of inventories (or acres surveyed) to confirm forest conditions (forest health, potential prescriptions, and identify native forest), number of candidate sites evaluated, Assessment of Need for Forest Legacy completed, priorities of willing landowners established for purchase/conservation easements, number of landowners in the program for purchase/easements, meetings held with or MOU's secured with funding partners, number of acres planted, number of acres of forest monitored. (as set asides or after the fact), number of landowners receiving technical assistance, number of landowners participating in educational programs, number of acres covered by new or revised Forest Stewardship Plans, number of acres in Important Forest Resource Areas, number of acres that are confirmed as being managed sustainably, number of surviving trees.

Strategy 3: Improve Fire Prevention, Control, Suppression and Prescribed Fire Activities through Organizing, Training and Equipping Staff and Resources.

National Themes Addressed: *Theme 2. Protect Forests from Harm*

Overview: There is an urgent need to increase the capabilities and capacities of Guam Forestry staff to manage fire. This strategy focuses on reducing risk from wildfire across

Guam through prevention, preparedness, cause investigation, suppression, and post-fire activities. Preventative measures include public awareness, education and outreach, and pro-active measures of prescribed fire activities to change the fuels profile prior to fire events. Control measures involve additional attack and suppression resources and training, including additional law enforcement initiatives. Overall, the goal is to reduce arson-based fire incidents though active outreach, education, investigations and enforcement, as well as minimize the potential perimeters of fires that do start through preventative prescriptions, and finally to provide well-trained and staffed crews to respond, attack, suppress and investigate fires when they do occur.

Scale: Island-wide, watershed and project-level.

Maps: Priority fire risks to forests and urban areas (treatment areas and also attack zones (Tables 7, 13, 14, 15, 16, 23 and Figures 12, 21, 22 & 23, 29, 30), standing forests on Guam, by ownership type.

Acres to be Treated: Approximately 20,000 acres bordering forest edges with high fire risk (prevention through prescribed burns, mechanical treatment, protection of newly planted trees from Strategy 1 and 2); Island-wide responses to fires to protect 56,000 acres of standing forestland on Guam with interagency partners.

Stakeholder Issues Addressed

- *Issue 1. Wildfire and Public Safety*: First response with Guam Fire Department to fires that threaten infrastructure, forest, and other properties. Reduction in hazardous fuels and integration with Guam Forestry activities to address fire risk will reduce the potential for large grass fires. Increases in capacity to attack/ suppress and control fires will improve public safety and protect resources. Increases in staffing and response training will decrease both response and fire duration times, preventing reported fires from growing in size. Education and outreach, coupled with law enforcement actions, will decrease the number of arsonists and likelihood of further ignitions.

- *Issue 2. Water Quality and Water Supply*: Decreasing the size and intensity of wildfires, and wildfire prevention, will decrease erosion and sediment delivery to streams, reefs and impoundments. This is especially true for areas with high erosion inputs to streams.

- *Issue 3. Deforestation of Native and Old Forests:* Decrease the number of fires

encroaching on forest edges to maintain forested lands and forest continuity.

- *Issue 4. Urban Forest Sustainability, Population Growth and Urbanization*: Decreasing fire size, frequency and intensity along the border of native forest and within the intermix between rural and urban communities will decrease mortality to urban forestry programs.

- *Issue 5. Degraded Lands*: A reduction of wildfire occurrences on Guam will decrease the number of degraded lands by allowing for vegetative regrowth; protection of new plantings that are specifically designed to restore degraded lands with a high fire risk (Strategy 1) will reduce overall degradation on Guam.

- *Issue 6. Invasive Species and Forest Health:* Decreasing fires that create corridors or breaks along the forest edges or forest interior maintains forest continuity. Increased fragmentation of forests and green spaces promotes the likelihood of invasive species intrusions.

Description: Guam Forestry has an active Cooperative Fire Protection Program that provides fire protection for Guam's wildland areas and conservation reserves. Guam Forestry also cooperates with the Guam Fire Department and Federal Fire Departments from Navy, Air Force and Marine Corps, for the protection of other wildland and rural areas outside of Guam Forestry's jurisdiction. The Guam Forestry Fire Program has expanded efforts to include a more robust outreach and education program, pre-fire mitigation efforts (installation and maintenance of firebreaks, fuel-load reduction work and establishment of green belts), incident response, and post-fire activities.

Illegal fires account for up to 80 percent of the fires annually on Guam. Previous efforts to reduce arson have focused on developing educational materials, briefing materials, and public education and outreach. Additional efforts to implement the '*Guam Wildfire Management Plan'* will provide a means for limiting the ignition success, isolating the fires that do burn, maintaining small fire perimeters, and decreasing the cost for fire suppression. The Department can build on existing relationships to expand fire prevention activities and take advantage of other federal programs to reduce the incidence of fire.

Program capacity to respond to fires is very low, particularly when incidents are large, or when there are multiple incidents occurring at the same time. There is a need to increase capacity for prevention, control, suppression, investigations and prescribed fire

through focused organization, training and equipping personnel. Increasing the ability to suppress fires is of importance as is the ability to prevent them through fuels treatments, education and working with law enforcement.

