The Republic of Palau Statewide Assessment of Forest Resources and Resource Strategy

A comprehensive analysis of forest-related conditions, trends, threats and opportunities

June 2010

Republic of Palau Statewide Assessment of Forest Resources
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Photograph of Ngatpang's forest taken by Dr. Michael Balick

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Written by
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Abbreviations used:

BOA	Bureau of Agriculture
BNM	Belau National Museum
BWA	Babeldaob Watershed Alliance
DFR	Division of Fire and Rescue
DFW	Division of Fish and Wildlife
EBMP	Ecosystems Based Management Program
EQPB	Environmental Quality Protection Board
MOE	Ministry of Education
NEMO	National Emergency Management Office
NRCS	USDA Natural Resource and Conservation Service
OERC	Office of Environmental Response and Coordination
PALARIS	Palau Automated Land and Resources Information Systems
PAN	Protected Areas Network
PCAA	Palau Community Action Agency
PCS	Palau Conservation Society
PCC	Palau Community College
PNRC	Palau Natural Resource Council
SIUL	Institute for Sustainable Living
SLUTF	Sustainable Land Use Task Force
SPC	Secretariat of Pacific Communities
TEI	The Environment, Inc.
TNC	The Nature Conservancy
UCFC	Urban and Community Forestry Council

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Executive Summary

The Republic of Palau is a small yet diverse island nation with similar areas to its neighboring islands in the region. The relatively small size and isolation of island nations linked by large bodies of water directly relates to the issues, challenges and opportunities island nations share. The rapidly increasing population is placing high demand and threats on Palau's forests, whether for wood products, wildlife habitat, clean water or large farms. Infrastructure to support an increasing population is expanding into forests and savanna causing the loss of these resources and services they provide as watersheds and for traditional uses. Forests serve as carbon sinks that mitigate the impacts of climate change and need to be safeguarded by all nations. The Urban and Community Forest Council, Palau Natural Resource Council and Natural Resource and Conservation Service were the main technical contributors to this report. Each council has members who work within the communities and brought their concerns and issues forward during are regular meetings. It was decided within a few months that the members of the Urban and Community Forest Council would also serve as members of the Stewardship Coordinating Committee for SWARS with additional technical experts and community leaders.

The impact of climate change coupled with population growth pose increasing threats as a result of storms, sea level rise, flooding and landslides, droughts, fire, deforestation for timber, invasive flora and fauna, and increasing reclamation for development and crop production. Managers are increasingly challenged to address these threats in an effective and efficient way that will ensure that available funds result in positive outcomes that mitigate impacts and that enable islands to adapt with a focus on their most vulnerable forests habitats.

This assessment analyzes Palau's current and projected forest conditions and trends and delineates priority rural and urban forest landscapes from which a nation-wide strategy will be developed. The focus of this assessment is based upon three themes: conserve working forests; protect forests from harm; and enhance the benefits from trees and forests. This geospatial based assessment used the best available data to describe forest conditions on all ownerships in the Republic and to identify forest related benefits, services and threats to forest resources. This assessment highlights issues and trends of concern and opportunities for action and delineates high priority forest landscapes.

Spatial data gaps existed for the States of Angaur, Peleliu, Kayangel, Sonsorol and Hatohobei and parts of Koror. Spatial data gaps existed for the size and locations and frequency of fires, sizes of tree plantations, sizes of forest habitats of endangered species. Infrastructure data gaps existed as there are many developments not yet mapped. Contour data gaps for sea level rise issues for climate change which require contour of 0.5 meter along the coastlines of the Republic.

The Republic of Palau Statewide Assessment of Forest Resources was developed around the issues facing the Republic's forest and tree resources rather than based on the forest resources themselves. With input from the community at all levels, the Palau Bureau of Agriculture's Forestry Section program managers identified seven primary issues of rural and urban forests in the Republic:

1) Climate Change
2) Population Growth and Urbanization
3) Water Quality and Quantity
4) Wildfire Prevention
5) Conservation and Protection
6) Sustainable Use of Forest Resources
7) Urban Forest Sustainability

For each issue, geo-spatial analysis was conducted to delineate areas across the Republic of Palau's landscape where future efforts might best be focused. These areas of priority were determined using weighted over lay analysis. This involved identifying thematic layers of spatial data that could inform the issue, weighting them according to their relative importance, and then combining them into one priority output layer on a map that provides a visual indication of where these priority areas occur. Thematic layers provided the necessary data for the overlay analyses. Additional layers were developed from the urban forest sustainability analysis. All land, public, private, rural and urban was prioritized for each issue. The following paragraphs summarize each of the seven issues:

Issue 1: Climate Change

In the past decade the impacts of climate change have been affecting all forests of Palau. Coastal forests are being lost due to shoreline erosion. Lowland forests along steep slope are being lost to massive landslides after extreme rains. Sea level rise is causing seawater intrusion in taro gardens. Heavy rains and winds are toppling large trees. These extreme weather conditions are leading to the spread of invasive species once forest are opened up or taro patches or agroforests are abandoned due to crop loss caused by drought or fire after extended periods without rain. Climate Change is a cross cutting issue and that will be discussed in each issue. This section will focus on two urgent problems related to climate change: landslides and coastal erosion.

Issue 2: Population Growth and Urbanization

The Republic of Palau's communities are growing at differential rates. In some States there is emigration and in others immigration. The largest population is in Koror which has increased in size by 40% in the past 25 years. The State of Aria's population has increased by 75% over the past 25 years. Housing developments within critical watersheds have led to concern because of the potential impact to water quality. Community leaders need proactive management tools and technical support systems to help prepare for the impacts this growth will have on the forests. Geospatial analysis revealed that areas of high priority were the city of Koror, Koror State, the Ngerikiil Watershed in Airai State, the National Capitol in Melekeok and Ngarchelong State. Population growth and urbanization is a cross cutting issue related to all other issues.

Issue 3: Water Quality and Quantity

In the Republic of Palau, freshwater quality and quantity is overall good and plentiful; the challenge has been in storage and distribution, especially during periods of drought. The main source of water for over 75-80% of the population is the Ngerikiil Watershed which produces 20 million gallons of water daily of which 4.0 million gallons of water is treated and supplied to communities in Koror and Airai. Each State in Babeldaob has a source of water. The outer states have ground water and wells. It is critical that these sources of water be protected and upstream of pumping stations be protected.

Issue 4: Wildfire and Public Safety

The Division of Public Safety is tasked with the responsibility to prevent and suppress wildfires. At the peak of the spring 1998 drought during the ENSO Event, there were daily fires throughout Babeldaob. The main challenge in 1998 was the lack of access roads and sources of accessible water to suppress these fires. This continues to be a challenge. Arson is common, particularly during dry month and dry years. Primary factors that relate to high incidences and intensity of fires are population growth, changing land use, and increasing drought frequency. There is also a need for more enforcement officers and trained firefighters, equipment and community education and awareness. Vulnerable areas are those near infrastructure with limited access for fire trucks and lack of sufficient supply of water. These areas are

either far from fire stations or fire hydrants and mainly savanna areas. Often these areas have easy access via the national highway yet relatively far or remote from village centers.

Issue 5: Conservation and Protection

Forest protection and conservation is critical to preserve terrestrial biodiversity, protect watersheds which are a source of timber, medicine, food, and a habitat for wildlife. The forests are threatened by population growth, land fragmentation, fire, and invasive species. Geospatial analysis revealed that areas of high priority were the upper watershed areas, and main water sources in Palau (Refer to Issue 3). Palau has about 130 endemic plant species confined to an area of 453km^2. About 15% of these are only known from type collections. For over 60% of these endemics there is insufficient data for establishing a red-list category. A complete IUCN Red Listing of endemic plants is important because of threats of habitat loss, development and climate change. The need to know which plants are most threatened will enable effective biodiversity conservation in Palau. Approximately 51 species of Palau's endemic plants species have been given a preliminary IUCN red-listing category.

Issue 6: Sustainable Forest Resource Use

The forests of Palau provide food, timber, medicine, materials for arts and crafts and recreation for the community. Population growth, ownership shifts, and new residential development have impacted the forest landscape. There is more demand for native trees that are good timber trees such as *Gmelina palawensis* for building homes. However sustainable harvest of local wood with an active replacement with local propagules has existed for many generations. Promotion of sustainable harvest of top timber trees for local use through proper site management has been ongoing with private land owners. Historically Nekken has planted two species of mahogany because of their fast growth rates. The coconut *Cocos nucifera* is a cultural key stone species with over 40 uses that is an invaluable resource to Palau. Old coconut plantations have existed in Palau since the German Administration over 100 years ago that can be put into production. A new coconut oil processing plant has recently opened providing an opportunity to revitalize the coconut oil production as a village industry. Palau's small size cannot support a major timber industry. The promotion of agroforestry as an alternative to commercial agricultural would provide both food and timber to communities. Hundreds of plants are used for local medicine and for cultural purposes. Visitors curious about traditional forest resource use support eco-tourism programs that sustain forests throughout the world. The unique craft of storyboard carving, as well as the construction of the abai, tools, baskets and traditional clothing are reliant on forest resources and play an integral role in sustainable tourism. Although the local growth rate is about 2%, the tourism industry continues to grow. Agro tourism has been promoted throughout the region. Guests enjoy demonstration of preparation of local foods and tasting unique foods of Palau.

Issue 7: Urban Forest Sustainability

With the national highway completed, residents are slowly building and relocating to their private lands in Babeldaob. Yet the urban center of Koror and Airai continue to expand and converting more and more forested areas into urban areas. More and more impervious surface exists in Koror and Airai. Widening the main road of Koror resulted in the loss of many large shade trees including large mango trees. Trees provide health and environmental benefits that are important for a good of quality of life for Palauan communities. It is critical to plant, care for and conserve trees in the communities where Palauans live, work and play. Koror and Airai are considered very high or high priority for focusing future programs of urban forests.

Conditions and Trends

The purpose of the new approach to State and Private Forestry (S& PF) is to shape and influence use of forest land to optimize benefits from trees and forests for both present and future generations. The USDA Forest Service (USFS) worked closely with the National Association of State Foresters (NASF) to do the following:

- Examine current conditions and trends affecting forest lands.
- Review existing S&PF programs to determine how best to address threats to forests.
- Develop a strategy for delivering a relevant and meaningful set of S&PF programs and opportunities.

The new Redesign approach focuses on three consensus-based S&PF National Themes and Objectives:

State and Private Forestry National Themes and Objectives

1. Conserve working forest landscapes
1.1. Identify and conserve high priority forest ecosystems and landscapes
1.2. Actively and sustainably manage forests
2. Protect forests from harm
2.1. Restore fire-adapted lands and reduce risk of wildfire impacts
2.2. Identify, manage, and reduce threats to forest and ecosystem health
3. Enhance public benefits from trees and forests
3.1. Protect and enhance water quality and quantity
3.2. Improve air quality and conserve energy
3.3. Assist communities in planning for and reducing wildfire risks
3.4. Maintain and enhance the economic benefits and values of trees and forests
3.5. Protect, conserve and enhance wildlife and fish habitat
3.6 Connect people to trees and forests, and engage them in environmental stewardship activities
3.7. Manage and restore trees and forest to mitigate and adapt to global climate change

National and State resources assessments are used to develop competitive proposals for S&PF funds. To receive federal funding under the S&PF Redesign Program, projects must follow the annual national direction developed by the USFS and directly address one or more of the three National Themes.

In order to ensure that S&PF resources are being focused on high priority areas with the greatest opportunity to achieve meaningful outcomes, each state, territory and island works collaboratively with the USFS and other key partners to develop a comprehensive statewide assessment of forest resources. This assessment provides a comprehensive analysis of the forest-related conditions, trends, threats and opportunities in each state

Comprehensive statewide assessments of forest resources provide a valuable and unique opportunity to highlight the full scale of work needed to address priorities in the forests of each state and potentially across multiple states. Statewide forest resources strategies will be developed on the basis of the state assessments by identifying landscapes and projects where an investment of federal competitive grant funding could most effectively accomplish goals or leverage desired action.

At a minimum this statewide assessment of forest resources:

- Describe forest conditions on all ownerships in the Republic of Palau
- Identify forest –related benefits and services
- Identify threats to the forest resources
- Highlight issues and trends of concern as well as opportunities for action
- Delineate high priority forest landscapes to be addressed
- Are geo spatially based and make use of the best existing data

Three components are required in the assessment and planning process:

- Statewide Assessment of Forest Resources- provides an analysis of forest conditions and trends in the state and delineates priority rural and urban forest landscape areas and is the focus of this document
- Statewide Forest Resource Strategy- provides long-term strategies for investing state, federal and other resources to manage priority landscapes identified in the assessment, identifying where federal investment can most effectively stimulate or leverage desired action and engage multiple partners
- Annual Report on Use of Funds- describes how S&SP funds were used to address the assessment and strategy, including the leveraging of funding and resources through partnerships, for any given fiscal year

The Republic of Palau's land is at least 30% privately owned land and 70% publicly owned. About 75% of Palau's land is forested. The Republic of Palau worked collectively with each State to identify following set of National priority issues to develop one State-wide assessment.

- Significant forest ecosystems and landscapes
- Urbanization, fragmentation, and loss of forestland
- Fire Prevention
- Forest Health
- Water quality protection and watershed management
- Wildlife habitat and species conservation
- Forest resource market opportunities

The Urban and Community Forestry Council and Palau Natural Resource Council members made up the assessment team led by Ms. Pua Michael, acting head forester of the Republic of Palau. The team decided to utilize the members of Urban and Community Forestry Council as its Stewardship Coordinating Committee and brought in partners from other agencies to contribute. The team represented all sectors and was familiar with the concerns and opportunities common to the Republic based upon their own programs within the community. A smaller technical team with GIS experience met with the PALARIS office on a regular basis to prioritize sites, layers and set up criteria. This was then brought to the larger council for their review and comments. Several meetings were held with the Division of Fire and Rescue and the Division of Fish and Wildlife. Meetings were held with Program Mangers at the Forestry Office to work on the specific details of the strategy.

The Republic of Palau Statewide Assessment of Forest Resources is issue driven, based upon State and stakeholder input, and meets the requirements as specified in the national guidance of state assessments.

The Republic of Palau Wildfire Risk Assessment

The Division of Fire and Rescue is developing the Republic of Palau Wildfire Risk Assessment (PWRA) to quantify and document the wildfire problem in Palau. The PWRA will be is a semi-quantitative assessment that provides baseline information that will allow Palau's fire managers to implement proactive fire management planning.

The objectives are to provide the information necessary to support the following key priorities:

- Identify those areas that are currently most prone to fire
- Identify areas that may require additional tactical planning, specifically related to mitigation projects and community wildfire protection planning
- Provide information needed to support resources, budget & funding request in response to wildfire risk
- Allow agencies to work together to define priorities and improve emergency response, particularly across jurisdictions
- Increase communication between local residents & the public to address community priorities and needs
- Plan and prioritize hazardous fuel treatment programs
- Establish a data repository and a series of software tools to support continued analysis and monitoring of wildfire risk throughout the Republic of Palau

The results of PWRA will allow the Republic to identify areas of wildfire risk in a relative manner from low to high, for each community fire response zone and State. This will allow fire managers to prioritize and focus resources and funding efforts in those areas that need it the most. The assessment is currently underway with the development of a database and mapping system and community outreach.

The Republic of Palau Forest Land Assessment
The Republic of Palau Forest Land Assessment (PFLA) is a cooperative project of the Republic of Palau State Forester to identify important lands across the landscape where future efforts in rural forestry assistance should be focused. The Republic of Palau will use the Spatial Analysis of this report as the assessment component for the Forest Stewardship Program.

Methods for SWARS
Weighted overlay spatial analysis of up to 10 input data layers were identified by the technical team to produce maps for each of the 7 issues. Criteria for each layer were set primarily by PALARIS with input from the technical team. Meaningful spatial analysis required 3-5 layers: vegetation, soil, rivers & streams, and infrastructure. Specific layers were only used for a given issue, such low elevation areas and areas of slope failure for Issue 1Climate Change, a priority watershed layer was used for Issue 3 Water Quality and Quantity, point locations for areas of chronic wildfires for Issue 4 Wildfire Prevention; important forest areas or endangered species for Issue 5 Conservation and Protection; plantations for coconut, mahogany, and other trees for Issue 6 Sustainable Use and urban forest projects for the Issue 7 Urban Forests. Often a good satellite image or aerial could demonstrate priority areas.

Data Gaps
Spatial data gaps existed for the States of Angaur, Peleliu, Kayangel, Sonsorol and Hatohobei and parts of Koror. There spatial analysis was done primarily for Babeldaob and aerial and satellite imagery was used for other states. Spatial data gaps existed for the size and locations and frequency of fires, sizes of tree plantations, sizes of forest habitats of endangered species. Infrastructure data gaps existed as new development was not yet mapped. Contour data gaps for the sea level rise issue of climate change require 0.5 meter contours along the coastlines to better prioritize areas of the Republic.

Physical Features

The Republic of Palau became an independent nation on October 1, 1994 in part with the implementation of the Compact of Free Association between Palau and the United States of America.

Palau stretches from about 2 to 8 degrees north latitude and 131 to 135 degrees east longitude. It is about 500 miles equidistant from the Philippines to the west and from Papua New Guinea to the south. It consists of more than 340 islands, of which only 9 are inhabited. These are, from Northeast to Southwest: Kayangel, Babeldaob including the southeastern rock islands, Koror including the rock islands, Peleliu, Angaur, Sonsorol, Pulo Anna, Hatohobei, and Helen Reef. Most of the islands are of volcanic origin, and others are of raised limestone (Figure 1). Babeldaob is the largest island, making up 80 percent of the total land area. Babeldaob Island consists of ten states, namely, Airai, Aimeliik, Ngaremlengui, Ngarchelong, Ngchesar, Melekeok, Ngiwal, Ngaraard, Ngardmau and Ngatpang. Including the states in Babeldaob, there are a total of 16 States in Palau.

Palau covers 189 square miles of land area including rock islands. The surrounding sea area is very large, including an exclusive economic zone extending over 237,850 square miles. Koror with a land area of 7.1 square miles is the most densely populated state: two thirds of the population resides in Koror. Koror lies just south of Micronesia's second largest island, Babeldaob, which contains 153 square miles of undulating forests, grasslands, rivers, waterfalls, wetlands, mangroves and some of the most beautiful stretches of beaches. The Capitol of Palau is in Melekeok along the east coast of Babeldaob.

Palau's distance to major cities in nautical miles:

Palau's distance to major cities in nautical miles: Guam (722 miles), Hong Kong (1,739 miles), Honolulu (4,449 miles), Manila (528 miles), San Francisco (5,751 miles), Shanghai (1,679), Sydney (3,319), and Tokyo (1,890 miles). The Palau Island is 9 hours ahead of Greenwich Mean Time. Palau is in the same time zone as Japan.

Figure 1 Republic of Palau
2006 Ikonos Satellite Image PALARIS

The Republic of Palau Forest habitats

The Republic of Palau is relatively small yet diverse with several habitats. The flora of Palau shares many common species with the Philippines and Indo-Malaysia, the source of biodiversity for this part of the world. Each of the forest types are best described as a complete habitat with unique soils, vegetation, landscape location and associated biological communities. Forest species composition in Palau is related to the soil type among other factors. Volcanic soils are found on Babeldaob, Ngerkebesang, Malakal and Koror. Coral limestone soils are found on Peleliu, Angaur, the Rock Islands, Kayangel and the Southwest Islands. All forests in Palau are classified generally as "lowland tropical rainforests". Lowland because they are below 300 meters in elevation and rain forests because Palau receives about 380 cm of rain distributed throughout the year. The volcanic islands support a primary vegetation type which is a mixed species lowland tropical rain forest we call volcanic forest (previously referred to as upland forest in Cole et al., 1987). Also on volcanic islands are swamp forests which are found on soils that are inundated with fresh-water. Mangrove forests are found along most of the coast of the volcanic islands and sparsely on limestone islands in salt or brackish water. Savanna grasslands are found where the forest has been removed, typically along the ridges. The coral islands support vegetation types which are species rich and variable; these include the limestone forests, atoll forests and strand vegetation along the coasts. Limestone islands also have limited areas of mangrove forests along the coastal flats mostly on Peleliu and on certain Rock Islands (Cole et al., 1987). There is some amount of overlap of species between the different forest types or habitats. Many species have adapted to both extremes of limestone soils and volcanic soils that have highly varying pH regimes.