Next Steps and Actions

- Secure additional support for Fire Management Officer as program has expanded, to provide continued support and assistance to consolidate existing fire plans, conducting a summary review of resources among stakeholders (staff, apparatus and collaborative agreements) and identify gaps for prevention and control procedures.

- Meet with stakeholders to develop Community Wildfire Protection Plans (CWPP) and leverage these activities to hold community meetings, provide fire prevention education and outreach, and build local support for successful restoration activities.

- Compete for Wildland Urban Interface (WUI) competitive grants to fund potential CWPP development and implementation projects.

- Develop fire protection and outreach methods and first response actions with forest expansion efforts identified in Strategy 1 and 2. This could involve pre-treatment, prescribed burning, and first response and incorporate attack and suppression points with the planting design to protect the plantings.

- Investigate FEMA – Pre-Disaster Mitigation Grant program with stakeholders, focused on priority areas.

- Develop a Fire Fighter Certification Program.

- Continue to conduct Fire Suppression Activities; build on coordination efforts with other fire departments

- Continue to implement innovative fire prevention Education and Outreach Activities

- Continue to implement pre-suppression (fuels reduction) with other enhancement projects (other strategies).

- Improve initial attack capability and ability to suppress fires through training, organization and equipment.

- Implement fire suppression activities that will access grants available in SFA programs by expanding Fire Watch suppression staff, apparatus and training. Increase local capacity to prevent, control, suppress and prescribe fires to meet

project goals through organizing, training and equipping personnel to protect project areas.

- Continue to screen available assets, such as supplies and or equipment for wildland firefighting through the Federal Excess Personal Property (FEPP) Program and Firefighter Program (FFP).

State and Private Forest Programs that Contribute: Cooperative Fire Program, Forest Stewardship, Forest Health, Urban and Community Forestry

Key Stakeholders: Guam Fire Department (including E911), Federal Fire Departments (Navy, Air Force, Marine Corps), Bureau of Statistics and Plans - Guam Coastal Management Program, Community Councils, Mayors' Council of Guam, DOAG-DAWR, DOAG-ADS, DOAG-BIOSEC, Soil and Water Conservation Districts, Guam Department of Education, NOAA Weather Service, Guam EPA, Guam GPA/GWA, Guam Homeland Security/Office of Civil Defense, Western Islands Association of Fire Chiefs, Farmers Cooperatives.

Resources Needed Including Staff and Project Funding

- Support for Fire Management Officer (or operational equivalent) is needed to support ongoing and expanding efforts to improve prevention, control, suppression, investigations and prescribed fire.

- Implement and develop a prescribed fire program to assist local farmers and to apply toward invasive species removal/eradication projects.

- Organize, train and equip additional crew resources to improve prevention, control, suppression, investigation and prescribed fire activities

- Build crew capacity to respond to multiple fire incidents and improve fire watch coverage

- Additional patrol units to detect and enforce anti-arson laws, especially during dry season (Law Enforcement)
- Additional public outreach staff, or coordination of outreach fire training needed to implement other Strategies.

- Additional fire vehicles, equipment, and personal protective equipment (PPE) to outfit additional crews, patrols, etc.

- Fire and safety training for additional personnel.
- Expansion of wildfire investigation trainings and the development of a regional training hub on Guam. The development of place-based training programs and manuals specific to island ecosystems.

Performance Measures: Fire Fighter Certification Program developed, number of communities/acres addressed by a Community Wildfire Protection Plan; Number of Community Wildfire Protection Plans created, Number of fire outbreaks by size and ignition, Number of acres/percentage of land burned, Number and acreage of firebreaks established/maintained, Number of public outreach events and number of people reached, number of communities assisted, number of certified fire fighters, number of outreach meetings involving fire that are incorporated with other Strategies (cross-over involvement).

Strategy 4: Implement a Forest Health Program and Unify Interagency Efforts to Control Invasive Species

National Themes Addressed: *Theme 2. Protect Forests from Harm*

Overview: Forest health is a serious concern on Guam and the capacity of Guam Forestry to respond to all forest health concerns as a single agency is severely limited. The purpose of this strategy is to form partnerships that pool human, funding and infrastructure resources to actively target species-based strategies and site-based control mechanisms for invasive species. Some of the partners in these efforts will be University of Guam (UOG), APHIS, GISAC, and Guam EPA.

This strategy aims to connect other strategies identified above for Guam Forestry, as well as helping to create a unified, cross-agency platform for invasive species prevention, detection, control and monitoring with other stakeholder groups.

Forest health concerns associated with fragmentation, compaction, fire risk and degradation are addressed in other Strategies.

Scale: Island-Wide Scale, Regional Micronesia, Local Communities

Maps & Figures: Map of all forests and ownerships identifies forested environments and stakeholders for forest health (Figures 2, 24, 28).

Acres to be Treated: Island-wide. Specific acres for monitoring and treatment will be identified in annual FH program proposal narratives and will be based on highest priority

pests, including invasive plants.

Stakeholder Issues Addressed:

- *Issue 1. Wildfire and Public Safety*: Invasive species and forest fragmentation increase wildland fire risk through fuels loading and forest degradation. Scorching by fire weakens tree health and can create openings for establishment of pests. Fires also increase bare soil, allowing for rapid establishment and spread of invasive species.

- *Issue 3. Deforestation of Native Forests and Old Forests*: Deforestation will increase edge effects, which has the potential to increase infestations within native forests. Active monitoring programs will assist in early detection of infestation to native forests and actions to treat pest areas will decrease risk of degradation of native forests.

- *Issue 4. Urban Forest Sustainability, Population Growth and Urbanization*: Education, monitoring and detection will increase knowledge about the hazards of activities that promote invasive species spread and will increase probabilities of success for eradication, containment and control. Working with contract laborers and companies positioned to serve the military buildup and other development to practice Best Management Practices (e.g., washing equipment to ensure spread does not occur to other areas of Guam, nursery quarantine and native species-driven landscaping) will improve sustainability outcomes. Tree ordinances with accountability for tree survival and routine monitoring will increase likelihood of success for meeting UCF objectives as well as for improving overall forest health to minimize vectors originating from infected zones.

- *Issue 6. Invasive Species and Forest Health*: Applying a unified strategy to increase invasive species prevention, detection, control, and monitoring on Guam is of paramount importance in protecting forest health. Increased preventions and involvement with APHIS and other partner agencies will improve control of invasive species. Increasing monitoring stations and incorporating Tree Ordinance measures to detect invasive species will aide to lower spread and establishment.

Description: Guam Forestry's in-house capacity in technical leadership is severely limited in its ability to perform day-to-day operations of Forest Health related activities of prevention (including education and outreach), early detection, or means of wide-spread

eradication, containment or control. As such, Guam Forestry has partnered with UOG for conducting monitoring and/or biocontrol projects for CRB, cycad scale, Casuarina decline, and some invasive plant species (see *Biotic Disturbances Affecting Forest Health* section, on page 87). UOG has received pass-through funding from S&PF programs via Guam Forestry to conduct assessments, monitoring and biocontrol efforts in partnership with Guam Forestry.

Despite these efforts, there are serious shortcomings in the Guam-based capacity to manage forest health concerns as a lead agency. Guam Forestry is a participant in the Guam Invasive Species Advisory Committee (GISAC), which is an interagency group with focus on invasive species prevention, detection and control, and has emergency response plans in place (dated 2005). Like Guam Forestry, GISAC has limited capacity to fully manage an island-scale invasive species program that includes prevention (education, outreach, port-of-entry inspection, etc.), early detection (survey and manage), eradication (complete removal), containment and control for species-based strategies, or to fully respond to serious emergency situations. Regionally, the Micronesian Regional Invasive Species Committee (RISC) has been developing a biosecurity plan to address prevention of invasive species spreading to other islands of the western Pacific.

The purpose and hopeful outcome of this strategy is to fortify relationships with local and regional partners to apply what capacity Guam Forestry has to the invasive species issues, and to build local, technically trained capacity to assist in local and regional efforts.

Next Steps and Actions

- Coordinate with Biosecurity and nursery trade to develop codes of conduct regarding the introduction, sale (nurseries) and use (landscapers) invasive plant species to minimize importation risks and spread through the impending development avenues.
- Implement use of GIS forest canopy layer for use as a database on forest health and to map the outbreak and spread of diseases and pests.
- Build capacity within Guam Forestry to identify invasive species and collaborate with Biosecurity, Customs, GISAC, and RISC in their control.
- Review available information on invasive species, gather additional information on distribution and local impacts (survey and map key species), and coordinate activities with APHIS, DoD, marine and wildlife resources, USFWS, GISAC and participate in RISC.
    - Increase the number and quality of stakeholder meetings on forest health.

- Coordinate with APHIS CAPS and Guam Department of Agriculture to include potential forest pests in biosecurity risk assessments.
- For ongoing cycad scale and CRB efforts: continue the emphasis on IPM programs, including continued monitoring, evaluation, biocontrol and pesticide control in urban areas.
- Continue CRB cooperative efforts with UOG and Emergency Incident Command System to support ongoing efforts to develop IPM programs for CRB. Continue participating in cooperative efforts with Guam Department of Agriculture, APHIS and UOG for sanitation, trapping and biocontrol of CRB.
- Increase monitoring of forest health concerns, particularly CRB, cycad scale and little fire ants in the urban environments (as well as invasive plants). Maintain an early detection program and create materials for local hotels, schools and business custodians and groundskeepers to assist with early detection and monitoring.
- Determine causes and solutions to Casuarina decline in collaboration with UOG.
- Develop an island wide tree health survey in coordination with UOG.
- Conduct island-wide forest inventories on a 5-year cycle (Established FIA and MC Plots).
- Develop and implement an invasive plant management strategy in cooperation with partners.
- Develop a conversion plan to restore native species within *Acacia* sites. Include protection and/or reintroduction of rare or listed plant species.
- Engage in cross-training of current Department of Agriculture staff to identify invasive species while implementing other projects. The training would be in collaboration with Biosecurity and UOG.
- Restore badlands by incorporating biochar or other biosolids in coordination with EPA, UOG, and other divisions within Department of Agriculture.
- Enhance limestone forest stands by removal of invasive species, targeted outplanting or seed dispersal to increase biodiversity, and control of forest pests.