Freshwater swamp forests

Freshwater swamp forests tend to occur slightly inland of mangrove forest in areas of fresh or slightly brackish water and in wet lowland areas or along the riparian zone. This sensitive forest habitat represents the least amount of area of all forest types and requires protection. The dominant canopy species in swamp forest are relative to their proximity to salt water and other topographic considerations, such as riparian verses lowlands near the coast or inland. The other layers of this forest vary less. Typically, the forest floor growth is predominantly the seedlings of the dominant trees. Species commonly found in freshwater swamp forests are *Barringtonia racemosa, Calophyllum pelewense, Campnosperma brevipetiolata, Cynometra ramiflora, Horsfieldia irya, Pandanus kanehirae,* and *Stemonurus ammui*. In disturbed areas or open areas *Hibiscus tiliaceus* and *Macaranga carolinensis* are found extensively. In the moist ravines and riparian areas, dense and diverse forest vegetation occurs including *Barringtonia racemosa, Colona scabra and* the poison tree, *Semecarpus venenosa.* A common, but not universal, trend of the zones of large swamp forests from upland to mangrove has been described by Canfield et al. (1992) as *Calophyllum, Stemonurus, Pandanus* association as transitional between inland mangroves and the *Horsfieldia* forest.

Volcanic forests

Volcanic forests are on basalt soils, these lowland forests are dense, multi-layered and structurally complex encompassing distinct subtypes of forest in undisturbed ecosystems. The volcanic lowland forests are considered the most species rich in Micronesia (Stemmermann, 1981) and have the highest rate of endemism. It has also been previously noted that the species composition varies with topographic richness (Canfield et al., 1992). Forests on ridges have higher species diversity with *Maranthes corymbosa* often dominant, whereas forests on the slopes and in valleys are less diverse and dominant with *Campnosperma brevipetiolata* and *Pinanga insignis.* Generally, the forests of Palau are heterogeneous, with no distinctly dominant species. There are, however, landscapes where dominant climax species prevail. One of the most common tree species found in Palau, as in the rest of the Caroline Islands, is *Campnosperma brevipetiolata.* Other common species found in the volcanic forests include *Alphitonia carolinensis, Calophyllum inophyllum, Calophyllum inophyllum* L. var. *wakamatsui, Elaeocarpus joga, Gmelina palawensis, Maranthes corymbosa, Pterocarpus indicus, Rhus taitensis, Semecarpus venenosa,* and *Serianthes kanehirae* Fost. var. *kanehirae.* Other species found in this mixed

species forest include *Atuna racemosa Rafin* spp. *racemosa, Cerbera* spp., *Fagraea ksid, Horsfieldia palauensis, Manilkara udoido, Myristica insularis,* and *Serianthes kanehirae*. Species commonly found in the understory of the volcanic forests include the palm *Pinanga insignis, Alpinia carolinensis, Cyathea sphaeropteris spp., Ixora casei, Osmoxylon oliveri,* and *Pandanus aimiriikensis.*

Mangrove forests

Mangrove forests comprise a dense forest which grows in brackish to salty water along a narrow strip of the tidal zone near the shore. Mangrove forests are widespread around Babeldaob and found in the low lying, coastal, muddy seashores, quiet bays and estuaries. Mangrove forests are also found in the Rock Islands, commonly along the edge of marine lakes. Mangroves play a vital role in buffering the effects of storms and waves along coastal areas. They also provide nursery habitat for marine life and filter runoff exiting terrestrial ecosystems. The filtration that mangroves provide helps to sustain coral reef and fish habitat by reducing siltation. The species-rich mangrove forests of Palau include over 24 different species. The principle species found in mangroves include the trees: the less common *Avicennia marina* subsp. *marina, Bruguiera gymnorrhiza, Ceriops tagal, Dolichandrone spathacea, Excoecaria agallocha, Lumnitzera littorea, Rhizophora apiculata, Rhizophora mucronata, Scyphiphora hydrophyllacea, Shirakiopis indicus, Sonneratia alba,* and *Xylocarpus granatum.* The smaller plants or lianas include *Dalbergia candenatensis, Derris trifoliata;* the palm *Nypa fruticans;* and the ferns *Acrostichum aureum* and *Nephrolepis acutifolia.* Mangrove trees adapt to a muddy saltwater environment by producing specialized roots such as prop roots for structural support, knee shaped pneumatophores or conical roots for gaseous exchange and elaborate buttress roots for both structural support and gas exchange.

Mangroves are the second largest forest type in Palau covering 48 km^2 or 11% of all vegetation. The mangrove-associated plants are adapted to soft muddy substrate, oxygen poor soils and saltwater with modified roots, leaves, flowers and fruits. Certain species such as the mangrove holly, *Acanthus ebracteatus* and the mangrove tree, *Avicennia alba* have more restricted distributions. An estimated 1.43 km^2 of forests, 0.28 km^2 of wetlands and 0.6 km^2 of mangroves were lost or reclaimed for the construction of national highway (TEI 2003). Using 2005 Quickbird imagery, an estimated 0.4 km^2 of mangroves has been lost in Palau for landfills, development and aquaculture. The National Highway completed in 2007 reclaimed an estimated 1.3 km^2 of mangrove forest. Thus, an estimated 1.7 km^2 of mangroves has been lost over the past 40 years at an estimated rate of 0.04 km^2 yr^{-1}. Margos et al. (1994) estimated mangrove cover at 45 km^2 compared to the current estimate of 48 km^2 or an estimated increase of 3 km^2 in 15 years (0.2 km^2 yr^{-1}).

A comparison of aerial photographs between 1968 and 2005 show that mangroves forests within Airai Bay nearly doubled in size (from 4.2 to 7.9 km^2) in a 37 year period at a rate of 0.1 km^2 yr-1. These rough estimates indicate that the rate of increase in mangrove forests is 2.5 to 5 times greater than the rate of loss from reclamation for development. Airai Bay has become a mud bank and is silting at a rate of 150 tons km-$2yr^{-1}$ (Golbuu et al. 2003). If siltation continues at its current rate it is estimated that the bay will be above sea level in 15 years (Victor 2007). This increase has been attributed to natural and accelerated growth due to increased sedimentation into the bay. Increasing populations, unplanned development and more frequent and intense rainfall result in accelerated rates of sedimentation which provides additional substrate for mangrove propagules to grow. Accelerated sedimentation from soil erosion and mangrove expansion may not be a new phenomenon. This process may have been initiated thousands of years ago when the first immense terrace systems were created (Masse et al. 2006). Sediment cores with pollen grain analysis of agricultural and native plants would enable scientists to reconstruct more accurate time lines and to better determine relationships between human activities, sedimentation and forest dynamics for a given location over a longer time frame.

Limestone forest
Limestone forest vegetation types are found on limestone islands and outcrops mainly on Peleliu, Angaur, the Rock Islands and Airai. On the Rock Island limestone substrate of the coral rock, the organic matter from the vegetation forms a thin layer of soil in places in which the vegetation grows. The karstic substrate is steep, porous and rugged. The species-rich forest includes *Aidia racemosa, Badusa palauensis, Barringtonia racemosa, Bikkia palauensis, Clerodendrum inerme, Cordia subcordata, Cycas micronesica, Cyrtandra todaiensis, Eugenia reinwardtiana, Flacourtia rukam* Zoll. & Mor. var. *micronesica, Garcinia matsudai, Garcinia rumiyo* Kaneh. var. *calicola, Geniostoma sessile, Guettarda speciosa, Hydriastele palauensis, Intsia bijuga, Ixora casei, Meryta senfftiana, Morinda latibractea, Pandanus dubius, Pemphis acidula, Pleomele multiflora, Polyscias grandifolia, Pouteria calcarea, Pouteria obovata, Premna serratifolia, Psychotria* spp., *Rinorea bengalensis, Scaevola taccada, Semecarpus venenosa, Soulamea amara* and *Tarenna sambucina* (Forst.) var. *oweniana.*

Atoll and Coastal forests
Atoll forests are usually found in the interior of larger and wetter atolls along sandy or rocky coasts and generally behind strand forest but can be mixed with strand species. The transition from strand to atoll forest is often gradual and indefinite. Species commonly found include an outer fringe of the shrubby *Scaevola taccada* (korrai or kirrai), *Heliotropium foertherianum* (rirs) and *Sophora tomentosa* (dudurs) Along the rocky limestone coastlines the tree *Pemphis acidula* is common. *Casuarina equisetifolia* (ngas) is common at areas of human settlement and expand into adjacent areas. Other atoll and coastal plant species include *Calophyllum inophyllum* (btaches), *Cordia subcordata* (badirt), *Hernandia sonora* (doko), *Guettarda speciosa* (belau), *Pandanus* spp. *Pisonia grandis*, *Terminalia catappa* (miich), *Morinda citrifolia* (ngel), *Ochrosia oppositifolia* (uaoch), *Hibiscus tiliaceus* (chermall), *Ficus* spp. and *Premna serratifolia* (chosm). Coastal forests along Babeldaob include a similar flora.

Agroforest
Agroforests are forests consisting of areas under cultivation for fruit and food crops and trees and wood products. Agroforests are often a mosaic of manmade landscapes that are integrated into the natural landscape. Traditional agroforests of Palau have complex irrigation systems with organic fertilization. The depth of soil for taro production within these systems can be more than one meter in depth.

Coconut plantations
Coconut plantations are agroforests dominated by *Cocos nucifera* (lius) that were cultivated in large plantations during the German, Japanese and American administration. Copra, a product of coconut was a major industry during the German period. Today many of these plantations still can be found throughout Palau.

Casaurina forests
Casaurina forests are dominated by *Casuarina equisetifolia* (ngas) which is a coastal tree common in sand and coral rubble that is often near the high water mark but can be found in both limestone and volcanic soils and as part of the coastal strand vegetation. The southern states of Angaur, Peleliu, and the Ngemelis Complex are dominated by large *Casaurina* trees. Some of the rock islands are now dominated by this species. This tree can also be found in Babeldaob in areas where coral fill was used to either reclaim reef or build roads. The wood of *Casaurina* is used for posts, handicrafts and fuel. This native tree is highly adaptable species and can grow in poor soils and marginal habitats. The needles can inhibit growth of other native trees.

Mahogany plantations
Mahogany plantations consist of two species of tall trees: S*wietenia macrophylla* and *Swietenia mahagoni*. Since the Japanese administration, mahogany has been actively planted as a source of timber with many small plantations and larger plantations of over 100 acres found in Palau.

Urban Forest
Urban forests are near homes and infrastructure in highly populated areas such as Koror and Airai State and areas with higher densities than the mean for a given state. Native and introduced trees in urban areas included 64 species and 37 families (Kitalong, 2001). The most common trees include *Mangifera indica (*iedel*) Areca catechu (buuch), Cocos nucifera* (lius), *Terminalia catappa (miich), Swietenia macrophylla* (mahogoni), *Spondias pinnata* (titimel), *Plumeria obtuse* (elilai) and *Artocarpus altilis* (meduu). Other important trees and shrubs were *Musa* spp., *Persea americana*, *Syzygium aqueum* and *Nephelium lappaceum*. Less common trees included *Carica papaya*, *Citrus* spp., *Psidium guajava*, *Annona muricata*, *Premna serratifolia, Averrhoa carambola, Muntingia calabura* and *Bambusa vulgaris*. Decorative bushes and plants included *Gardenia jasminoides, Hibiscus rosa-sinensis* and *Cordyline fruticosa*. Large trees observed included *Serianthes kanehirae* Fosb. var. *kanehirae, Falcataria moluccana, Cananga odorata*, *Samanea* sp. and *Campnosperma brevipetiolata*. *Rhizophora mucronata* and *Calophyllum inophyllum* were found near homes adjacent to the mangroves and coasts.

Volcanic steep slope palm forests
High basaltic outcrop ridges represent 1% of Babeldaob's forests and are dominated by the palm *Heterospathe elata* var. *palauensis* (demailei or beokl) and also dominates steep cliffs in limestone forests (Costion and Kitalong 2006).

Savanna grasslands
Savanna grasslands with associated trees occur on volcanic soil substrates where the primary forest has been removed and some are naturally occurring. There are over a dozen endemic savanna species suggesting that there may have been some isolated pockets of native savanna. The loss of native forest resulted in soil erosion and degradation decreasing the probability of forest regeneration. The savanna systems persist due to repeated periodic fire caused by humans. Savanna is found throughout the island of Babeldaob and in areas of Koror. The vegetation consists of grass, sedges, ferns, shrubs and a few scattered tree species including some endemic species. Trees and shrub species that grow in the harsh savanna ecosystem are potential reforestation species. These species included *Commersonia bartramia, Morinda citrifolia, Morinda pedunculata, Mussaenda frondosa, Pandanus tectorius, Pleomele multiflora, Symplocos racemosa* var. *palauensis, Timonius subauritus,* and *Trichospermum ledermannii and Calophyllum inophyllum var. wakamatsui.* Shrubs often found include *Decaspermum parviflorum, Dianella carolinensis, Eurya japonica* Thun. var. *nitida, Hedyotis korrorensis* (Val.) Hosok. var. *korrorensis, Melastoma malabathricum* L. var. *mariannum, Phyllanthus palauensis, Pleomele multiflora, Spathoglottis* spp., and *Wikstroemia elliptica.* Forest-savanna edge species are exposed to more light than the surrounding forest and included *Alphitonia carolinensis, Calophyllum inophyllum* L. var. *wakamatsui, Fagraea ksid, Garcinia matsudai, Pleomele multiflora, Pouteria obovata* and *Rhus taitensis.*

Status and Trends of Forest Resources

The Palau Bureau of Agriculture's Forestry Division in cooperation with the US Forest Service conducts forest inventories to measure the status of all the forest resources in the state. The goal of the Forest Inventory and Analysis (FIA) program is to determine the extent, growth, composition, mortality, and health of forests as well as land use changes and potential for wildfire in the Republic. The inventory consists of a series of permanent survey plots established in a grid pattern across the Republic that are surveyed every 10 years.

Forest Type

Cole et al. (1987) estimated a forest cover of 80% including agroforest and secondary forest vegetation and 20% non-forest vegetation. Donnegan et al. (2007) estimated a forest cover of 82% including agroforest and secondary forest vegetation and 18% non-forest. Cole et al. (1987) mapped 412 km^2 with a canopy threshold equal to or greater than 30% using 1976 aerial photography. Donnegan et al. (2007) covered 445 km^2 with a canopy threshold of equal to or greater than 10% using 2003 IKONOS (GeoEye Corp.) and 2005 QuickBird satellite imagery. Given the difference in canopy cover thresholds between 1987 and 2007 surveys it is not possible to make a direct comparison between studies. Trends indicate that there may be some areas in Babeldaob where non-forest vegetation reverted to forest. Comparisons of the 1987 and 2007 surveys suggest that forested land in Babeldaob was maturing and may be encroaching slightly on non-forest vegetation. In contrast, Peleliu, Koror and Angaur were losing forested land to urban and non-forest vegetation land uses. Donnegan et al. (2007) estimated that 16% of the forest was limestone and 66% was volcanic.

MacLean et al. (1988) conducted a timber inventory using forty nine plots of which three plots were in swamp forest, five plots were in mangrove forest and 41 plots were in either limestone or volcanic forests of Babeldaob. Donnegan et al. (2007) delineated land cover using 54 permanent plots of which 11 plots were in limestone forest and 43 plots were in volcanic forest in Babeldaob and Koror. Donnegan et al. (2007) estimated 2,115 trees ha-1 (SE=68) compared to 3,168 trees ha^{-1} (SE=102) in 1988. The estimated basal area was 33.5 m^2 ha^{-1} in the 2007 survey compared to 31.2 m^2 ha^{-1} in the 1988. The estimated tree volume per hectare was 192 m^3 (SE=296) in the 2007 survey compared to 122 m^3 (SE=188) in the 1988 survey. Donnegan et al. (2007) suggested that some trees were increasing in size while others died during a thinning phase. The 2007 inventory data further suggested there was a higher net wood volume in limestone than volcanic forests with less species per plot in limestone (10 species) compared to volcanic forests (12 species).

Endress & Chinea (2001) studied landscape change in the Ngeremeduu Bay Drainage Area, an 84 km^2 area located along the west central coast of Babeldaob. They overlaid 1947 maps over 1992 maps and set plots with the study site. Their results showed that the forest increased by 10.9% and the grasslands decreased by 11.2% between 1947 and 1992. Therefore, the rate of forest growth over this 45 year period was 0.22% yr^{-1} or 3 times greater than the rate of growth estimated throughout Palau derived from the Donnegan et al. (2007) study. The majority of this transition occurred between 1947 and 1976 when 41.6% of the grassland cover was converted to forest. This conversion slowed substantially after 1976 as only 3.6% of the grassland areas were further converted to forest by 1992. Forests expansion was significantly associated with the location of abandoned agricultural communities. Over 92% of the forests expansion occurred within 100 m of established forests suggesting that nearby forests facilitate recovery following human disturbance. This may also suggest that agricultural lands originally within forested areas became reforested after abandonment because the soils were less degraded than open savanna areas.

Over a 13 year period (1992-2005), analysis of aerial images indicated that there was differential forest growth for 46 forest patches within a watershed area in Airai, southeastern Babeldaob, with an overall increase in forest size of 2.28 hectares or 0.5% (462.26 ha in 1992 to 464.54 ha in 2005) or a rate of

0.04% yr^{-1} which is slightly lower but within a similar range as the rate derived by Donnegan et al. (2007). Further analysis showed that the mean rate of expansion (±1 SD) was 38 ± 525 m^2 yr^{-1}. Nine of the forest patches increased in size at a rate of 608 ± 461 m^2 yr-^{1} with a maximum expansion of 1,725 m^2 yr^{-1}. Three forest patches decreased in size at a rate of 1,267 ± 1,150 m^2 yr^{-1} with a maximum rate of loss of 2,594 m2 yr^{-1}. A total of 35 forest patches remained unchanged. This preliminary study showed relatively slow forest growth in recent years in southeastern Babeldaob. More field investigations are needed to determine the composition of these forest patches and possible causes for these differential growth rates. Tree species commonly found along forest edges include the endemic *Trichospermum ledermannii*, *Macaranga carolinensis*, *Cerbera manghas*, *Rhus taitensis*, and *Maranthes corymbosa*; they have been observed to gradually expand into grasslands. These species are typically more stunted in growth in open edge areas than in the interior of the forest. More research using similar methodologies at finer spatial and temporal scales would provide a better understanding of changes in vegetation landscape of Palau.

During 2004 and 2005, a semi-quantitative survey of Babeldaob was conducted to determine important forest areas of Babeldaob (Costion & Kitalong 2006). A total of 51 transects and 398 stations were covered in this study. At each station an area within a 20 m radius was assessed covering 1256 m^2 per station and a total area of 50 ha. An average of 5 transects and 40 stations were visited at each state. The stations were mainly in lowland forest (60%), followed by savanna (15%), riparian forests (11%), swamp forests (11%), limestone forests (4%), marshes (4%), mangroves (4%) and coastal forests (3%). The southern state of Airai has the only limestone forests in Babeldaob. Coastal forests were surveyed along the northeastern coast of Babeldaob. During this survey over 342 plant species were recorded including 249 native plants, 31 introduced species; 47 species determined to genus and 21 undetermined plant species. The most frequently encountered tree species found in the 1988, 2003 and 2005 surveys were ranked according to relative abundance. The most common species were *Pinanga insignis*, *Maranthes corymbosa*, *Alphitonia carolinensis*, *Semecarpus venenosa*, *Campnosperma brevipetiolata*, *Horsfieldia palauensis*, *Horsfieldia irya*, *Gmelina palawensis*, *Rhus taitensis* and *Pouteria obovata*. The largest trees by volume were *Campnosperma brevipetiolata*, *Maranthes corymbosa*, *Horsfieldia irya*, *Pinanga insignis*, *Sonneratia alba*, *Rhizophora apiculata* and *Intsia bijuga* (Table 2). The dominant Families included Anacardiaceae, Clusiaceae, Fabaceae, Myristicaceae, Myrtaceae, Sapotaceae and Tiliaceae. Relative rankings differed between surveys as each survey was conducted in different habitats and locations in Palau. These findings corroborate with an earlier botanical reconnaissance study (Raulerson et al. 1997) and an earlier forest habitat study (Kitalong & Holm 2004).

Stunted mangrove trees of *Sonneratia alba*, *Rhizophora mucronata*, *Bruguiera gymnorrhiza*, *Scyphiphora hydrophyllacea* and *Ceriops tagal* grow on marginal elevated areas such as raised man-made berms composed of coral fill from abandoned dredge sites. Inner zones of mangroves along southeastern Babeldaob have extensive stands of *Rhizophora apiculata* with stunted growth compared to larger forms of the same species along the seaward edge and adjacent to *R. mucronata*. Dwarfism may enable specific mangrove species to grow and reproduce in elevated, less optimum conditions and enable them to retreat to higher ground as the sea level rises in the next century.

Forest Ownership

Individuals, partners, corporations and traditional clans own 29% of the land. Most of the land (71%) is considered public land and under the jurisdiction of the individual States (Table 1). In the states of Kayangel, Angaur, Peleliu and Ngarchelong, the key stakeholders are the private land owners. In most of Babeldaob designated public lands range from 50% in Ngiwal to 94% in Ngaremlengui. Therefore the State Public land authorities play a critical role in land use. Since over 80% of Palau's land is forested. Most of the forested land is under the jurisdiction of the State Public Land Authorities.