State and Private Forest Programs that Contribute: Forest Health Program, Urban

& Community Forestry, Forest Stewardship

Key Stakeholders: University of Guam, US Fish & Wildlife Service, Guam Invasive Species Advisory Council (GISAC), APHIS, NRCS, RISC, Guam Wildlife Division, Guam EPA, Guam Bureau of Statistics and Planning, Guam Tourism Bureau, nursery industry, and hotel association

Resources Needed Including Staff and Project Funding: The staff in the Forestry Division needs training in the identification and control of invasive species, forest surveys, GIS mapping, managing forest databases, reclaiming badlands, conducting stakeholder meetings and evaluating programs. General education on forest health needs to be provided to nursery operators, landscapers, and land managers.

Performance Measures: The performance of the Forestry Division can be assessed by number of surveys completed, number of training opportunities for staff, number of invasive species identified, number of acres treated for invasive species, number of acres converted from Acacia to native species, number of badland acres reclaimed, number of successful introductions of biocontrol, increase in the number of stakeholder meetings, and the adoption of a code of conduct for nurseries in the introduction of new plant species.

Step-Down Approach for Landscape Management

A general approach for resource management involves the staging of management strategies in a "vision-to-outcome" approach. Completion of a management strategy can be gauged from a "1 %" (or the "vision") to a 100% (completed "outcome") stage. The approach is designed to be nested so that individual actions are targeted to meet desired goals beyond the project site scale. This approach has been successful with other large-scale efforts and builds in efficiencies in assuring that invested time and funds meet desired outcomes. The following description provides the linkage between each planning stage, starting with the GFAP strategy, and the subsequent stage ending with project implementation.

Island Assessment & Resource Strategy (1-10% Design). This represents the initial scoping of questions at broad scales to identify the stakeholders, major issues affecting forestry resources, and how forestry is tied to other natural resource management and conservation objectives. This begins with the GFAP planning process and document. G***eographic Scale****: Island and Neighboring Islands (largest scales, 100,000s of Acres).*

Watershed Assessment (10 – 30% Design). This is the synthesis of connecting resources within a single watershed or a small group of watersheds. The assessment involves a multidisciplinary approach to resource management, involving vegetation, hydrology, soils, wildlife, marine resources, agriculture, recreation, and other cultural resources. Typically, this involves an assessment of the *current conditions,* an estimate of the *potential future conditions*, and a framework for developing and attaining the *desired future conditions* through planning, design, and implementation. The purpose is to investigate, identify, and synthesize what limiting factors are affecting watershed-level processes. The watershed assessment leads into an Action Plan for restoration and resource enhancement. ***Geographic Scale****: Watershed Scale (1,000s of Acres).*

Watershed Action Plan (30 – 40% Design): This is a concise listing of the limiting factors affecting natural and cultural resources by geographic area (e.g., watershed) and provides an adaptive management approach for restoration and enhancement projects. Projects are prioritized on the basis of resource needs and stakeholder criteria. The Plan identifies the range of needs (staff, funding, outreach, partners) for full design and implementation, and in effect serves as the 'to do' list for restoration/ enhancement projects in the watershed as a whole. ***Geographic Scale****: Watershed Scale or Smaller (1,000's of acres).*

Site Design & Implementation Strategy (40 – 70% Design). This piece focuses on one or more of the identified projects/ action items from the Action Plan and provides the technical and cost basis for implementation, the completed restoration plan with "typical" prescriptions, establishes project costs and staff commitments, and begins the "project rollout". In this phase, specific standards for meeting regulatory and stakeholder issues are described, a public outreach campaign is conducted (with appropriate feedback and modifications), funding for materials for implementation are secured (e.g., nursery stock, tools, chemicals, etc.), and a monitoring plan is assembled to meet project-level guidelines. ***Geographic Scale****: Project Scale (single or multiple, 10-100 acres).*

Implementation (70 – 100% Design). At this stage the project design and specifications are completed with sufficient detail to specify staff requirements, issue Request for Proposals to contractors and implement the project with Forestry staff oversight. The 70 - 80% design is the preferred design scale for implementation to allow for *ad hoc* decisions that are inevitable when implementing the plan. Crews, volunteers, and contractors are organized, and the project is completed (100%). The monitoring plan is also initiated where appropriate. **G*eographic Scale****: Approved and Vetted Project Areas within Watershed (site-specific, 10's of acres).*

Monitoring (Feedback Loop). The technical monitoring study is implemented by collecting field data as identified in the Monitoring Plan. In addition, benchmarks are established that can readily be tracked by managers and communicated to decision makers and grantors. Adaptive management is used to ensure project implementation success, evaluate if benchmarks are realistic and attainable, and account for unforeseen challenges through time. A Technical Advisory Committee (TAC) involving specialists and citizen stakeholders should be established for this long-term phase to assist in project evaluation. ***Geographic scope****: Specific to process monitored.*

Program Capacity

Introduction

The Assessment identified the resource issues, their geographic location and magnitude. The Strategies describe an approach and the actions to be taken to conserve, protect and restore forest resources in Guam. Guam Forestry currently does not have the program capacity to implement these strategies and actions in full. It is critical in meeting the purpose and objectives of the GFAP planning process to identify current and future needed capacity. Program capacity is further compounded by the planned increase in population and stress on resources that is envisioned with military expansion and development that will occur throughout the island. This section addresses the following objectives:

1. Identify the current program capacity and limitations.

2. Identify the capacity needed to implement the strategies and meet the challenges on an increasing population.

3. Identify potential funding sources from a diversity of sources – GovGuam, US Forest Service, DoD, EPA, FEMA, NOAA, NRCS, NGO's, private, etc. and devise an approach to putting these funding sources together to meet the overall program needs.