Table 1. Estimated area of public and private land by state with total area and percent of public Lands in the Republic of Palau.

STATES (Unit in Hectares)	PUBLIC LANDS	PRIVATE LANDS	TOTAL	Percent Public
AIRAI	4936.02	1569.02	6505.04	75.88%
AIMELIIK	4282.05	1394.72	5676.76	75.43%
NGATPANG	2120.17	928	3048.17	69.56%
NGAREMLENGUI	4713.54	303.81	5017.35	93.94%
NGARDMAU	4339.55	957.01	5296.55	81.93%
NGARAARD	2224.81	863.77	3088.58	72.03%
NGARCHELONG	163.17	609.43	772.6	21.12%
NGIWAL	1867.91	1853.15	3721.05	50.20%
MELEKEOK	1554.26	818.44	2372.7	65.51%
NGCHESAR	3407.92	807.3	4215.23	80.85%
KOROR MAIN. IS.	309.25	487.18	796.43	38.83%
PELELIU	296.56	941.21	1237.76	23.96%
ANGAUR	51.02	803.68	854.7	5.97%
KAYANGEL	0	170.94	170.94	0.00%
Total	30266.23	12507.66	42773.86	
Percent of Total	70.76%	29.24%		

Populations and Demographics

The population of Palau is estimated 19,907 in 2005 (Table 2). An estimated 77% of the population lives in urban areas and 23% live in rural areas. The population density was 116 people per square mile in 2005. The mean growth rate declined to 0.8% in 2005 (Table 2 and 3). The number of visitors has ranged between 53,000 to 94,000 people with a decline in visitors in recent years due to the world economic crisis (Table 4). The visitors are mainly from Japan, Taiwan and Korea (Table 5).

Table 2. Population Statistics from 1986-2005. Source: Office of Planning and Statistics 2008

Census Years	1986	1990	1995	2000	2005
Total Pop^{n}	13,873	15,122	17,225	19,129	19,907
Urban	9,442	10,501	12,299	13,303	15,399
Rural	4,431	4,621	4,926	5,826	4,508
Male	7,398	8,139	9,213	10,450	10,699
Female	6,475	6,983	8,012	8,679	9,208
Pop^{n} Density (per Sq. Mi.)				112	116
Urban	642	642	Need data---		
Rural	Data	Data	Data	25	31
Average Growth Rate	2.3	2.2	2.6	2.1	0.8
Median Age	22.0	25.6	28.1	30.8	32.3
Male	0.53	0.54	0.53	0.55	.54
Female	0.47	0.46	0.47	0.45	.46
Average Household size		5.01	4.86	4.63	3.86
Urban				4.76	3.94
Rural				4.22	3.63
Female		18.55	21.35	15.01	

Table 3 Census years of population: Total population by sex: 1980-2005. Source: Office of Planning and Statistics 2008

Year	Total	Male	Female
1980	12,116	6,279	5,837
1986	13,873	7,398	6,475
1990	15,122	8,139	6,983
1995	17,225	9,213	8,012
2000	19,129	10,229	9,028
2005	19,907	10,699	9,208

Table 4 Visitor arrivals by purpose of visit - 2001 – 2008. Source: Palau Visitors Authority

Year	Total	Tourist	Business	Employ	Other *
2001	54,111	45,866	2,930	5,315	-
2002	58,560	50,513	3,431	4,458	158
2003	68,296	59,851	3,472	4,679	294
2004	94,895	83,041	4,422	5,361	2,071
2005	86,124	76,180	4,398	5,322	224
2006	87,206	78,252	4,150	4,557	247
2007	93,031	84,566	3,610	4,641	214
2008	83,114	75,829	3,407	3,678	200

Table 5. Visitor arrivals by country of residence and Purpose of Visit - Source: Palau Visitors Authority 2008

Country of Residence	Visitors					
	Total	Tourist	Business	Employ	Other	% of Total
Total	83,114	75,829	3,407	3,678	200	100.0
Australia/NZ	738	512	200	26	0	0.9
CNMI	402	295	100	1	6	0.5
Europe	2,078	1,893	54	40	27	2.5
FSM	544	282	236	6	20	0.7
Germany	645	623	13	7	2	0.8
Guam	2,156	1,572	551	13	20	2.6
Hong Kong	341	320	12	9	0	0.4
Japan	30,319	29,632	379	306	2	36.5
Korea	14,275	14,081	107	82	5	17.2
Philippines	2,541	659	256	1,623	3	3.1
PRC China	1,384	407	123	830	24	1.7
ROC Taiwan	14,593	14,175	116	282	20	17.6
US Mainland/Canada	10,442	9,376	757	259	50	12.6
Others	2,479	1,745	500	192	21	3.0

Climate

Palau has a tropical wet climate. Palau has a complex pattern of monthly rainfall with the highest average rainfall in the months of June and July and the lowest average rainfall in the months of February, March and April (Figure 2). A secondary rainfall minimum occurs in August and September when the monsoon trough and typhoon tracks move well to the north of the islands causing a lowering of rainfall. On an average, the annual rainfall ranges from 3 to 4 m with a mean of 3.7 m per year. The dry period occurs from January to April and a wet period is from June to August. The humidity ranges typically between 75 to 85%. The mean air temperature is 27°C and the maximum diurnal and seasonal variation is 5.5°C. The large-scale near-surface water circulation is a westward-flowing North Equatorial to the North of Palau and an eastward flowing Equatorial Countercurrent to the South of Palau. Palau is located in a recirculation zone. Palau has prevailing northeast trade winds from November to May and a southwest wind from June to October. The wind field around Palau varies with the topography of the land. Weak east trade winds prevail from December to April changing to southwest trade winds from May to October (Wolanski & Furukawa 2007).

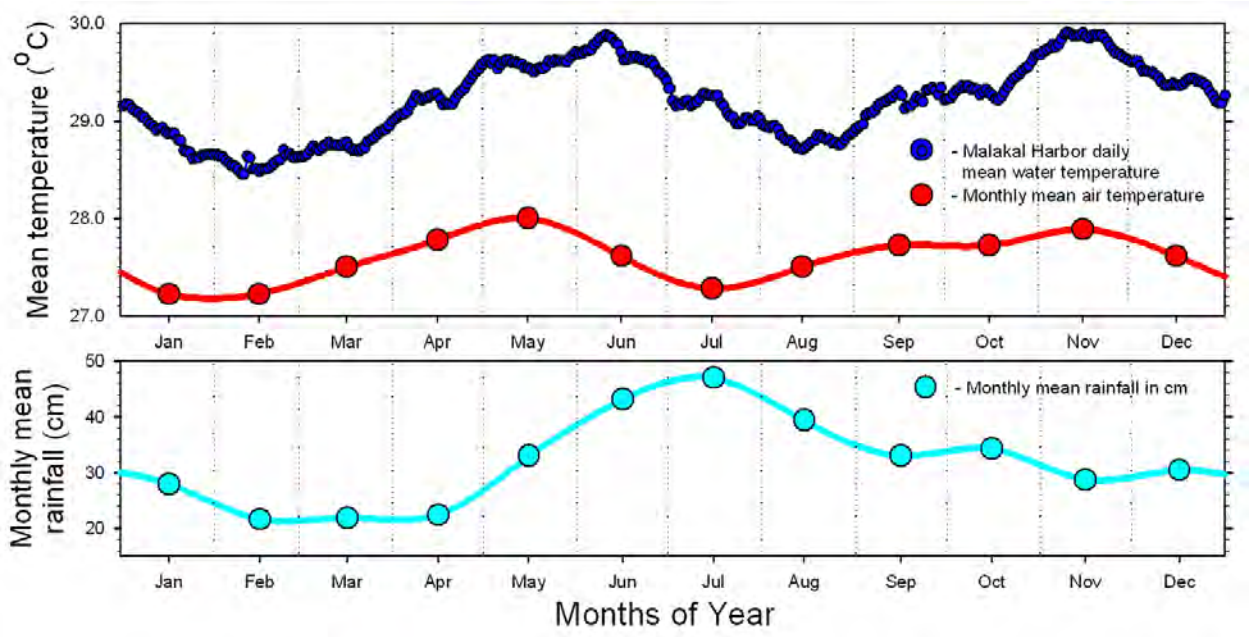

Figure 2 Upper graph: The annual mean air (red) and lagoon water (blue) temperatures for the island of Koror follow the same pattern. The air temperature varies only about 1°C over the course of the year while the water temperature varies about 1.5°C. Both values show decreases in the middle of summer, probably due to higher cloud cover and westerly winds during the summer monsoon. The highest temperatures occur during the late spring (May–June) and late fall (November). Lower graph: The average monthly rainfall for Koror, based on records from 1926 to 1988, is lowest during February–April and highest during July (modified from Lundgren 2002). Figure from Marine Environments of Palau, courtesy Coral Reef Research Foundation.

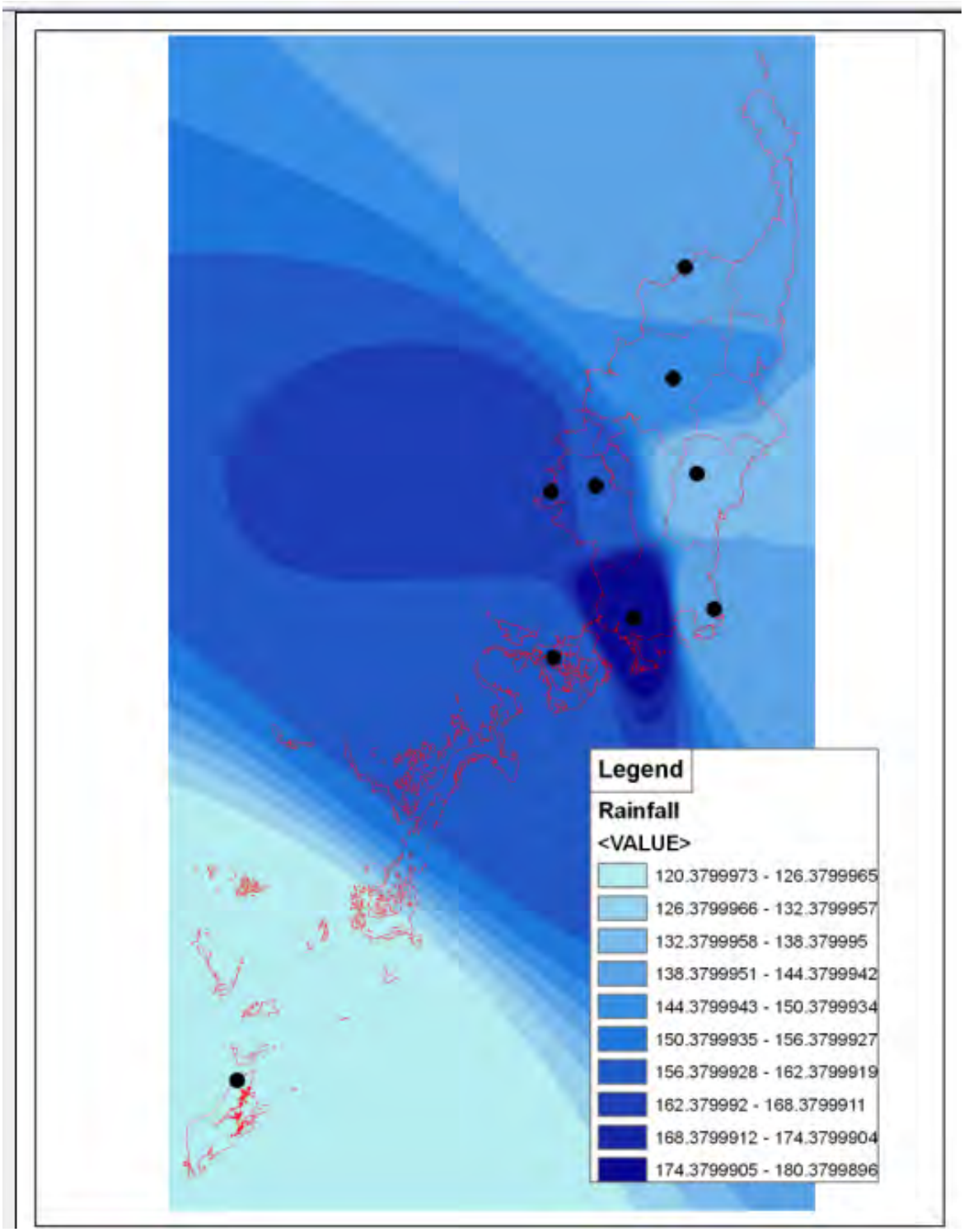

Figure 3 Annual Precipitation Map for Palau (inches/year) showing location of rain gages as black dots

Source: Palau Automated Land & Resources Information Systems (PALARIS) 2009

Table 6. Yearly average temperature, total rainfall & mean monthly rainfall

Source: Palau National Weather Service

Climatic Conditions	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Mean Temperature	82.1	82.6	82.1	82.1	82.8	83.2	82.7	83.2	82.6	82.9
Total Rainfall (inches)	150.5	114.4	171.9	161.4	168.5	130.8	177.25	125.05	166.75	157.03
Average monthly Rainfall (inches)	12.5	9.5	14.3	13.5	14.0	10.9	14.8	10.42	13.90	13.09

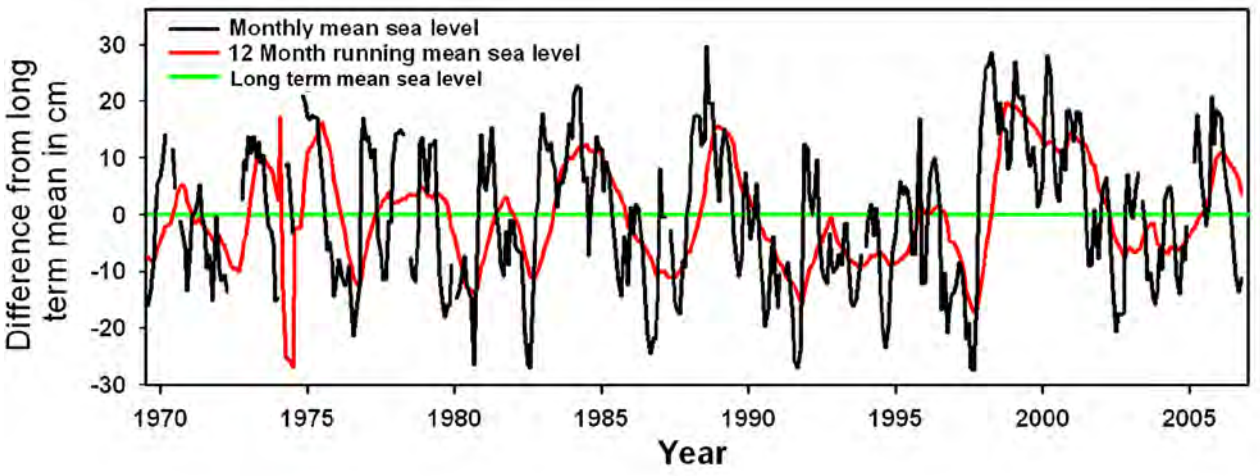

Figure 4 Great variations in the mean monthly sea level in Palau (1970-2007) overwhelm the much smaller, gradual increase in sea level due to long term climate change. The monthly mean values (black line) can change fairly rapidly, as much as 50 cm in a few months, leading people to believe they are seeing sea level rise due to global warming. Actually these changes are short term variations related to global climate conditions (El Niño/La Niña). A 12-month running mean (red line), which averages the mean monthly sea level for the previous 12 months, smoothes out some of the short term variation, but still shows how much mean sea level can change over only a few months. The long-term mean sea level (green line) is much more consistent and is rising slowly (compared to the month to-month variation) at only about 0.64 mm per year. This gradual rise in mean sea level is due largely to global warming. It is easy to see that the short term changes in sea level due to ENSO values hide the slow but insidious rise of sea level from melting of glaciers and polar ice. The slow changes from global warming will eventually result in major flooding of coastal areas; the short-term variation shown here will always be present in addition to the long-term changes. Figure 4 and Figure 4 caption from Marine Environments of Palau, courtesy Coral Reef Research Foundation.

Review of Republic of Palau Natural Resource Plans

National guidance on state assessment and the 2008 Farm Bill require that state assessments and resource strategy plans pertaining to forestry assess commonalities between a statewide assessment of forest resources and a national wildlife action plan. The 1997 national wildlife action plan recommends enforcement, training of at least 4 officers, a study on ways traditional and western laws could be more compatible. This plan further recommends better coordination with DOA to develop and implement a consistent strategy for the enforcement of regulations regarding the import and export of species to and from Palau. The plan also recommends education and outreach about Palau's fragile environment and unique culture, training of officers, educators and naturalist guides for eco-tourism and sustainable economic activities. Issue 5 on Conservation and Protected Areas assesses commonalities for endangered species of flora and fauna that the Division of Fish and Wildlife monitor and protect and regulations regarding import and export of species. Issue 7 Urban Forest Sustainability is address in DFW plan for capacity building in sustainable economic activities. The FWP also state how laws and policies affecting wildlife conservation and mange should be coordinated with the endeavors undertaken by EQPB to protect Palau's fresh and marine waters related to Issue 2 Water Quality and Supplies. The Plan address gaps information related to life history of endangered species, botanical and florist research, forest ecology studies and the role of fruit bats, frugivorous birds in the pollination and dispersal of fruiting trees and fossil pollen studies to see have the environment has changed over time from climate and human settlements. The Strategic Plan for the Division of Fish and Wildlife has similar goals, objectives, proposed activities as Forest Health, Urban and Community Forest, Forest Stewardship, Conservation and Education Program and Forest Legacy. The driving issues of SWARS are also driving Issues for Fish and Wildlife. These future work plans are all related to Issue 5 Conservation and Protected Areas and overlapping with strategies of BOA BNM, PCS, and TNC.

The BOA Strategic Plan for Invasive plants was incorporated into Issue 5 Conservation and Protected Areas and Issue 4 on Wildfire Prevention. The Bureau of Agriculture Nekken Agriculture Station Plan was the key document used for Issue 6 Sustainable Use of Forests Resources. The Five Year Urban and Community Forestry Plan was the key document used for Issue 7 Urban Forest Sustainability. The Republic of Palau Wildfire Plan 2008-2013 was the key document used for Issue 4 Wildfire Prevention. The EQPB Ngerikiil Integrated Watershed Management Demonstration Project and Babeldaob Watershed Alliance Plan were key documents used for the Issue 3 Water Quality and Quantity and Issue 2 Population Growth and Urbanization. The National Biodiversity Strategic Action Plan was incorporated into Issue 5, the Ngardok Management Plans was incorporated into Issue 2 and 5, the Ngeremeduu Plan was reviewed and portions incorporated as part of strategy for. First National Communication to the UNFCCC was a key document used for the Issue 1 on Climate Change. The Belau National Museum Natural History Section is incorporated into Issues 5, 3, and 7. The Republic of Palau National assessment Report, National Disaster Risk Management Framework, and National Action Program to Combat Land Degradation were incorporated into mainly Issue 1. The Rock Island Southern Lagoon Management Plan was incorporated into Issue 5.

The agency documents reviewed and incorporated into the SWARS narratives and strategies are listed below:

Bureau of Agriculture	Nekken Agriculture Station Plan Strategic Action Plan 2005-2007
	Five Year Urban and Community Forestry Plan For the Republic of Palau 2002-2007
	Five Year Urban and Community Forestry Plan For the Republic of Palau 2009-2014
	Strategic Plan for Invasive plants 2009-2014 Republic of Palau
Palau Public Safety Fire and Rescue Division	Republic of Palau Wildfire Plan 2008-2013
Division of Fish and Wildlife	A Preliminary Wildlife Management Plan for the Republic of Palau
The Nature Conservancy and Palau Conservation Society	Babeldaob Watershed Alliance Plan
Palau Conservation Society	Palau Conservation Society Strategic Plan 2010-2015.
Melekeok State	Ngardok Management Plan
Koror State	2004-2008 Rock Islands-Southern Lagoon Area Management Plan
Division of Conservation and Entomology	A Management Plan for the proposed Lake Ngardok Watershed Reserve Melekeok State
Belau National Museum	Natural History Section Plan
Environmental Quality Protection Board	Ngerikiil Integrated Watershed Management Demonstration Project
Office of Environmental Response and Coordination (OERC)	National Biodiversity Strategic Action Plan
	National Action Program to Combat Land Degradation
	First National Communication to the UNFCCC
National Emergency Management Office	National Disaster Risk Management Framework 2009
Ministry of Resources and Development	Republic of Palau National Assessment report Barbados Programme of Action +10 Review

Stakeholder Issues

Issue 1 Climate Change (CC)

Issue 2 Population Growth and Urbanization (PG)

Issue 3 Water Quality and Quantity (WQ)

Issue 4 Wildfire and Public Safety (F)

Issue 5 Conservation (CO)

Issue 6 Sustainability of Forest Resources (SF)

Issue 7 Urban Forest Sustainability (UF)

Stakeholder Involvement

The Republic of Palau has a relative small population and most people in the communities know one another. Individuals involved in forest related activities and the environment are a small group of professionals and friends. The Palau Natural Resource Council is more of an advisory body to the President while the Forestry Programs has one active Urban and Community Forest Council. The Palau Conservation Program through its Ecosystem Based Management Program and the Babeldaob Watershed Alliance works directly with communities to develop Conservation Action Plans. The Ngerikiil Watershed and Ngerdorch Watershed have been a focus of forestry activities for many years. During a series of meetings the Urban and Community Forest Council voted that its members would serve a dual function as members of the UCF Council and members of the Stewardship Coordinating Committee and take a lead on the SWARS project. Those members with GIS training and interest had smaller meetings at the PALARIS office to discuss the GIS layers and criteria. Monthly or bimonthly meetings occurred through the Council where the Consultant presented updates and gathered additional information from the members from their various projects and activities that addressed the 7 issues. The seven issues were in part derived during the SWARS introductory stakeholder meetings hosted by Forestry. The council agreed to have an issue driven SWARS. The Consultant also had several meetings at the Division of Fire and Rescue and the Division of Fish and Wildlife in order have participation with as many of their staff as possible. The NRCS technical committee included most of the members of Urban and Community Forest. NRCS provided a good review and engaged in the SWARS process.

Overview of Spatial Analysis

For each stakeholder issue, a separate geospatial analysis was conducted to identify areas across the landscape that are important for focusing forestry efforts. Geospatial analysis or simply spatial analysis integrates layers of spatial information that are related geographically and expressed visually on a map. Spatial analysis involves geospatial layers or themes. A layer is a thematic set of spatial data representing one type of information such as vegetation, infrastructure, rivers and streams, soil types and elevation. When only two or three layers are overlaid and are made somewhat transparent, the apparent relationship between the two layers can be readily seen and understood. However, as more layers are added, it is a challenge to understand the relationships between layers.

In producing the priority maps for this assessment, weighted overlay analysis was used. This technique involves assigning a percentage weight to each of several geospatial layers, overlaying them and summing the weighted values of coincident pixels of all layers. A pixel is a square unit that represents a specific spot on the ground and is the smallest unit of resolution of geographic area used in an analysis. The Palau analyses were done with a 10m by 10m pixel size resolution. For each issue, layers were identified and weights assigned by the Palau Forest Division program managers, and partner agencies especially the PALARIS office. Weights added up to 100%. During the analysis it was found that only certain layers were available for spatial analysis. Some layers that were available and identified as important and weighed into the analysis by the stakeholders and technical teams, but when the analysis was run those layers did not significantly contribute to prioritizing landscapes for a given issue. In these cases the analysis was rerun without certain layers to better prioritize areas. In many cases there was insufficient data to run a full analysis. For most cases there was only data available for Babeldaob and Koror therefore spatial analysis could not be done for other parts of Palau even though they are considered priority areas by the stakeholders and technical groups. There is limited spatial data for fire, endangered species, drinking water sources, and invasive species. There is no contour data for 1m for Palau to determine priority areas for sea level rise. In some cases there is point data but this cannot be processed with data that is in polygons such as locations of fire, an endangered species and infrastructure like a water source. Development of geospatial databases for each program is critical for future analysis.

Issue 1 Climate Change

Global warming is a major threat and issue for coastal forests and communities. Forests act as important carbon sinks that absorb carbon dioxide, a major green house gas and mitigate the impacts of climate change. Global warming is causing extreme weather events including severe droughts and water shortages during the 1997-1998 ENSO event (OERC 2002). Climate change was considered one of the top threats to Palau's environment during a national meeting of conservation and environmental professionals in 2008 (PCS 2010-2015 Strategy). These climate changes affect the health of the trees causing stressed conditions that make trees vulnerable to pathogens and insects. Loss of coral reef barriers and storms cause coastal erosion and loss of beaches in Palau. The top tourism destinations are the Rock Islands and several of the designated picnic areas along the east coast are losing their beaches and trees as shown above for the island of Ngermeaus (Figure 5). This beach and others are not only important for the tourism industry but as important hawksbill nesting grounds. Hawksbills are critically endangered species that depend upon vegetation to camouflage their nests (Kitalong et al. 2007).

Figure 5 Ngermeaus Beach with exposed *Casaurina equisetifolia* roots

The number of landslides (Figure 6) and road collapses (Figure 7) has increased significantly in the last decade. Forests are sliding down the slopes. The increased intensity and duration of rainfall attributed to climate change is a major contributing factor. Palau's high rainfall and highly erodible soil also make infrastructure design and construction a constant challenge.

Figure 6 Chronic failure of slope along Compact Road at Ngaremlengui in 2009

Seawater and freshwater inundation of coastal agroforests is impacting food production in lowland agroforests. The less drastic and gradual rise in sea level rise is predicted to be from 0.2 to 0.9m by 2100. The state of Kayangel will be completely underwater by 2100 if sea levels rise is close to 1m. In Koror all of its coastal infrastructure will be underwater shown in red for the map of Koror (Figure 3). This is critical for Koror which has the largest populations with many homes along the lowland areas. Extreme droughts will be addressed under the water issue. Increased numbers and extent of fire will be handled under the Fire issue. We will focus on two top concerns that impact our forests: coastal erosion and flooding and landslides.

Figure 7 Collapsed national highway in Ngchesar State after heavy rains in 2009

A geospatial model is being developed to determine the highest priority areas in which forestry efforts should be directed to protect forests from flooding and salt water intrusion and landslides. Forestry will work with home owners and business in agroforestry and conservation on their land. Six data layers were identified by the technical team to be used in the model analysis (Table 7). Each layer was weighted based upon its perceived relative importance to this issue of landslides, coastal erosion and flooding as a result of increased extreme weather events. Although a layer for contour elevation at 1m is highly weighted there is no data available. Coastal erosion hazard areas is also highly weighted however these areas have not been surveyed and no geospatial data is available. Endangered species such as nesting turtles and nesting shorebirds are known from areas but their habitats have not yet been mapped. The GIS analyst showed low coastal areas in Figure 8. When these critical data has been collected, the spatial analysis can be done for all layers. The current analysis for coastal erosion and slope failure is based on two layers that were weighted equally: infrastructure (weight=50%) and contour (weight =50%). For coastal flooding contours 0-1m were priority areas for stabilization and reforestation. For slope failure, contours 50 to 100m were priority areas for stabilization and reforestation.

Table 7. GIS layers identified and weighed for Climate Change- Sea level Rise & Coastal Erosion

Layer Rank	Layer Name	Layer Weight	Layers and Weights Used
1	Infrastructure	15	50
2	Soil	15	
3	Contour (elevation) at 0-1, 1-5 and 5-10	20	50
4	Coastal erosion hazard areas (East beaches of Rock Islands & Babeldaob	20	
5	Forest (Mangroves- coastal protection)	20	
6	Endangered species	10	

Table 8. Criteria used for GIS Analysis for Climate Change- sea level rise & coastal erosion

Factor	Condition	Suitability
Infrastructure	more than 25 buildings/0.1ha less than 25 buildings/0.1ha Less than 10 buildings /0.1ha	10- high 5- medium 1- low
Soil types	Soil types Mesei, Swamp forest Marsh, Coastal	10- high
Contour (elevation)	0-1m 1-5m 5-10m	10- high 5- moderate 1- low
Priority coastline	Kayangel & Southwest Islands SE beaches of Koror Southern lagoon, beaches of NE Babeldaob Low lying parts of Peleliu	10- High
Forest	Swamp & Coastal Forest All other forest	10- High 1- Low
Endangered species	Habitat for critically endangered species Habitat for endangered species Habitat for threatened species	10- High 5- Medium 1- Low

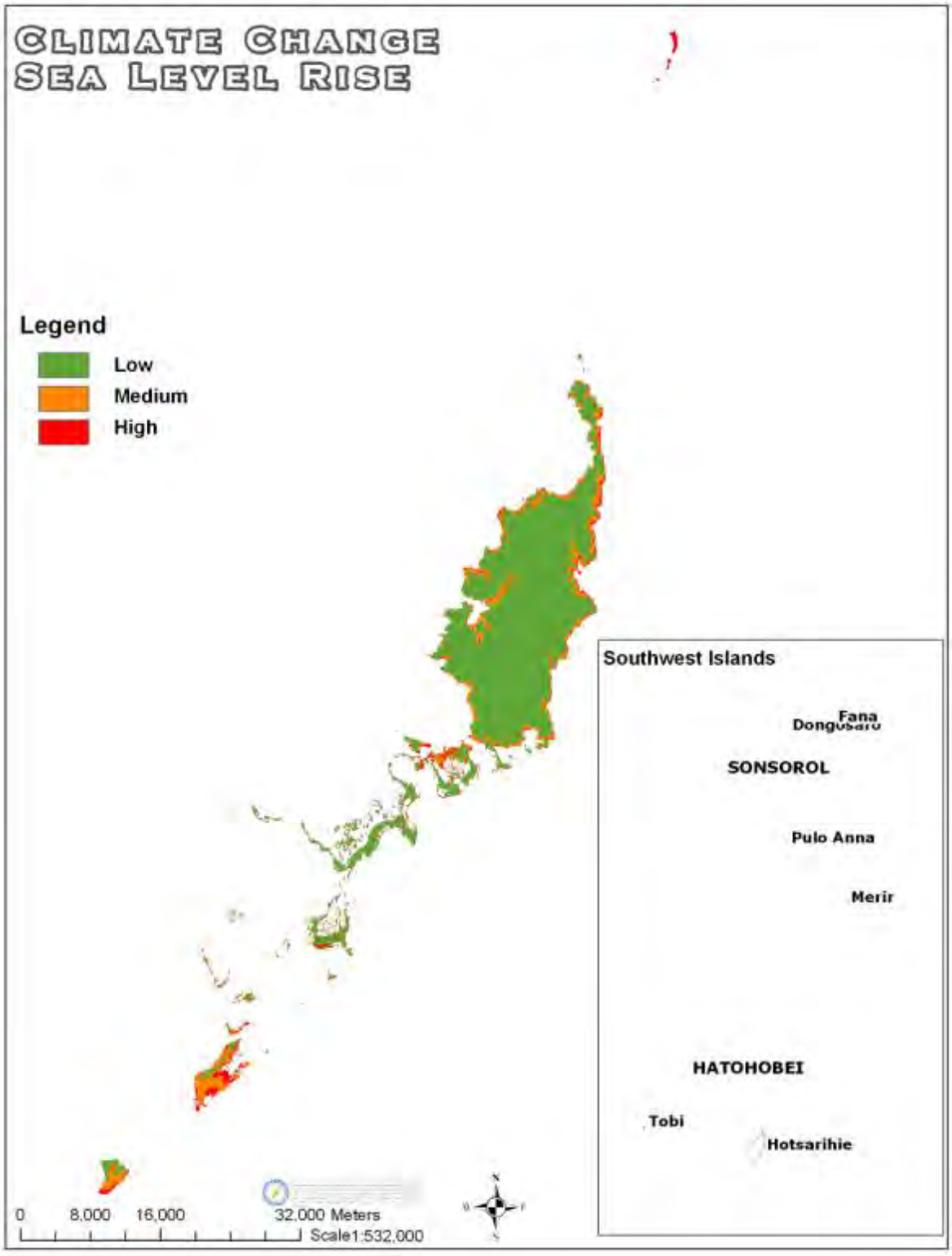

Figure 8 Map showing areas vulnerable to sea level rise and flooding within the 0-1 m (high priority red), 1-5m (medium priority-orange) and 5m and greater (low priority-green) in urban areas.

Results

Sea level Rise

Results from the overlay analysis are shown in Maps of Palau and Koror (Figure 8). High priority areas for flooding are coastlines 0 to 1m above sea level. Koror is of highest priority because it is the most densely populated State. Other vulnerable States with lower population densities include the low lying States of Kayangel, Peleliu and Southwest Islands. Key tourist beaches of the southeastern lagoon are being eroded away by several factors including sea level rise, storms, loss of reefs from prolonged elevated sea temperatures, loss of leaf litter and strand vegetation due to much raking and removal for tourist to experience "sandy white beaches" and the impact of tourists (Figure 5). More studies are needed to determine best management practices for these

Conclusion

A geospatial model will be developed to determine the highest priority areas in which forestry efforts should be directed to mitigate or prevent coastal erosion caused by sea level rise and storms based upon frequency and magnitude of use, density of infrastructure, elevation of 1m or less above sea level
wildlife use, urban centers of Koror priority area and top tourist locations. The analysis will also address the east coasts of Babeldaob and the Rock Islands and the islands of Kayangel to the north and Hatohobei and Sonsorol States to the southwest. Most of these islands highest elevation is a few meters and it is critical to get the needed data for this analysis.

Landslides

Ranking of priority sites for mitigation efforts through reforestation and civil engineering was the result of a series of discussions with partners (TNC, EQPB, PALARIS, PCS, and BOA) as shown in Table 9. Presently ground truthing along the Compact Road and existing roads in Koror and geo referencing locations with a handheld Garmin GPS unit was done to produce a map of these sites (Figures 9, 10 and 11). There are no spatial layers for these areas yet. The geospatial analysis will be used to focus on these selected sites to determine specific areas in which Forestry efforts will direct their efforts to stabilize sites to either protect existing forests or restore lost forests. The geospatial analysis will be limited to Babeldaob because data is lacking for other areas. The forestry staff currently assists home owners and businesses to apply best practices in agroforestry to conserve their soils and forests especially in areas vulnerable to landslides. A total of 6 data layers were used in the model analysis (Table10) with each layer weighted according to its perceived relative importance to this issue. The map will mask out elevations between 0 and 10 m. Priority Areas are listed in order of importance for slope stabilization and mitigation based are in the box below. Ranking was based upon meetings with the technical committee and community. The criteria include the degree of impact a specific failed slope had upon vital infrastructure and the percent of the total population at risk (Table 11). The team reviewed the geospatial map produced (Figure 9) and decided to re-analyze adjust to contours greater than 30% because the contours greater than 12% do not
adequately prioritize sites.

Table 9. Priority Sites in order of importance (1- Highest, 5 Lowest) based upon expert opinion and consultation

Rank	Location	Justification
1	Malakal Quarry	Site of chronic landslides is top priority as it crushed infrastructure and adjacent to several business- this is a private lease to Palau Development Company – much forest lost and still unstable
2	Ngerikiil Road near the National airport	Site of chronic landslides. This is a critical road for the populated area of Ngerikiil as well as the eastern States of Babeldaob. This area is also critical because of the National Airport & heavy traffic and from the airport in Airai and Babeldaob
3	Ngaremlengui State Landslide site	Forests with serious & chronic slope failure along the national highway. This area is along the western alignment & the main road for transport along the west coast of Babeldaob.
4	Ngatpang State Landslide site	Chronic slope failure along the main road close to Nekken State and good demonstration site.
5	Topside area in Ngermid Hamlet, Koror State	This is a critical area as there is heavy daily traffic along this main road going and coming into the city of Koror. The Division of Forestry worked with Public works on revegetating this slope after Storm Utor.

Table 10. Ranked Layers for the issue of slope failure - Climate Change

Layer Rank	Layer Name	Layer Weight
1	Infrastructure	15
2	Soil Type	15
3	Contour (elevation) at 50 to 100m	20
4	Slope failure hazard areas (Koror Babeldaob	20
5	Forest	20
6	Endangered species	10

Table 11 Criteria used for the GIS Analysis for the issue of slope failure -Climate Change

Factor	Condition	Suitability for reforestation & mitigation
Infrastructure (15)	Within 0-500 m Within 500-1000 m Within 1000 to 1500m	10 High 5 Medium 1 Low
Soil (15)	Highly erodible soils Less erodible soils	10 High 1 Low
Contour (20)	100-50m 50-20m 20-0m	10 High 5 Medium 1 Low
Slope (20)	Less than 12% More than 12%	10 High 1 Low
Forest (20)	Grasslands, Savanna or Bare areas All other forest types	10 High 1 Low
Endangered species (10)	Habitat for critically endangered species. Habitat for endangered species Habitat for threatened species	10 High 5 Medium 1 Low

Table 12. Areas where landslides occurred marked as codes on Figure 9 with soil type, slope and Characteristics

Soil type	Slope	Area
436	6-12%	Ngatpang
401	12-30%	Ngaremlengui
401	12-30 %	Ngaremlengui
400	6-12%	Koror Topside
401	12-30%	Koror Topside
401	12-30%	Koror Topside
403	50-75%	Malakal quarry
411	30-50%	Ngerikiil
401	12-30%	Ngchesechang
402	30-50%	Ngchesar
416	30-50%	Ngchesar road collapse
416	30-50%	Melekeok
402	30-50%	Ngkeklau- chronic fire - areas of 0.5km
411	30-50%	Ngardmau

The soil types where landslides or road collapse occurred are described below:
Soil type was 400 Aimeliik –Palau Complex has 6 to 12% slightly convex slopes. The native vegetation is mainly tropical forest. Cleared areas support savanna vegetation. The unit is 60 percent Aimeliik silt loam and 30 percent Palau silty clay loam. Included in this unit are small areas of Babeldaob soil on ridges and small convex knolls in areas of grassland, Ngardok soils, and soils that are moderately well drained to somewhat poorly drained and are in drainage ways and other concave area. Most areas on Koror and Arkabesang are used for urban development and have the surface layer removed. Some areas have been deeply cut and underlying material is exposed. A few large boulders are on the surface of the soil or buried in the soil profile. The Aimeliik and Palau soil is very deep and well-drained and derived from volcanic rock. The soil permeability is moderately rapid. Effective rooting depth is 150 centimeters or more. If vegetation is removed, runoff is medium and the hazard of water erosion is moderate. Most of this area is watershed and can be used for pasture, crops and woodland. This soil unit is poorly suited to use as pasture. A few areas are used for homesite and garden crops. This unit can be used for pasture where savanna vegetation is present. This soil is well suited for pasture, subsistence agriculture and forest crop production. This site is poorly suited for homesite development due to the slope and low soil strength. If buildings and roads are built, the low soil strength can be improved with adequate amounts crushed coral or basalt. Structures to divert runoff are needed. All soil materials need to dry sufficiently before filling and compacting areas of this unit. This unit is poorly suited to on-site waste disposal. The main limitations are slope and the hazard of lateral seepage. (Smith C. W. 1983. Soil survey of Islands of Palau Republic of Palau. Soil Conservation Service USDA.)

Soil type 401 Aimeliik –Palau Complex has 12 to 30% convex slopes. The native vegetation is mainly tropical forest. Cleared areas support savanna vegetation. The unit is 60 percent Aimeliik silt loam and 30 percent Palau silty clay loam. Included in this unit are small areas of Babeldaob soil on ridges and small convex knolls in areas of grassland, Ngardok soils, and soils that are moderately well drained to somewhat poorly drained and are in drainage ways and other concave areas. Most areas on

Koror and Arkabesang are used for urban development and have the surface layer removed. Some areas have been deeply cut and the underlying material is exposed. A few large boulders are on the surface of the soil or buried in the soil profile. The Aimeliik and Palau soil is very deep and well-drained and derived from volcanic rock. The soil permeability is moderately rapid. Effective rooting depth is 150 centimeters or more. If vegetation is removed, runoff is medium and the hazard of water erosion is moderate. Most of this area is watershed and can be used for pasture, crops and woodland. This soil unit is poorly suited to use as pasture. A few areas are used for home sites and garden crops. This unit can be used for pasture where savanna vegetation is present. This soil is well suited for pasture, subsistence agriculture, and forest crop production. This site is poorly suited for home site development due to the slope and low soil strength. If buildings and roads are built, the low soil strength can be improved with adequate amounts crushed coral or basalt. Structures to divert runoff are needed. All soil materials need to dry sufficiently before filling and compacting areas of this unit. This unit is poorly suited to on-site waste disposal. The main limitations are slope and the hazard of lateral seepage. (Smith C. W. 1983. Soil survey of Islands of Palau Republic of Palau. Soil Conservation Service USDA.)

Soil type 402 Aimeliik-Palau Complex has a 30–50% slope. This is on high hills and ridges. The native vegetation is mainly forest and cleared areas support savanna vegetation. This unit includes small area of grasslands, Ngardok soils and somewhat poorly drained to moderately well-drained soils. The Aimeliik and Palau soil is very deep and well drained with moderately rapid permeability. Effective rooting is 150-centimeters. Runoff is rapid and the hazard of water erosion is high. Most of this area is watershed. Some areas are used for farmland and moderately suited as pasture. The soil has low fertility and the erosion and soil degradation are hazards due to the slope. This area is poorly suited for home sites. Road requires the use of crushed basalt. Structures to divert runoff are needed. This unit is poorly suited to on sewage disposal. Deep well-type leaching pits can be used where the depth to bedrock is greater than 6 meters.