Current and Needed Program Capacity

The current allocation of S&PF funds is predominantly applied to Cooperative Forest Health Management, Forest Stewardship, Cooperative Fire Protection and Urban and Community Forestry Programs. (Landscape Scale Restoration grants may be competitively obtained for projects with any of the above program authorities.)

Some elements of the Assessment of Need (AON) required for the Forest Legacy Program were completed during the GFAP assessment. Guam Forestry is the Lead Agency for the

Forest Legacy Program and may prepare a program-specific "Assessment of Need" that may be added to this Forest Action Plan as a separate chapter or appendix in the future including its own public and stakeholder review. After Forest Service review and approval, this would complete the planning requirements needed to participate in the Forest Legacy Program in the future (elect in favor of the "state option" for Forest Legacy).

The total current staff in the Guam Forestry program in FY2020 is heavily weighted to Forestry Aides with few staff in the professional forestry positions. More professional positions are needed to provide the planning, leadership, and communication skills and knowledge necessary to implement the future programs envisioned by the strategies described above.

Guam Forestry has been working within the Guam Department of Agriculture to identify current and future staffing needs to meet existing requirements as well as to implement the strategies identified in this document. The future visioning process anticipates that the Cooperative Forest Health and Stewardship programs will require a total of 12 staff, comprised of 2 professional foresters (Forester I, II, and or III positions) and 10 Forestry Aides. Cooperative Fire Protection will need similar increase in staff support to 2 professional foresters and 5 Forestry Aides. Urban and Community programs will need 2 professional foresters and 5 forestry aides. Additional future visioning includes the creation of Forestry Technician positions which will provide a ladder for upward mobility and entry level technical positions.

The current program in Guam Forestry is severely understaffed. The lack of professional staff translates into an inability to complete the planning, prescriptions, and on-the-ground leadership visualized in the Strategy section, and therefore is a major obstacle to addressing the issues identified in the Assessment and the actions identified in the Strategy Section.

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Appendices

Appendix 1: Guam Forest Action Plan (GFAP) Coordination

The Chief of Forestry is part of the NRCS Local Working Group. The Local Working Group has had the opportunity to review this Forest Action Plan. Since Guam is a small community Guam Forestry decided to have the same members on each stakeholder group. This makes for a more efficient way of deciding issues related to each board. The GFAP Advisory Council consisted of both the FSP board and UCF council that contributed to identification of threats and conditions.

The Forest Service Checklist for the GFAP report requires coordination of Stakeholder Groups with the Statewide Assessment and Strategy. Because Guam is a small island in comparison to mainland states many of these required coordinating group members participated on the GFAP Advisory Council. The required Stakeholder Groups on the checklist are listed below with an indication of their participation in development of the GFAP document. The table below shows the crosswalk of committee members that also are on the Stewardship Coordinating Committee and the Urban Forestry Council.

1. **State Forest Stewardship Coordinating Committee**: Members of Stewardship Committee were included on the GFAP Advisory Council
2. **State Wildlife Agency:** The State Wildlife Agency (Guam Dept. of Agriculture, Aquatic and Wildlife Division) was included on the GFAP Advisory Council**.**
3. **State Technical Committee:** The GFAP Advisory Council functions as the State Technical Committee. The USDA NRCS does convene a "State Technical Committee" but is regional and administered out of Hawaii. Therefore, the requirement for STC review of this FAP was addressed by the GFAP Advisory Council, which includes Guam NRCS staff.
4. **Forest Legacy Lead Agency**: Guam Forestry is the lead agency for the Forest Legacy Program.
5. **Applicable Federal land management agencies:** U.S. FWS, Navy, NRCS were included on the GFAP Advisory Council, National Park Service was consulted. The NAVFAC Naval Facilities Engineering Command is the lead agency for the relocation EIS and therefore provide representation for the U.S. Marine Corps, U.S. Army, and U.S. Air Force.

Table 24. Guam Forest Action Plan Advisory Council

Name/Position	Agency
Chelsa Muña-Brecht, Director	Guam Department of Agriculture
Christine Camacho Fejeran, Forestry Division Chief	Department of Agriculture, FSRD
Ruddy P. Estoy, Jr., Forester I	Department of Agriculture, FSRD
Lola Leon Guerrero, Chief Planner	Bureau of Statistics and Plans
Hope Cristobal, Chairperson	Northern Guam Soil & Water Conservation District
Michael Aguon, Chairperson	Southern Guam Soil & Water Conservation District
Dr. James McConnell	University of Guam
Dr. John W. Jenson, WERI Director	WERI (Water & Energy Research Institute of Western Pacific
Daniel Stone, Fire Chief	Guam Fire Department
Joey Manibusan, Assistant Chief, Prevention Bureau	Guam Fire Department
Jay Gutierrez, Acting Chief	Department of Agriculture, DAWR
Brent Tibbatts, Biologist	Department of Agriculture, DAWR
Margaret Aguilar	Guam Environmental Protection Agency
Evangeline Lujan	Guam Waterworks Authority
John Cruz, Assistant General Manager of Engineering and Technical Services	Guam Power Authority
Joseph M. Borja, Director	Department of Land Management
Margarita V. Borja, Land Management Administrator	Department of Land Management
Jack Hattig, Administrative Director	Chamorro Land Trust
Jesse Garcia, Deputy Director	Guam Department of Public Works
Carlotta Leon Guerrero	Chief Advisor, Military and Regional Affairs
Trina Leberer	The Nature Conservancy
Jocelyn Bamba, District Conservationist	USDA Natural Resources Conservation Service
Michael Jordan	USDA Forest Service, Pacific Southwest Region
Jacqueline Flores, Island Team Manager	U.S. Fish and Wildlife Service
Marybelle Quinata	Guam National Wildlife Refuge, U.S. Fish & Wildlife
Scott Vogt, Natural Resource Specialist	Naval Base Guam
Jennifer Horeg, Conservation Res. Program Manager	Joint Region Marianas
Lauren Gutierrez, Supervisory Nat. Res. Specialist	NAVFAC Marianas
Adrienne Loerzel, Forest Enhancement Prog. Manager	NAVFAC Marianas

Appendix 2: Forest and Non-forest Acres within the Urban Intermix

Table 25. Forest and non-forest acres within the WUI.

Region	Water-shed	Watershed Acres	Urban		Non-Forest		Forested	
			Acres	% Water shed	Acres	% Urban Intermix	Acres	% WUI
Eastern Watersheds	Pago	6,683	3,748	56%	2,000	53%	1,748	47%
	Ylig-Togcha	10,067	6,561	65%	3,502	53%	3,059	47%
	Talofofo	15,016	6,085	41%	3,460	57%	2,625	43%
	Ugum	4,851	600	12%	354	59%	246	41%
	Asalonso-Dandan	4,183	2,321	55%	1,288	55%	1,033	45%
	Inalajan	5,564	1,707	31%	1,140	67%	567	33%
Western Watersheds	Manell	3,107	1,000	32%	583	58%	417	42%
	Geus	1,120	527	47%	349	66%	178	34%
	Toguan	903	556	62%	453	81%	103	19%
	Umatac	2,447	776	32%	607	78%	169	22%
	Cetti	1,928	430	22%	327	76%	103	24%
	Taelayag	1,639	647	39%	435	67%	212	33%
	Agat	2,511	2,131	85%	1,439	68%	692	32%
	Apra	8,283	6,230	75%	4,287	69%	1,943	31%
	Piti/Asan	1,993	1,604	80%	1,068	67%	536	33%
	Fonte	1,575	1,266	80%	694	55%	572	45%
Northern Watersheds	Agana	8,717	8,322	95%	5,733	69%	2,589	31%
	Mangilao	8,772	7,638	87%	3,599	47%	4,039	53%
	Northern	44,971	36,242	81%	20,601	57%	15,641	43%