Soil type 403 Aimeliik-Palau Complex has a 50-75% slope. This is on high ridges and hills. The vegetation is mainly forest with cleared areas supporting savanna. The soil is moderately to poorly drained. A few large boulders are on the surface of the soil and buried in the soil profile. The Aimeliik and Palau soil are very deep and well drained with moderately rapid permeability. Effective rooting is 150 centimeters. If vegetation is removed runoff is very rapid and the hazard of water erosion is very high. Most of this area is watershed. This unit is poorly suited as pasture and moderately suited to subsistence agriculture forest crop production. This unit is poorly suited to use as a source of road fill because the low soil strength when wet. Crushed basalt can overcome this. This unit is poorly suited to on site waste disposal because of the steep slope. (Smith C. W. 1983. Soil survey of Islands of Palau Republic of Palau. Soil Conservation Service USDA).

Soil type 411 Ngardmau –Babelthuap complex has a 30 to 50% slope on ridges and upper side slopes. The vegetation is deteriorated savanna. The soil is very deep and well drained. Rooting extends down to 150 centimeters or more. If vegetation is removed, runoff is rapid and the hazard of water erosion is high. This is a watershed area poorly suited to agricultural forest crop production. The limitations are slope, erosion hazard, very low soil fertility and large gravel near surface. This unit is poorly suited to home site development and requires a crush coral and basalt to strengthen the soil. Structures to divert runoff are needed. Allow the soil material to dry sufficiently before filing and compacting areas of this unit. Suitable ground cover is needed to reduce the hazard of sedimentation of stream. This unit is poorly suited to onsite waste disposal systems.

Soil type 416 Ngardok silt loam has 30 to 50% slopes. This soil is very deep and well drained and found on low-lying foothills. The vegetation is mainly forest. Cleared areas support savanna vegetation. The soil surface layer is dark yellowish brown silt loam 5-centimeters thick. In some

areas there are a few boulders or outcroppings of hard rock. Included in this unit are small areas of Babeldaob soils on ridges and small convex knolls in areas of grassland. Some areas of Aimeliik and Palau soils are found with slopes from 30 to 50%. There is badland consisting of grassland that has been severely gullied exposing the substratum. Permeability of the Ngardok soil is moderately rapid. Effective rooting depth is 150-centimeters or more. If the vegetation is removed, runoff is rapid and the hazard of water erosion is high. This unit is used for watershed, food and woodland. Practices that expose the highly eroding substratum and clear cutting should be avoided. This unit is poorly suited for home sites development and roads due to the high hazard of erosion and low soil strength. This unit is poorly suited to septic tank absorption fields. This unit is very poorly suited to sanitary facilities such as trench sanitary landfill and area sanitary landfill. The soil conditions are very unfavorable or severe and very difficult to overcome. Special design, a significant increase in construction costs and possibly increased maintenance are required. Conditions are poor for daily cover for landfill because it is too clayey. (Smith C. W. 1983. Soil survey of Islands of Palau Republic of Palau. Soil Conservation Service USDA.)

The soil unit 436 Tabecheding is silty clay loam with 6 to 12% slopes. This soil is very deep, somewhat poorly drained and on dissected marine terraces. The soil is very deep, somewhat poorly drained and on dissected marine terraces. It is formed in bedded marine clay from volcanic rock. The vegetation is deteriorated savanna with scattered *Pandanus* trees. The unit has small areas of Ngatpang soils in the high and better drained areas and severely eroded Tabecheding soils in steeper slopes. Some areas have slopes less than 6% and more than 12%, soils with a water table at the depth of less than 38 centimeters or more than 91 centimeters. Soils are underlain by lignite to 150-cm depth. Small shell fragments and marl in pockets and in the substratum. Permeability of the Tabecheding soil is very slow. Effective rooting depth is 150 cm or more for water tolerant plants. If vegetation is removed, runoff is medium and the hazard of water erosion is moderate. The water table is near the surface a few days following storms. The area is used as a watershed and can be used as a reservoir if they are placed downstream from an adequate watershed area. Wetness and low soil strength limit the use of heavy equipment. This unit is poorly suited to home site and urban development due to wetness and clayey subsoil. Drainage is needed if roads and building foundations are constructed on this unit. Wetness can be reduced by installing drain tiles around the footings. Excess water can be removed by the shallow ditches and diversions and provided the proper grade. The very slow permeability and wetness may cause failure of septic tank absorption. This soil type is not suited for trench sanitary landfill, moderately suited for area sanitary landfill and poorly suited for daily cover for landfill because it is too clayey.

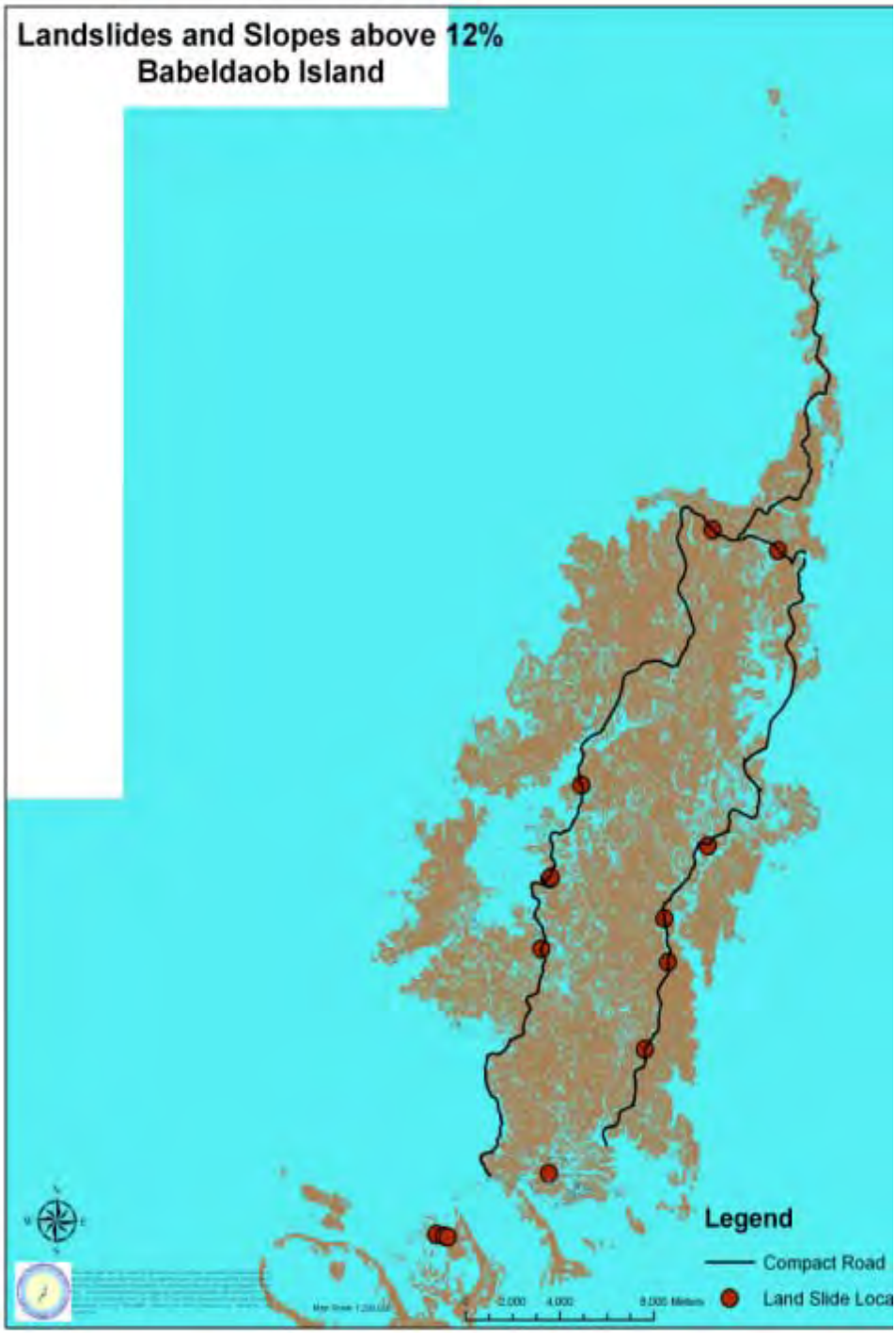

Figure 9 Major landslides in Babeldaob and Koror in recent years marked with red circle. Locations are based upon field observations along the alignment of the National Highway of Babeldaob and road of Koror Source: PALARIS Ikonos Satellit 2006 Image

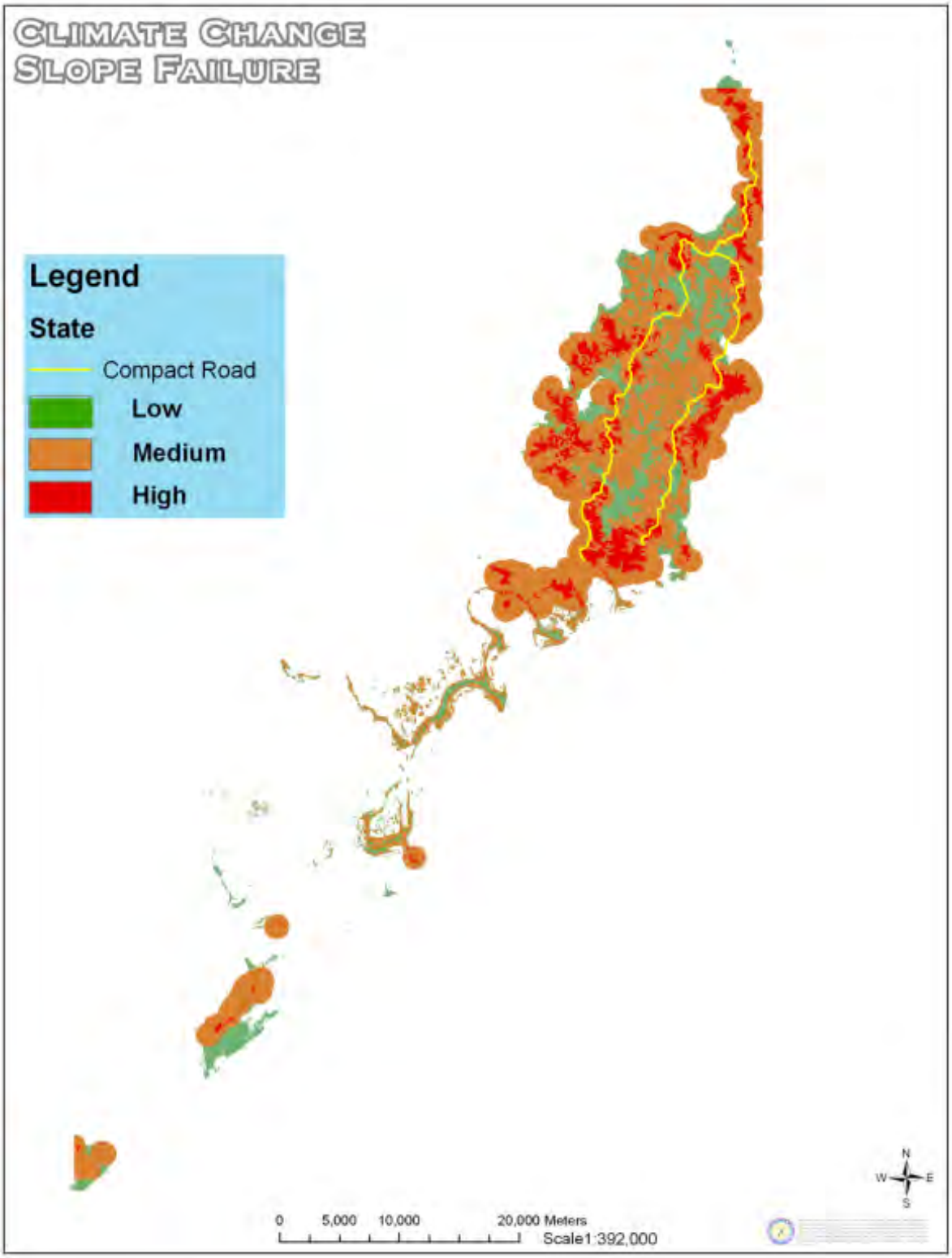

Figure 10. Spatial analysis of contour and infrastructure shown areas of high priority to stabilize slopes and reforest.

Figure 11 Malakal Island showing basalt quarry area (66,282 m^2) marked in red circle which was once forest. An area of chronic landslides is circled in yellow that crushed an adjacent warehouse downslope after heavy rains in 2009. The area of slope failure has 70% slopes. Quarry activity has left a thin and unstable rim of steep sloped forests that has caused several landslides after heavy rains. Source: PALARIS 2006 Mikonos Satellite Imagery.

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Table 13. Strategic Matrix for Issue 1- Climate Change- Slope failure or landslides

Long Term Strategy	Priority Landscape Areas	2^0 Issues Addressed	Program Areas that Contribute	Key Stakeholder	Resources Available/ Required to Implement	Measure of Success	Supports National Objectives
Stabilize slopes & Reforest Priority Landscape areas	Malakal Quarry Ngerikiil Watershed Ngchesar Ngaremlengui Ngatpang	Population Grov and Urbanizatio Water Quality & Quantity Wildfire & Public Safety 5 Conservation Sustainability of Forest Resources Urban Forest Sustainability	Urban & Community Forestry (UCF) Forest Health (FH) Forest Steward-Ship (FS) Conserva-tion and Education (CE)	Communities in priority landscape areas	Technical Assistance and personnel from: EQPB, National Public Works State Public Works, BOA, & NRCS 500 saplings of native trees in State Nurseries of priority areas, natio state & community personnel /Funds needed For: civil engineer, forest ecologist, tree pathologist, field equipment, fuel	Best management guidelines for slope stabilizati for EQPB, Restored and stabilized 4 slopes in critical areas by 2015	Conserve 1.1 Protect 2.1 Enhance 3.1 3.4 3.5 3.6 3.7
Impact of Climate Change on forest health from extreme weather events						Report on forest Health in priority Landscape areas	

Table 14. Strategic Matrix for Issue 1- Climate Change- Coastal erosion

Long Term Strategy	Priority Landscape Areas	2^0 Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/ Required to Implement	Measure of Success	Supports National Objectives
Restore Trees, shrubs and vegetation to stabilize coastlines within 10m of from high tide mark	Koror Southern Lagoon Eastern Babeldaob Kayangel Peleliu Angaur Hatohobei Sonsorol	Population Growth and Urbanization Water Quality and Quantity Wildfire & Public Safety Conservation Sustainability of Forest Resources Urban Forest Sustainability	Urban & Community Forestry (UCF) Forest Health (FH) Forest Stewardship (FS) Conservation ar Education (CE)	Communities in priority areas	Technical Assistance from: BOA, NRCS,EQPB, DFW, BMR, PC TNC, PVA, BTA , PICRC Plants from Nat'l & State nurseries /Funds for Equipment Fuel & boat Rental, expert on coastal erosion, tree ecologist/ pathologist	Report on Best management practices & guidelines 5 sites restored & stabilized by 2015. Erosion pins set at 5 beaches 5 community outrea programs	Conserve 1.1, 1.2 Protect 2.2 Enhance 3.5, 3.6 3.7
Protect Littoral forests and mangroves	Koror Southern Lagoon and East Coast of Babeldaob Mangroves in Priority sites					Report on Best management practices guidelines for littoral forests and mangroves with 1-2 day training 1 study on human impact to mangroves	Conserve 1.1, 1.2 Protect 2.2 Enhance 3.5, 3.6 3.7
Assess forest health from seawater intrusion						Report of forest Health and impact of seawater intrusion	

Issue 2 Population Growth and Urbanization

Over the past two decades the mean annual growth rate has been 2.0% with 71% of the population in the urban areas of Koror and Airai and 29% of the populations in rural areas or the other 14 State of Palau The total land area is reported at 491 km^2 in the 2005 Census with a mean density of 40 people/km^2 (Tables 15 and 16). The highest population growth rates over the past 25 years occurred in Airai (75%), Ngatpang (60%) and Koror (40%). The increase in population in Ngatpang is attributed to a foreign labor work camp for the national highway which is now completed and the camp has been vacated. In Airai, housing developments within the Ngerikiil Watershed are of concern as this is the top priority as a source of water for both Koror and Airai (Figures 11and 12). Rapid growth occurs where there is a large water source. Rapid urban growth has led to increasing health problems related to septic overflow from improperly managed systems, increased solid waste, loss of vegetation and an increase in impervious surfaces. It is urgent that a national sanitary landfill be constructed immediately to serve all of the States and community sewage systems are upgraded and well maintained. The forests play a critical role in filtering runoff and the placement of buffers along the rivers near development areas is critical. Land use planning integrated with SWARS is critical to ensure that watersheds are protected from potential pollutants such as solid waste. The PCS 2010-2015 strategy is to integrate protected areas into land use planning. The Republic is required under the Convention on Climate Change to submit a Green House Gas Inventory that requires quantification of land use change which is primarily due infrastructure development from population growth. Through a well documented planning process land use change can be followed over time and incorporated into the GHG inventory. Lose and degradation of habitats due to urban and commercial development is considered one of the top threats to Palau's terrestrial and marine resources during a 2008 consultation process sponsored by PCS.

Figure 12 View showing urban growth in the Ngerikiil Watershed in Airai State

Table 15 Population growth between 1986 and 2005 in Urban and Rural Areas.

Census Year	Population	%Annual Growth Rate	Urban Population (Koror & Airai)		Rural Population Other States	
			Number	Percent	Number	Percent
1986	13, 873	2.3	9,442	68.1	4,431	31.9
1990	15,122	2.2	10,501	69.4	4,621	30.6
1995	17,225	2.6	12,299	71.4	4,926	28.6
2000	19, 129	2.1	13,303	69.5	5,826	30.5
2005	19,907	0.8	15,399	77.4	4,508	22.6
mean	17,418	2.0	12, 188	71.2	4,862	28.8

Source: Census Reports and Census of Population and Housing, Republic of Palau

Table 16. Population growth for each State in the Republic of Palau from 1980 to 2005

State	total area (km^2)	population	Population per km^2	% of total population	25 yr (1980-2005) population growth
Aimeliik	52	272	5.19	1.4%	0
Airai	44	2,723	61.89	13.7%	75%
Angaur	8	320	40	1.6%	24%
Hatohobei	3	44	14.67	0.2%	-40%
Kayangel	3	188	62.67	0.9%	34%
Koror	18	12,676	704.22	63.7%	40%
Melekeok	28	391	13.96	2.0%	-9%
Ngaraard	36	581	16.14	2.9%	21%
Ngarchelong	10	488	48.8	2.5%	-32%
Ngardmau	47	166	3.53	0.8%	3%
Ngaremlengui	65	317	4.88	1.6%	-13%
Ngatpang	47	464	9.87	2.3%	64%
Ngchesar	41	254	6.2	1.3%	-43%
Ngiwal	26	223	8.58	1.1%	-20%
Peleliu	13	702	54	3.5%	13%
Sonsorol	3	100	33.33	0.5%	21%
Rock Islands	47	0	0		
Total	491	19,907	40.54		

Sources: 2005 Census Monograph and 2000 and 2005 Census of Population and Housing. Office of Planning and Statistics.

Spatial Analysis

A geospatial model was developed to determine the highest priority areas in which Forestry efforts should be directed to protect forests from being replaced by infrastructure or assist home owners and business in agroforestry and conservation on their land. A total of 11 data layers were identified for the model analysis (Table 17) with each layer weighted according to its perceived relative importance to this issue. The criteria are explained in Table 18. Comparative spatial data used in the analysis was

Table 17. Ranked Layers for the issue of Population Growth and Urbanization

Layer Rank	Layer Name	Layer Weight
1	Infrastructure	19.8
2	Forest	13.8
3	Wildfire	9.8
4	Riparian Area	8.8
5	Threatened and Endangered species	8.4
6	Soil	7.8
7	Watershed	7.2
8.5	Fault line	6.8
8.5	Cultural Site	6.8
10	Protected Area	5.4
11	Public Drinking Water	5.2

Table 18. Criteria used for the GIS Analysis for the issue of Population Growth and Urbanization

Factor	Condition	Suitability for reforestation
Infrastructure	Density > 7 buildings/0.5 ha Density > 5 < 7 buildings/0.5 ha Density >1<5 buildings/0.5 ha	10- high 5- medium 1- low
Forest	Grasslands, Savanna or Bare areas All other forest types	10 1
Wildfire	Known fire risk Unknown fire risk	10 1
Riparian Area	Less than 10m from stream Less than 20m from stream Less than 40m from stream	10 5 1
Threatened and Endangered species	Habitat for critically endangered species. Habitat for endangered species Habitat for threatened species	10 5 1
Soil	Highly erodible soils Less erodible soils	10 1
Watershed	Ngerikiil Ngerdorch Ngermeduu Diongradid Ngerbekuu	10 10 5 5 1
Fault line	Within 100 to 500m Within 50 to 100m Within 0-50m	10 5 1
Cultural Site	Within 0-50m Within 50 to 100m Within 100 to 500m	10 5 1
Protected Area	Within a protected areas Within 0-100m Within 100 to 500m	10 5 1
Source of Public Drinking Water	Within 10 m Within 20 m Within 50 m	10 5 1

Results

The highest priority area for urban growth is within the Ngerikiil Watershed of Airai State and most of Koror State. The Ngerikiil Watershed is also a critical watershed for drinking water and is highly vulnerable to fire and invasive weeds and its upper watershed is an important bird area. Koror State is a top priority area because it is home for several endangered species and has recurrent landslides. Koror's urban forests cover 2, 102 acres of land. A small population of the critically endangered palm *Ponapea* is found on the rock islands near the urban center. The only other known small population of Ponapea is found on a rock island being considered for a quarry site. In addition, Malakal Island in Koror is the only

know location of *Timonius salsedoi* and only known from a type specimen (Costion et al. 2009). It is critical to locate this species and protect it from encroaching development.

Conclusion

The geospatial analysis identified primary areas in which future efforts should be concentrated. The Ngerikiil Watershed of Babeldaob and Malakal Island of Koror are two critical areas to implement reforestation projects to protect the existing forests and provide healthy forests to the urban communities Of these two most densely populated States of Palau.

References

Office of Planning and Statistics. 2005. 2005 Census Monograph and 2005 Census of Population and Housing.

Table 19 Strategy Matrix for Issue 2 Population Growth and Urbanization

Long Term Strategy	Priority Landscape Areas	2[0] Issues Addressed	Program Areas that Contribu	Key Stakeholders	Resources Available/ Required to Implement	Measure of Success	Supports National Objectives
Develop and implement land use plans. Build capacity for Land use planning Land use change for GHG Inventory	Koror State Airai State Village with 5 or more buildings per 0.5ha	Climate Change (CC) Water Quality & Quantity (WQ) Wildfire & Public Safety (Fire) Conservation (C) Sustainability of Forest Resources (SF) Urban Forest Sustainability (UF)	Urban & Community Forestry (UCF) Forest Health (FH) Forest Stewardship (FS) Conservation & Education (CE) Forest Legacy (FL) Cooperative Fire (CF)	Koror & Airai Community Including Public & Private land owners & members of the public land authorities	Technical Asst from: BOA, PCS,TNC PALARIS EQPB OERC / Funds for: Equipment & supplies Aerial & Multi-Spectral Imagery Certified urban planner	Draft Land use plan for Airai State by 2015 One land Use Planning Training by 2015 for members of State and National Public Land Authorities	Conserve 1.1, 1.2 Protect 2.2 Enhance 3.3, 3.5, 3.6
Native Tree propagation & planting on private public lands	Koror State Airai State Village with with 5 or more Homes per 0.5ha			Public & Private Land Owners	Technical Asst from BOA, NRCS State Nurseries Nekken Nursery PCS, BWA Didil Belau Inc. Seeds of Promise /Equipment & supplies Fuel, boat rental	1,000 Native Trees propagated in Nekken & Airai Nursery Annually a minimum survival rate of 50% at priority sites	Conserve 1.2 Protect 2.2 Enhance 3.6

Issue 3 Water Quality and Quantity

Forests produce the cleanest waters as they absorb rainfall, reduce flooding, recharge aquifers, and provide habitat to wildlife and act as buffers along streams and rivers to retard flows of sediment laden runoff into streams. Riparian forests can trap over 80 percent of sediment and nutrients and reduce peak flooding by 50% (Cooper et al. 1987). Water storage, distribution and protection are critical for extreme drought periods associated with ENSO events and Climate Change. In 2006 the Babeldaob Watershed Alliance was formed to help states sharing the same watershed coordinate efforts through Conservation Action Plans to better protect and manage their forests and water supplies. Most States of Babeldaob have become involved in this process. The vision of the Babeldaob Watershed Alliance is to become a model for ensuring states have continued access to clean water and healthy environments and promote environmentally sustainable economic development through collaborative efforts of a diverse array of stakeholders (TNC 2007). Forestry is assisting in this process and addressing the technical needs of each State. In Palau, there are five main watersheds based upon their size and as potential sources of water shown in the table below. Ngerikiil is the most important watershed for the people in Palau as the main source of drinking water for Koror and Airai serving 77% of the population. The Airai-Koror waters supply system derives its water from the Ngerikiil river diversion dam and the Ngerimel Dam with a storage capacity of 75, 700 m^3 (20 million gallons). The Ngerikiil has an average daily flow of 20 million gallons of surface water. Ngeremeduu and Ngerdorch are important as centers of biodiversity. The Ngerdorch Watershed includes Ngardok Lake, the largest freshwater lake in Micronesia. Currently there is a restoration demonstration project within the degraded savanna areas in partnership with the USDA Forest Service Institute of Pacific Islands Forestry.

The threat to water quality from pollution is a top concern in Palau. During stakeholder meetings for SWARS in 2009-2010; during stakeholder meetings in Airai State for the EQPB Ngerikiil Integrated Watershed Management Demonstration Project; during NBSAP community consultations by PCS, during a national meeting of professional environmentalists and conservationist consultations sponsored by PCS in 2008 and during community meetings on mangroves, and target resources in Airai State by TEI from 2006-2009 - the community consistently mentioned their primary concerns about water quality and pollution. They were concerned about the impact of soil erosion and sedimentation, nutrient fertilizers, pesticide, septic systems and solid waste disposal on water quality. The lack of proper erosion and sedimentation management plans for all earthmoving projects of all sizes; the improper application of fertilizers and pesticides and management of soil on farmlands and the lack of a permitted and properly designed or maintained septic systems and solid waste disposal sites were the most frequently mentioned problems that the community wanted to be corrected. The loss of vegetation from development and long periods of soil exposure caused invasive species to grow was also a concern. Polluted waters also threaten wildlife that need clean water to survive and the lack of monitoring of areas downstream of developed sites was also discussed. Approximately 72% of the Ngerikiil watershed has slopes greater than 12% and 44% of the watershed has slopes greater than 30% account for 44% of the watershed (Gavenda et al. 2005).In 2010, a major earthmoving project for the expansion of the airport is in progress that is cutting and filling tons of soil in this watershed.

In 1999, EQPB proposed amendments of the marine and freshwater quality regulations to include riparian and wetland buffers. It was proposed that all forests upstream from a pumping station for drinking water be restricted. A 20m stream side buffer was proposed for rivers downstream of the pumping stations with options for variances for small land parcels. DeMeo (2003) recommended a 27 acre riparian forest buffer or 18 m (60ft) on either side of 3,000m of river from just above Yano's farm to the mangroves. Gavenda et al (2005) recommended to designate a riparian buffer exclusion zone of 10 to 20m along the entire length of the Ngerikiil and Edeng rivers of the Ngerikiil Watershed and recommended to stop all farming activity within 10m of the rivers. The 2010 EQPB guidelines for Erosion and Sediment Control Plans are to have a 50 ft buffer for wetland areas.

Recently the Babeldaob Watershed Alliance was formed. The mission of the Babeldaob Watershed Alliance is to protect, maintain and enhance the high quality water and other public benefits. All Babeldaob states are at various stages of awareness raising, assessment and strategic planning for the watersheds under the Alliance. The mission of the Babeldaob Watershed Alliance (BWA) is to protect the water resources of Babeldaob through collaborative outreach, education, information sharing and technical assistance by and for the communities of the island. The goals of BWA are to get the leadership actively involved, secure financial and technical support, integrate planning with watershed management, implement water monitoring and include all States of Babeldaob in this process. The Environmental Quality Protection Board has initiated an Integrated Watershed Management Project entitled the Ngerikiil Watershed Restoration for Improvement of Water Quality to promote proper watershed and integrated management practices. The goal of this project is to reduce land degradation while preserving ecosystem stability, functions, and services such as soil and watershed protection, water purification and nutrient retention.

Through a series of technical meetings with representatives from PALARIS, TNC, BOA, BNM, NRCS, PCS, the main watersheds of Palau were weighted in importance. Weights were based upon the services the watersheds provided or their unique features (Table 20). The Ngardok Watershed (Figure 12) was ranked second in importance as a water source and an area of high biodiversity. The top two watersheds, Ngerikiil and Ngerdorch Watersheds were used as case studies for this issue.

Table 20 Priority Watersheds in Palau based upon consultations that decided a potential source of freshwater serving the largest population was the most important factor in ranking

Name of Watershed	Weight	Rank	Total Ar km^2	Main River and Features
Ngerikiil	34	1	28.5	The Ngerikiil River is the main source of drinking water for Airai & Koror.
Ngerdorch	20	2	44.2	Ngerdorch River-longest river, Ngardok Lake (largest lake) and source of water for Capitol
Ngeremeduu	19	3.5	80.6	Ngermeskang , Ngatpang and, the Tabecheding Rivers are part of the largest watershed- 3 State conservation area.
Diongradid	16	3.5	23.4	Diongradid River source of water for Ngardmau & potential source of water for Babeldaob – largest waterfall
Ngerbekuu	11	5	18.2	Ngerbekuu River- deforested, to soil erosion
Total Area of Babeldaob			330	Babeldaob Island is the 2nd largest Island in Micronesia
% of total area of Babeldaob			58.3	

Spatial Analysis

A geospatial model was developed to determine the highest priority areas in which Forestry efforts should be directed to protect water quality and quantity. Nine data layers were identified by the technical team and weighed for model analysis (Table 21) with layers weighted according to its perceived relative importance to this issue. Rivers and streams below pump stations were give a 20m buffer or either side. The Criteria for each layer is given in Table 22. A map showing the drainage areas for public drinking water were totally buffered and shown in dark blue if on public land is shown in Figure 12. Currently there is a gap available spatial data for endangered or threatened species, wild fire and pumping stations

so these were not used in the spatial analysis. When running the spatial analysis seven layers had enough special information in Babeldaob- infrastructure (40% weight), riparian area (35% weight) and forest (25% weight) (Figure 14). Further data collection is needed for spatial analysis focusing on priority watersheds.

Table 21 Ranked Layers for the issue of Water Quality and Quantity

Layer Rank	Layer Name	Layer Weighting by Technical group	Usable Layers & Weights
1	Priority Watershed	20	not used
2	Public Drinking water	15	not usable point data only
3	Riparian Area	10	35
4	Wetland	5	not used
5	Forestland	15	25
6	Protected Areas	10	not used
7	Infrastructure	10	40
8	Endangered or threatened Species	5	n/a
9	Wildfire Risk	10	Not useable -some point data- not used

Table 22 Criteria used for the GIS Analysis for the issue of Water Quality and Quantity

Factor	Condition	Suitability for Reforestation
Priority Watersheds	Ngerikiil Ngerdorch Ngermeduu Diongradid Ngerbekuu	10 10 5 5 1
Public Drinking water	Within 0-100m Within 100-500 m	10 5
Riparian Area	Within 0-50m Within 50-100m	10 5
Wetland	Within 0-20m	10
Forest	Bare Areas Savanna & Burned forest All other forests	10 5 1
Protected Areas	Within a protected area Within 50-100m of a protected area Within 100-500m of a protected area	10 5 1
Infrastructure	Within 25-50m Within 50-100m	10 5
Endangered or threatened species	Habitat of Critically Endangered Species Habitat of Endangered Species Habitat of Threatened Species	10 5 1
Wildfire Risk	Ngerikiil Ngetkib Ngatpang-Aimeliik Ngardmau-Ngkeklau Choll-Ngarchelong	10 7.5 5 5 5

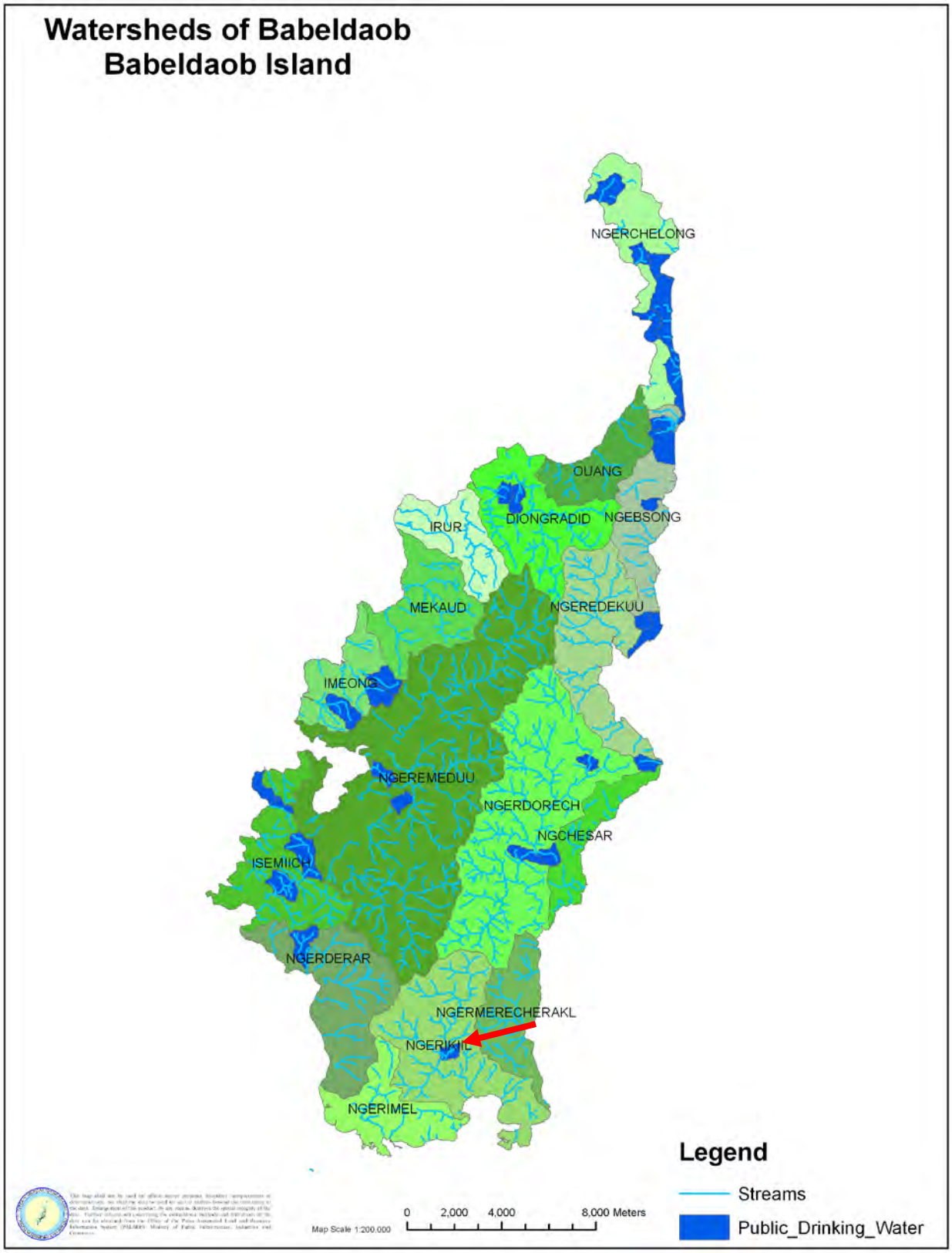

Figure 13 Map showing the upper watershed areas for public drinking waters sources of Babeldaob The upper Ngerikiil watershed provides the largest supply of public drinking water in Palau & is shown with red arrow

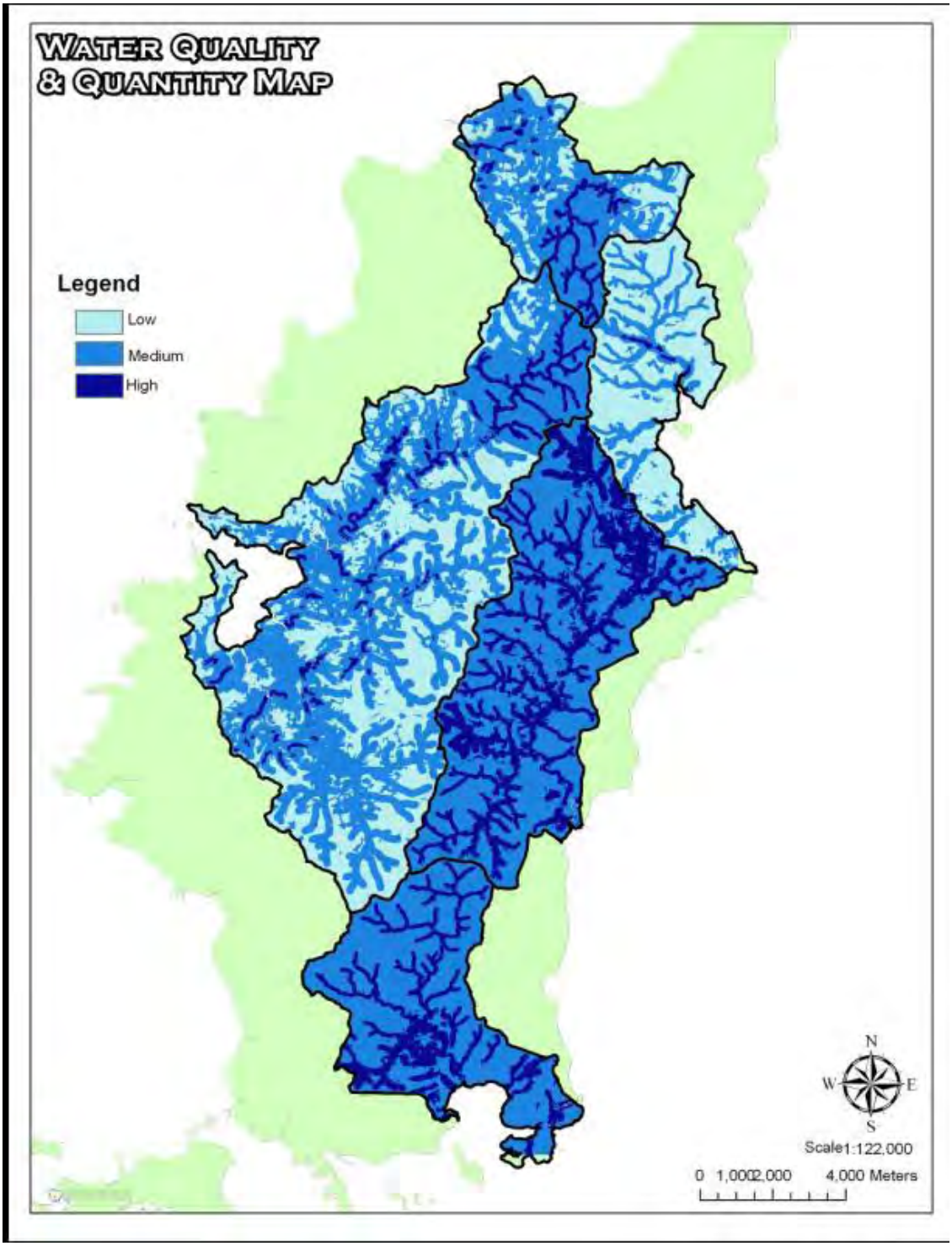

Figure 14 Spatial Analysis of priority water quality areas showing high priority areas in darkest blue, medium areas in lighter blue and lower priority areas in sky blue.