Appendix 3: Previous Vegetation Maps

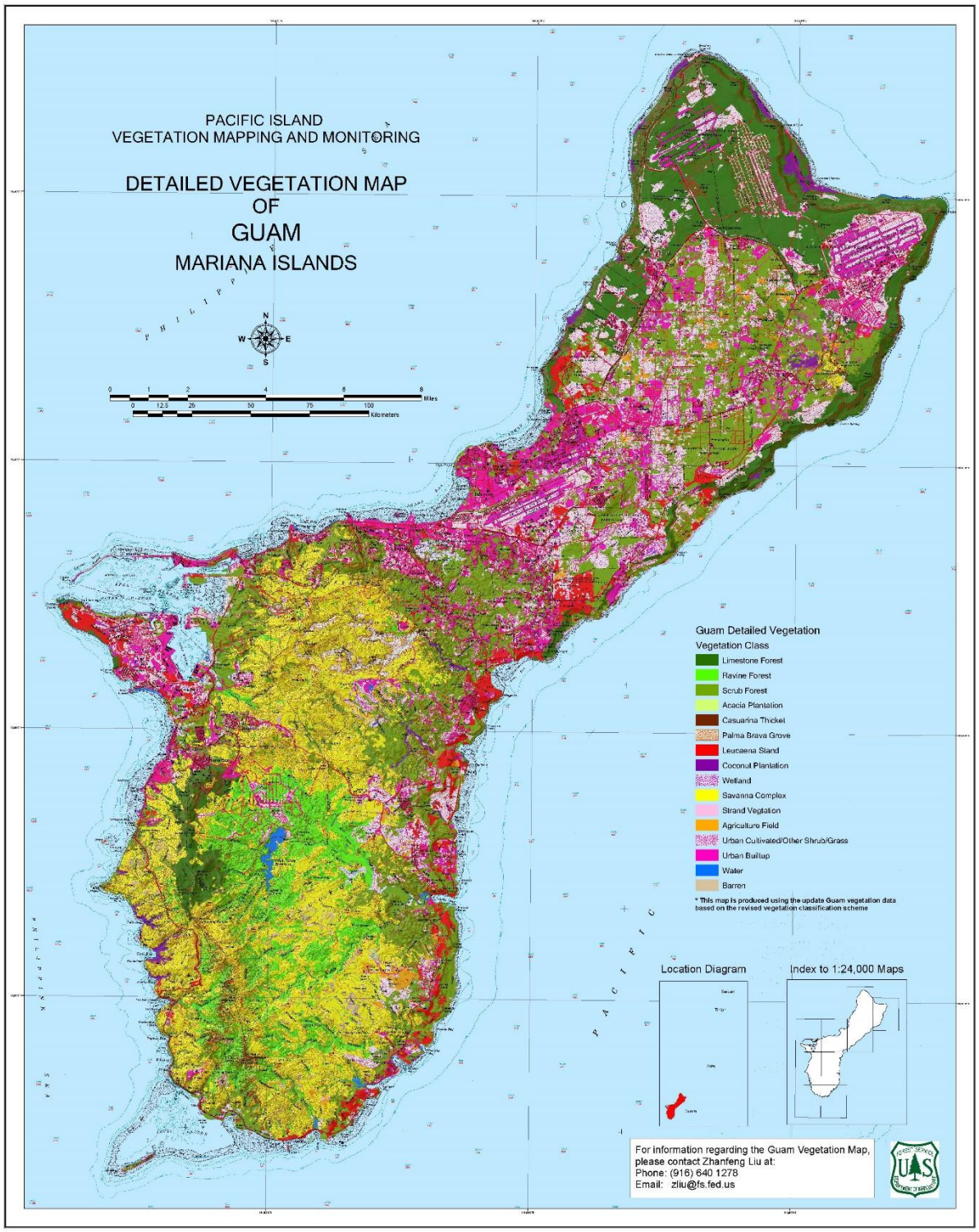

Figure 31. Detailed Vegetation Map of Guam 2006. Used for Stakeholder Issues. Reprinted from Liu (2006).