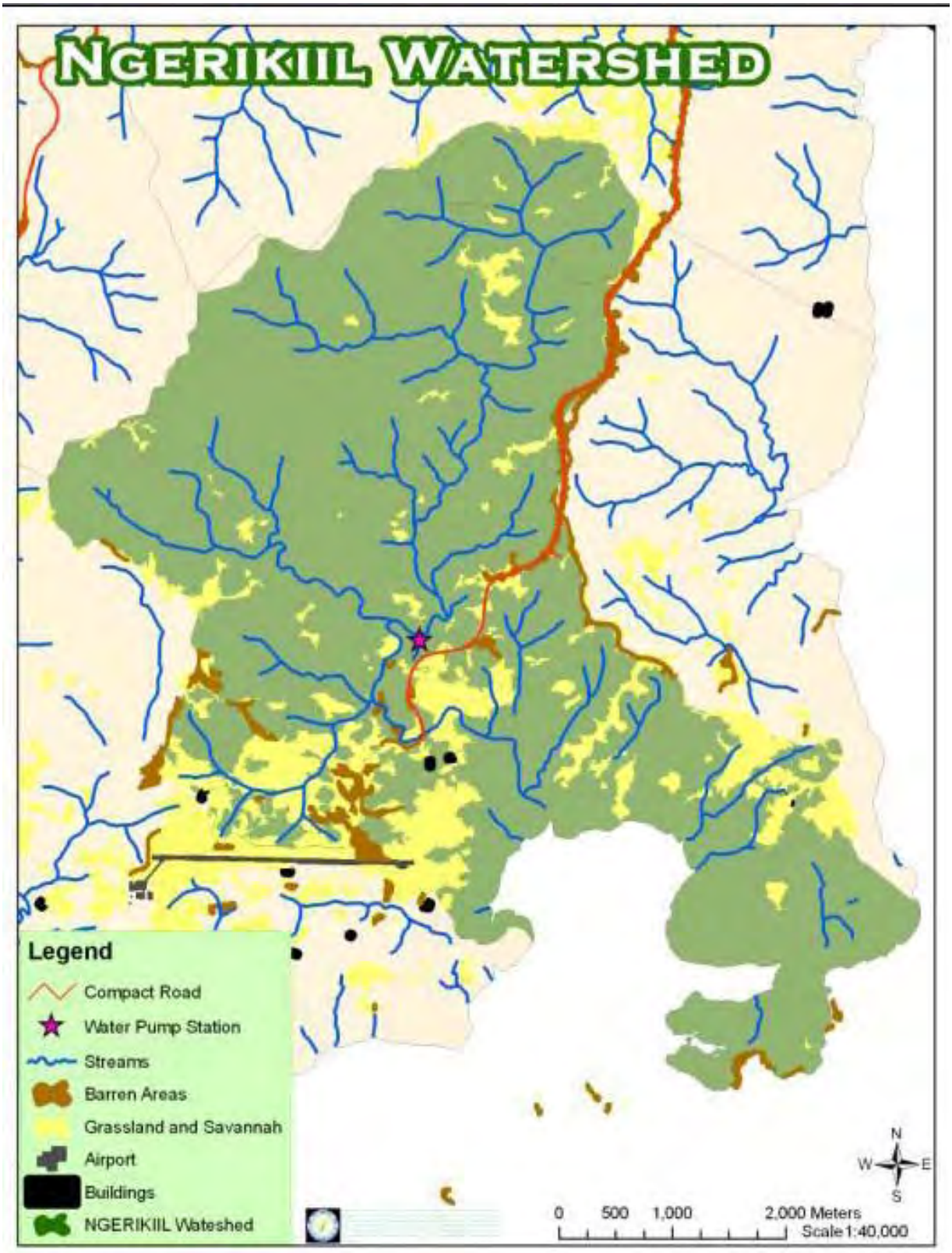

Figure 15 A close-up view of the Ngerikiil Watershed showing barren areas that need revegetation along the streams

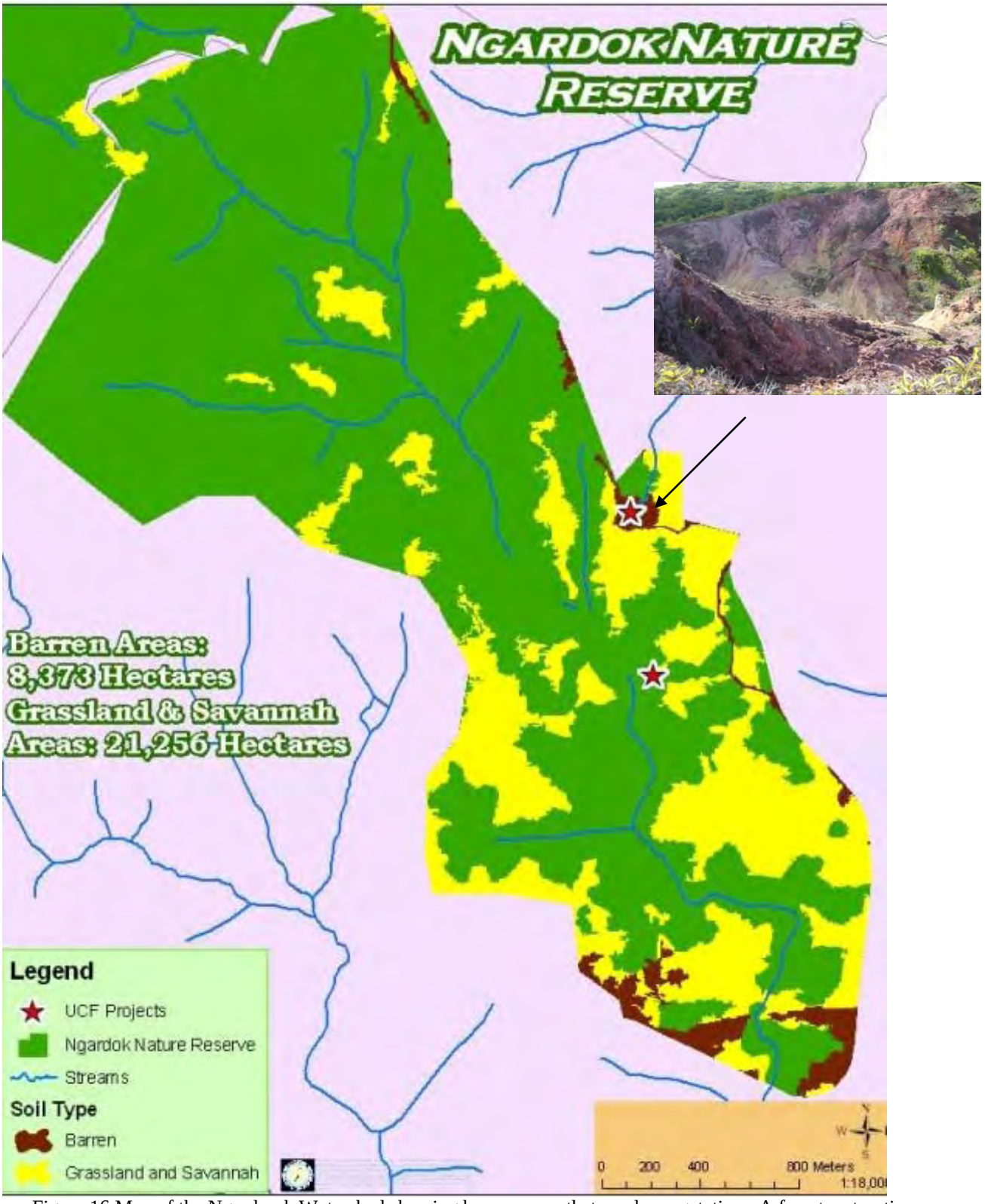

Figure 16 Map of the Ngerdorch Watershed showing barren areas that need revegetation. A forest restoration project is being conducted in the along the northern boundary of the watershed. An insert of a barren canyon just north of an ongoing reforestation project is also show.

Results

Results from the spatial analysis are shown in on Figures 14. The Ngerikiil Watershed (Figure 15) and the Ngerdorch watershed (Figure 16) are 2 of 5 high priority areas for forest restoration in barren areas and savanna areas. A total of 8,373 hectares of barren areas and 21, 256 ha of grassland and savanna exist in the Ngerdorch Watershed. Ongoing spatial analysis will quantify the number of hectares of needed forest buffers in the Ngerikiil and Ngerdorch Watersheds.

Conclusion

The technical group identified priority watersheds and the preliminary spatial analysis shows these as critical watershed areas. Ngerikiil and Ngerdorch Watershed were priority landscapes in which current and planned projects for reforestation are occurring. Sustainable agroforestry and buffers are planned in the lower watershed of Ngerikiil with mangrove conservation and sustainable management also being advocated. Ngerikiil is the fastest growing watershed in Palau with major earthmoving activities that threaten water quality. In contrast, Ngerdorch Watershed is a Reserve with restricted activities however the soils are very poor and ongoing reforestation activities are occurring within the Reserve which is also home to the largest freshwater lake in Micronesia and a source of water for the newly relocated Capitol. Currently forestry is conducting a restoration study of forests within the Ngardok Reserve.

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Table 23 Strategy Matrix for Issue 3 Water Quality and Quantity

Long Term Strategy	Priority Landscape Areas	2[0] Issues Addressed	Program Areas that Contribute	Key Stake-holders	Resources Available/ Required to Implement	Measure of Success for priority sites	Supports National Objectives
Inventory current land use & correlate with water quality & quantity	Watersheds Ngerikiil Ngerdorch Ngeremedu Diongradid Ngerbekuu	Climate Change (CC) Population Growth & Urbanization (PG) Wildfire & Public Safety (Fire) Conservation (C) Sustainability of Forest Resources (SF) Urban Forest Sustainability (UF)	Urban & Community Forestry (UCF) Forest Health (FH) Forest Stewardship (FS) Conservation and Education (CE) Forest Legacy (FL) Cooperative Fire (CF)	Communities within priority watersheds	Technical assistance from: BOA, EQPB, PALARIS BWA, DFW, DFR, TNC, PCS, TEI, OERC, Communities in priority landscapes /funds for equipment supplies, Aerial Photography Multi-spectral Imagery Inventory Team Expert planner	Inventory & correlations for priority landscapes by 2015	Conserve 1.1, 1.2 Protect 2.2 Enhance 3.1, 3.5, 3.6,
Buffer Initiative for each State						Buffer initiative establish in each State by 2015	
Build capacity within Communities to produce Watershed Management Plans						Four community Watershed management plans by 2015 2 certified watershed planners by 2015	Conserve 1.1, 1.2, Protect 2.2 Enhance 3.1, 3.5, 3.6, 3.7
Establish Buffer zones						Permanent (Zone1) & sustainable harvest (Zone 2) buffers established at by 2015 Install fire breaks in prone areas by 2015 Remove invasive species in buffer zones Report on assessment of need for easements from private land owners of permanent buffer areas of high priority upper watershed areas by 2015	Conserve 1.1, 1.2, Protect 2.2 Enhance 3.1, 3.5, 3.6, 3.7
Support EQPB develop & Implement a water quality monitor program & build community capacity to monitor water quality						Reforest areas of Point & non-point sources of pollution identified in Ngerikiil by 2012 Collaborate with EQPB in water testing before & after reforestation to determine effectiveness of buffers in priority watersheds by 2013	Enhance 3.1, 3.5, 3.6
Identify & Secure Funding sources & link with PAN						Secured funds from PAN by for at least 1 watershed by 2014	Enhance 3.1, 3.2, 3.3

Issue 4 Wildfire and Public Safety

Wildfires are a major threat to Palau's infrastructure and terrestrial landscape. During ENSO related drought years, the danger of wildfire increases and the impact of wildfires during these critical periods of drought can be catastrophic. During severe droughts, the savannas burn uncontrollably in remote areas. Fire burns through buffer zones of major rivers. Kitalong observed fires burning to the edge of the Ngermeskang River in 1997-1998 ENSO events. During March 1998 there were daily fires throughout Babeldaob. A recent fire in the Ngerikiil watershed (Figure 17) shows the threat fire has on homes and vegetation. Fluctuations in sea level associated with ENSO events are linked with more severe droughts and areas burnt by wildfires in Guam based on a 20 year record. It is critical that Palau quantify and document the extent and frequency of fires through field work linked with annual aerial photography.

Figure 17 A wildfire within the Ngerikiil Watershed in 2009

Republic of Palau Wildfire Plan 2008-2013 shows that the mean number of fires is greater during periods of the lower annual rainfall (February, March and April) than the rest of the year. The highest mean number of fires over a 9 year period (2001-2009) was during the month of March (Figure 18). A total of 68 reported fires burning an estimated 70,165 m^2 or 7 ha in Babeldaob was reported from Melekeok Sub-station from 2007 to 2009 (Refer to Table 24). Most of these fires were reported from Melekeok followed by Ngaraard, Ngchesar and Airai. Another fire substation is planned for Ngardmau State. Three fires occurred near the solid waste disposal sites in Ngaraard, Melekeok and Ngiwal. Much of Palau (53 ha) is covered with flammable savanna grasslands that cannot reforest naturally due to the high incidence of wildfires and the poor soils that result from the lack of forest canopy (Figure 20). The priority areas where wild fire fighters have the largest and most frequent fires are shown as large red dots on Figure 20. No spatial data is yet available for analysis.

The Republic of Palau National Biodiversity Strategy and Action Plan (2004) lists uncontrolled fires with repeated fires as one of the major threats to terrestrial biodiversity. Grasslands originating from abandoned agricultural land fail to reforest and often vegetation is lost and soil erosion occurs. The Fire and Rescue Division of the Bureau of Public Safety is mandated to suppress both urban and rural fires but is understaffed and has limited equipment and staff. The Forestry Section of the Bureau of Agriculture has very limited fire management or suppression capacity (ROP NBSAP).

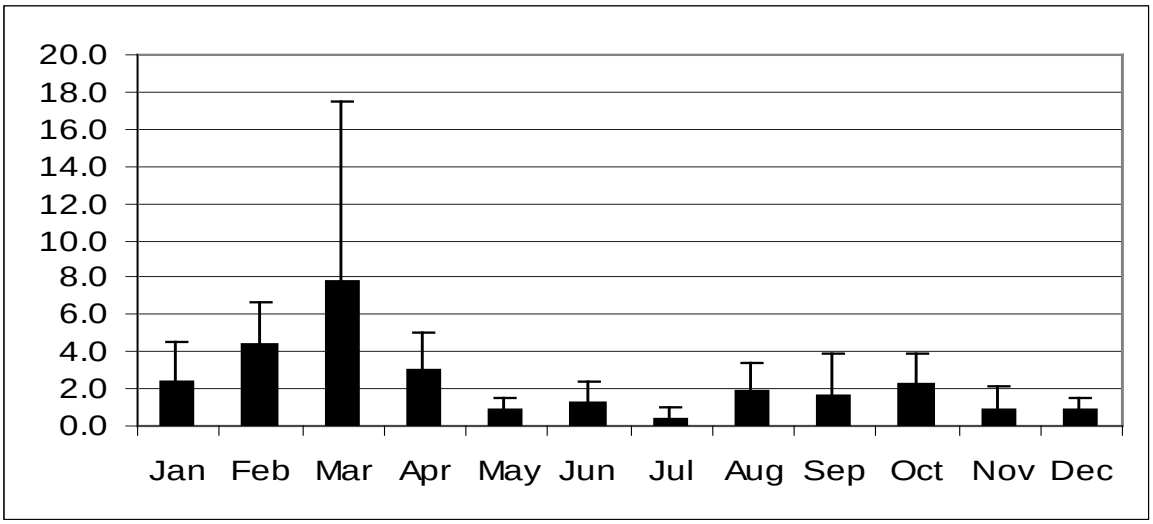

Figure 18 Mean number of fires (sd=1) for the years of 2001 to October 2009

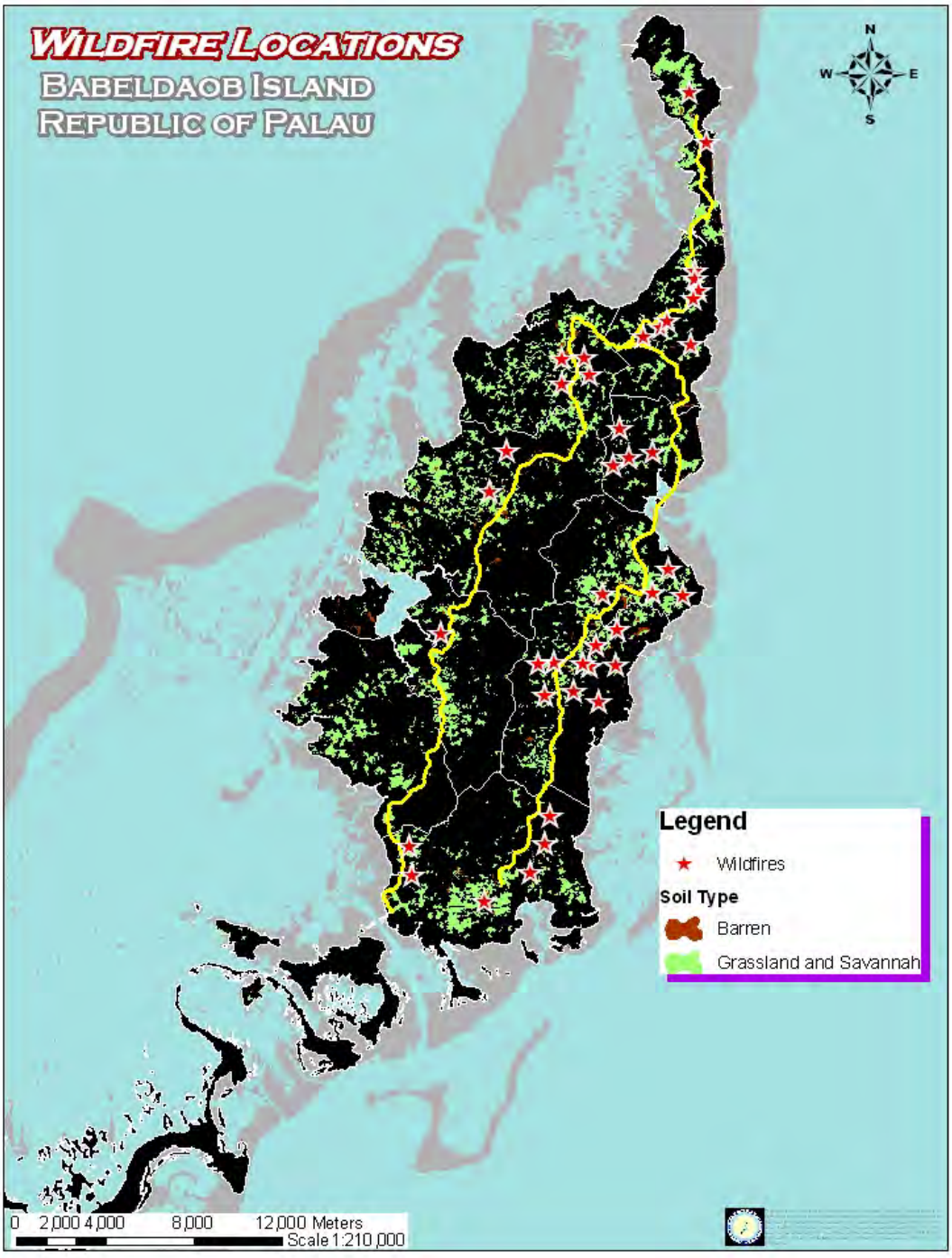

Figure 19 Map of fire locations reported from the Melekeok fire substation listed in Table 24 from 2007 to 2009 The yellow line is the national highway.

Table 24 Frequency and total area (m^2) of reported fires at Melekeok Sub-Station from 2007- October 2009

State	Number	Area (m^2)
Melekeok	10	16,100
Ngaraard	10	15,840
Ngchesar	8	12,125
Airai	6	6,350
Ngardmau	4	5,700
Ngaremlengui	2	4,800
Ngiwal	4	4,300
Ngatpang	2	2,550
Ngarchelong	2	2,400
Aimeliik	0	0
Total:	**48**	**70,165**

The recent introduction and spread of invasive plant species such as *Imperata cylindrica* (referred to as kerosene grass in Palau because it burns so readily) is near the Airai airport is currently being treated and controlled (Figure 21). If possible, eradicate *Imperata* from Palau. Although under control by the airport it is a threat to nearby farms and ongoing treatment and monitoring is required. *Pennisetum* grass and the climbing Siam weed *Chromolaena odorata* have served as a catalyst for fire as they easily invade savanna and forest and can easily burn.

Most wildfires are initiated by people with drier periods and periods of higher wind contributing to the incidence of uncontrolled fire. There are two main types of burning in Palau: burning for traditional agricultural purposes or to claim land and simply setting fires for sport which is arson. Fire has long been a tool used by traditional gardeners to clear areas for gardening. Today abandoned gardens are overtaken by invasive plants of which some are more flammable than other. These invasive plants inhibit reforestation and cause areas to be more vulnerable to fire. Recreational burning (arson) and burning to clear hunting trails or paths are believed to be the main cause of wildfire. To better manage and control fire related activities, burning permits are administered through the Environmental Quality Protection Board (EQPB). The permit is aimed at preventing air pollution and prohibits the burning of tires. The permit regulates the size of fire and requires fires to be contained. When a burning permit is issued the Division of Fire and Rescue is notified. A citation is issued for cases of non- compliance with the permit process. Currently there is poor compliance, especially in less accessible areas in Babeldaob and the outer states of Angaur, Peleliu, Kayangel, Hatohobei and Sonsorol.

Republic of Palau Wildfire Plan 2008-2013 describes the Fire and Rescue Division as a branch of the Bureau of Public Safety under the National Emergency Management Office within The Ministry of

Justice with a bill pending to change the Division into a Bureau. The Plan states that the staff includes a Chief, an Assistant Chief, 11 full time officers and a Secretary. The Officers are located in Koror (6) and the Melekeok substation (4). A new substation is being planned for Ngardmau State. It is estimated that an additional 39 firefighters are needed. The Division of Fire and Rescue has a central fire station and 2-3 800 gallon crash trucks (forestry trucks) and a substation in Melekeok State. Firefighting equipment provided by US Forest Service Region 5 Cooperative Fire Program includes flappers, backpack sprayers, Pulaksi's shovels. It is estimated that 2 new 1, 500 gallon fire engines and 2-3 smaller 500-800 gallon engines with hoses and pumps are needed. Given the size of Babeldaob at least one additional substation at the West Coast is needed. Community fire substations are needed in each state.