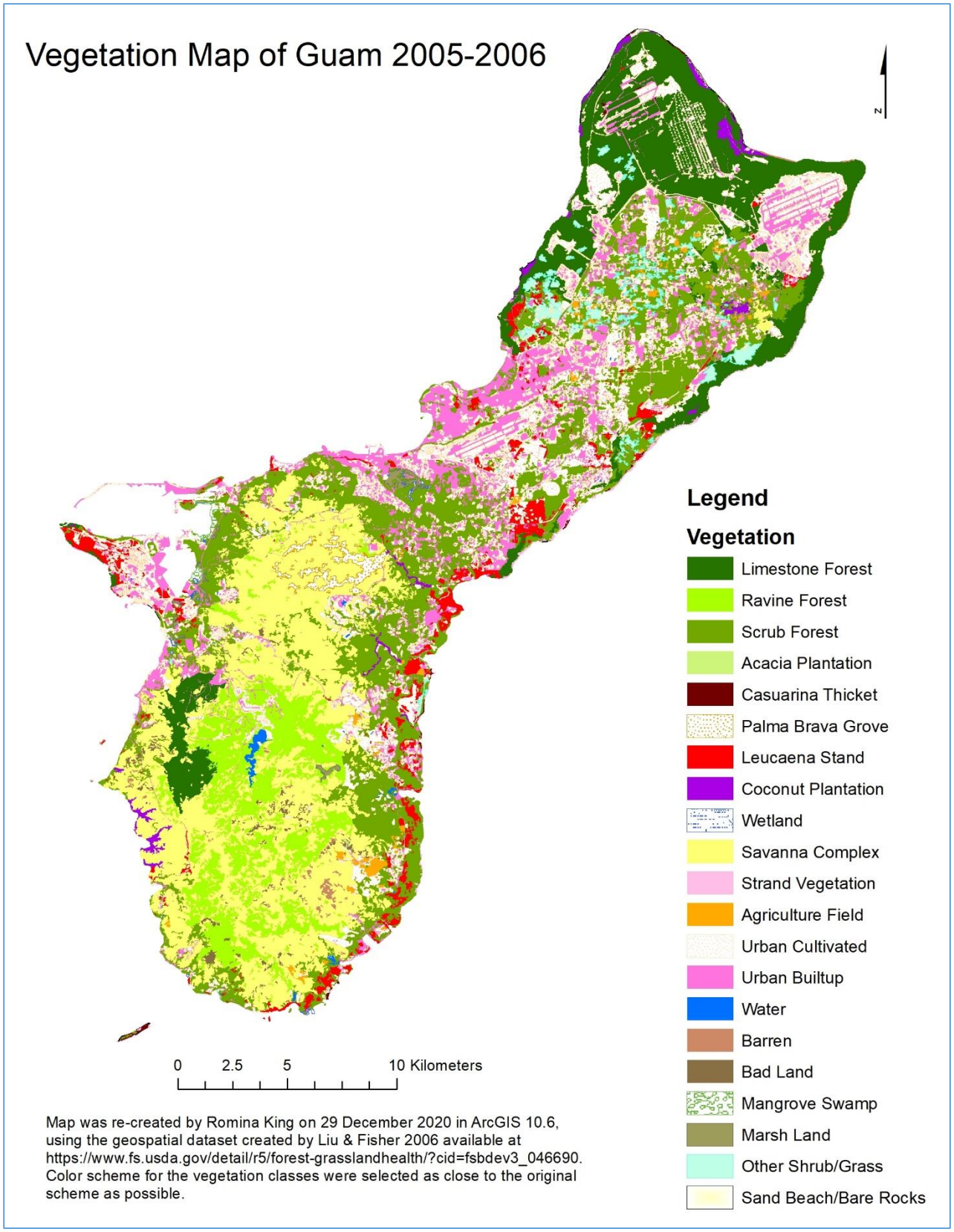

Figure 32. Vegetation Map of Guam 2005-2006, showing all categories.

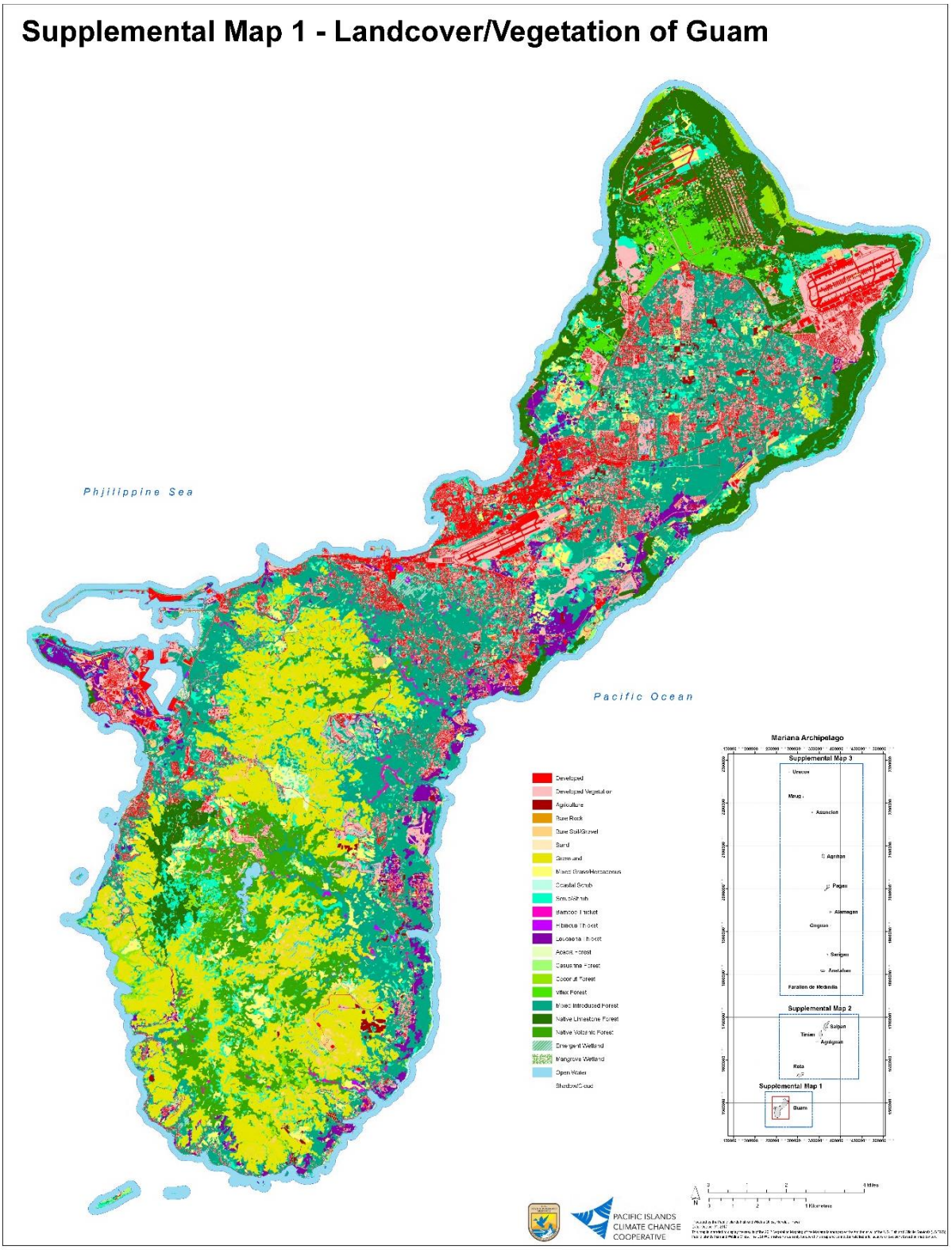

Figure 33. 2017 Detailed Vegetation Map of Guam. Reprinted from Amidon et al. (2017).

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