Table 25 Priority Wildfire Areas based upon consultations with the Bureau of Agriculture Forestry Section and the Division of Fire and Rescue 2009

Rank	Location and criteria for selection and estimated area
1	Ngerikiil Watershed- a priority watershed and main supply of drinking water, densely populated areas; location of chronic landslides and fires location of airport and invasive kerosene grass A fire substation for airport but trucks too big and mandated to serve airport only >1.0 km^2
2	Barren savanna hills of Ngetkib Hamlet in Airai State near homes farms, power lines chronic fires 0.25km^2
3	Road intersection by Ngatpang; near power lines & infrastructure about 0.5 km^2
4	Area along compact road between Ngardmau & Ngkeklau -site of chronic fires of large fires about 0.5 km^2
5	Road area between Choll & Ngarchelong is about 0.5 km^2 – area of chronic large fires

Spatial Analysis

A geospatial model was developed to determine the highest priority areas in which Forest Service efforts should be directed to protect forests from harm of wildfire and assist communities to develop fire plans for their homes and businesses. Eight data layers were identified and ranked by the technical team for spatial analysis (Table 26) with each layer weighted according to its perceived relative importance to this issue. The criteria are given on Table 27. Spatial data is needed for the top weighted layer-wildfire areas and frequency. Currently the only data layers available are forestland, wetlands infrastructure.

Table 26 Ranked Layers for Issue 4 Wildfire and Public Safety

Layer Rank	Layer Name	Layer Weight
1	High Wildfire Risk- Priority fire areas	20
2	Infrastructure	15
3	Forestland	10
4	Priority Watershed	10
5	Public Drinking water	15
6	Riparian and wetlands	10
7	Protected Areas	10
8	Endangered or threatened Species	10

Table 27 Criteria developed for the GIS Analysis for Issue 4 Wildfire and Public Safety

Factor	Condition	Suitability for Fire Suppression
High Wildfire Risk- Priority fire areas	Priority Fire Areas Unknown Fire Risk Areas	10 5
Infrastructure	Within 100 m Within 500 m Within 1000m	10 5 1
Forest	Savanna Agroforest Other forest types	10 5 1
Priority Watershed	Ngerikiil & Ngerdorch Ngermeduu & Diongradid Ngerbekuu	10 5 1
Public Drinking water	Within 10m Within 20m Within 50m	10 5 1
Riparian Area	Within 0-20m Within 20-40m Within 40-100m	10 5 1
Wetlands other than Riparian Areas	Within 0-20m Within 20-40m Within 40-100m	10 5 1
Protected Areas	Within protected areas Within 100 m of a protected area Within 250 m of a protected area	10 5 1
Endangered or threatened Species	Habitat of Critically Endangered Habitat of Endangered Habitat of Threatened	10 5 1

Results and Conclusion

The geospatial analysis identified primary areas in which future efforts should be concentrated to prevent, pre-suppress, control and suppress the frequency and sizes of wildfires. Results from the overlay analysis of vegetation and invasive species are shown in Figure 19. The five high risk wildfire areas are priority areas for reforestation and fire prevention comprise 2.75 km^2 of savanna. Vulnerable forests make up the adjacent landscape. Key areas identified by the fire fighters were within the savanna areas of Airai – especially by the airport the Ngerikiil Watershed (Figure 21), and the savanna areas in Ngatpang (old communication center), Ngardmau (between Ngardmau and Ngkeklau), Ngaraard (Choll) and Ngarchelong of Babeldaob. Most reported fires occur along the National Highway which provides easy access to these vulnerable areas. An education awareness program, community fire plans and training and updating maps and databases, upgrading equipment and ongoing training for wildfire suppress will mitigate wildfires in Palau.

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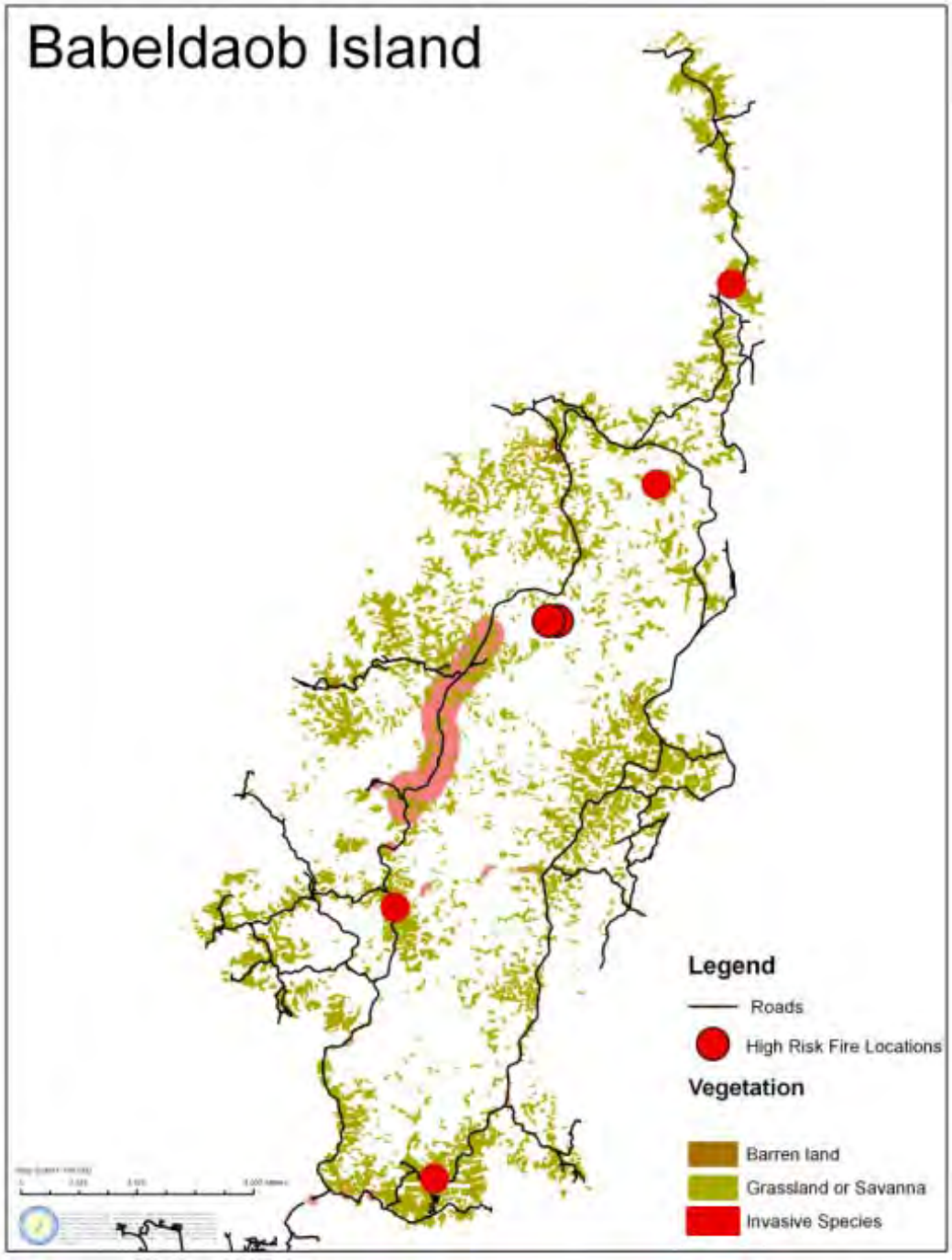

Figure 20 Map of High Risk Wildfire locations in red with barren areas and grasslands
The invasive species are shown in areas of concentration in light pink

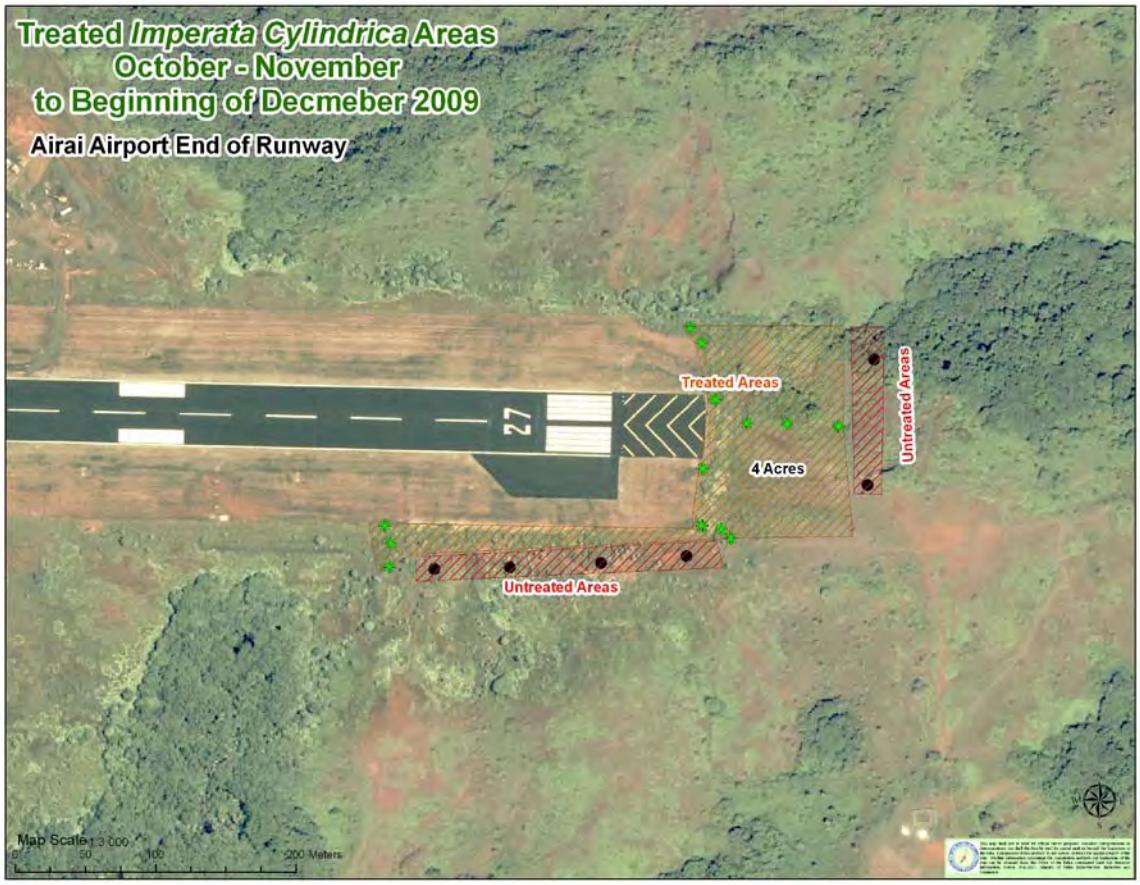

Figure 21 View of airport within Ngerikiil Watershed showing plots of treated areas (4 acres) and untreated areas for *Imperata cylindrica* grass

Table 28 Strategy Matrix for Issue 4 Wildfire and Public Safety

Long Term Strategy	Priority Landscape Areas	2^0 Issues Addressed	Program Areas that contribute	Key Stake-holders	Resources Available/ Required to Implement	Measure of Success at priority landscapes	Supports National Objectives
Develop and implement monitoring methods to determine baseline & ongoing levels of burning by 2010	Airai (Ngerikiil & Ngetkib) Ngaraard Ngarchelong Ngatpang	Climate Change (CC) Population Growth & Urban-ization (PG) Water Quality & Quantity (WQ) Conserva-tion (C) Sustain-ability of Forest Resources (SF) Urban Forest Sustain-ability (UF)	Urban & Community Forestry (UCF) Forest Health (FH) Forest Stewardship (FS) Conservation and Education (CE) Cooperative Fire (CF)	Communities in priority areas	Technical assistance & personnel from: DFR, BOA, PALARIS EQPB, DFR, BPS, CRRF & DFW / funding for: GPS units, laptops, field monitoring equipment & supplies Aerial & Multi-spectral imagery	Database for all fires including frequency, size, location, mitigation & long term monitoring Production of one fire vulnerability map for Palau Annual Wildfire Summary Report Integrated Reporting Permit & Assessment System between EQPB, DFR & BPS	Protect 2.1, 2.2, Enhance 3.3
Conduct ongoing education campaigns to educate Babeldaob Residents about existing Legislation and effects of burning by 2010	Airai (Ngerikiil & Ngetkib) Ngaraard Ngarchelong Ngatpang				Technical assistance & DFR staff & partners / funding and equipment including Laptops, video production, printing costs & supplies	A "Smokey the Biib" mascot & campaign each year 10 school visits on fire prevention education One 5 minute video on Fire prevention 4 radio shows on fire prevention 1 brochure on fire prevention	
Develop & implement community–based fire response & suppression plans with training in fire response & suppression by 2015	Airai\ (Ngerik & Ngetkib) Ngaraard Ngarchelong Ngatpang				DFR& DOE PCS, BOA, BWA staff, community / funds for training & flappers, backpack sprayers, Pulaksi's shovels, two new 1,500 gal fire engines, 2-3 500-800 gal engines with hoses & pumps	Four community wild fire prevention plans (CWPP) by 2015 4 community groups trained on fire response & repression Reduced area of impact from wildfires by 25% in priority sites by 2015	

Table 28 continued. Strategy Matrix for Issue 4 Wildfire and Public Safety

Long Term Strategy	Priority Landscape Areas	2^0 Issues Addressed	Program Areas That Contribute	Key Stakeholde	Resources Available/ Required to Implement	Measure of Success l at priority landscapes	Supports National Objectives
Develop & implement a fire hazard reduction program	Airai (Ngerikiil & Ngetkib) Ngaraard Ngarchelong Ngatpang	Climate Change (CC) Population Growth & Urban-ization (PG) Water Quality & Quantity (WQ) Conser-vation (C) Sustain-ability of Forest Resources (SF) Urban Forest Sustain-ability (UF)	Urban & Community Forestry (UCF) Forest Health (FH) Forest Stewardship (FS) Conservation and Education (CE) Dept of Fire and Rescue (DFR)	Communities in priority areas	Technical assistance and personnel from: DFR, DFW, CRRF, BWA, BOA, State & communities /funding for: fuel & equipment, aerial maps each year at end of March & multi-spectral imagery (i.e. LIDAR, SAR)	Fire Hazard Reduction Program by 2011 Establish green annually for priority areas Map & treat *Imperata* annually with goal to eradica Control *Chromolaena odorata* at priority sites Set 1 fire breaks at each priority site by 2015	Protect 2.1, 2.2, Enhance 3.3
Demonstration Plot for fire suppression	Airai (Ngerikiil & Ngetkib) Ngaraard Ngarchelong Ngatpang Nekken Station					Set up 5 fire suppression demonstration plots by 2015	
Fire breaks at reforested buffer areas	Conservation areas of Ngaremlengui Ngerdorch Ngiwal					Fire breaks established site reforested Buffer zones near forests by 2015	
Control *Imperata cylindrica* and *Chromolaena odorata* growth	Ngerikiil watershed-airp Ngaraard Ngarchelong Ngatpang					Ongoing control program for 5 acres of *Imperata* Control for *Chromolaena* at priority areas	

Issue 5 Conservation and Protected Areas

Effective conservation is a challenge as populations grow, local resources decrease, imported resources increase, technology improves and access to habitats increase. On October 1, 2007, the 53 mile (83 km) national highway was officially completed in Babeldaob, Palau's largest island. Secondary impacts have begun with chronic incremental loss of forests for new homes and infrastructure. Previously inaccessible upper watersheds with old growth forests and swamp forests are now vulnerable. Clearing of limestone and volcanic forests, burning and clearing of savanna and clearing and filling of wetlands and mangroves is causing the loss of forests and potentially impacting the terrestrial species dependent upon them.

The Republic of Palau's National Biodiversity Strategy and Action Plan (NBSAP) requires an inventory of all species of plants including the distribution and relative abundance. NBSAP also address the threats and challenges to maintain the integrity of Palau's ecosystems. One of the NBSAP strategies is to protect its terrestrial ecosystems. The Protected Areas Network Act (RPPL No 6-39) of Palau was established to enable States with the Republic to designate areas for protection. Area can be for restricted non extractive uses, non-extractive uses, and sustainable uses. Protected areas within the network will be managed mainly for science, wilderness protection, ecosystem protection, conservation of natural feature, conservation with management intervention, landscape/seascape conservation and recreation and for sustainable use. Currently Palau has terrestrial PAN sites in Melekeok with Lake Ngerdorch and in Ngiwal. Palau's PAN sites contribute to the Micronesian Challenge for long term conservation and protection. PCS Strategic Plan for 2010-2015 is to protect Babeldaob's key biodiversity areas and assist in management planning for protected areas.

The Micronesia Challenge is a commitment by the Chief Executives of the Federated States of Micronesia (FSM), the Republic of the Marshall Islands (RMI), the Republic of Palau, the U.S. Territory of Guam and the U.S. Commonwealth of the Northern Mariana Islands (CNMI) to *effectively conserve at least 30% of the near-shore marine resources and 20% of the terrestrial resources across Micronesia by 2020.* This ambitious challenge far exceeds current goals set by international conventions and treaties, which call for countries to conserve 10% of terrestrial and marine resources by 2010 and 2012 respectively. More than 20% of Palau's land is protected and funds being secured for the long term management. The challenge emphasizes regional collaboration between Micronesian leaders to confront environmental and sustainable development issues. (http://www.micronesiachallenge.org/files/history_of_the_micronesia_challenge.doc)

Forestry's Conservation Education program works in partnership with communities to promote opportunities to develop awareness and understanding of environmental issues so citizens will act responsibly to care about and conserve their natural and cultural resources. This Program crosses all other forestry programs and fosters awareness of the interdependence of humans and the natural world. Through this program Forestry increases awareness, knowledge and appreciation of natural and cultural resources and promotes critical thinking skills that enable the people to recognize resource issues complexities within current social, political, scientific and economic realities. This program fosters individual responsibility to conserve, preserve and wisely use their natural resources. This is a fairly new program that had produced two calendars that highlight the importance of forests and a mangrove poster that is being produced (Pua Michael, pers. comm. 2010).

The Forest Inventory and Analysis of Palau was set up to address long term changes and regular 5 to 10 year monitoring of the permanent plots is needed to determine the impacts and the resilience of Palau's forests to disturbances caused by fires, land clearing, typhoons and invasive species. Forest growth and loss can to be monitored over time to determine if reforestation is working over the long term. The FIA permanent plots were established and data was compiled and mapped and made available to users. The Forest Inventory and Analysis provides baseline and broad scale changes. Small scale studies to deal

with management issues for a specific habitat or species of tree builds upon the FIA process. Existing data on forests plots needs to be shared, archived and retrievable for future planning, forest management and protection.

Preliminary floristic studies were done within Babeldaob and to the other States of Palau and will be expanded over time. Pollination and seed dispersal studies of endemic plants by insects, birds and bats are being planned. The fruit bat, *Pteropus mariannus pelewensis* is an endemic subspecies, known to feed upon the nectar and fruits of 67 plant species representing 35 families of which 11 are endemic trees (Wiles et al. 1997). The Preliminary Wildlife Management Plan recommends fossil pollen (palynological) and fossil fauna studies have been initiated in Palau to study the vegetation history and identify changes in climate and human activities. The Wildlife Management Plan recommends more floristic studies and life history studies of endangered species. The Belau National Museum is collaborating with the Australia National University through internships to train and collaborate on pollen identification, collection and processing. The distribution of invasive tree species such as *Falcataria moluccana*, *Adenanthera pavonina* and other invasive species need to be mapped, monitored and effectively controlled. Regular surveys are also needed to determine if new species to provide and early response to new species incursions.

The Republic of Palau has approximately 802 native vascular plant species: 130 are endemic and 23 are endemic varieties. Palau's rate of plant endemism is 18.7% which is higher than Pohnpei at 16.4% (Lorence & Flynn 2007).The Belau National Museum Herbarium has over 3,000 voucher species of plant species from Palau and serves as national depository for plants and insect species in Palau. The BNM Herbarium works in partnership with the several herbariums throughout the world to safeguard the terrestrial biodiversity. About 61% of Palau's endemic species cannot be adequately assessed under the IUCN criteria because there is insufficient data (Costion et al. 2009).The percent endemism is highest in the limestone islands (Table 29). During a 2005 survey of Babeldaob an estimated 54 endemic plants or 37% of known endemics were collected or observed. A mean number of 27 endemic species were found in each state of Babeldaob. (Each state owns and manages all resources up to 12 miles seaward.) The numbers of endemic plants found in Babeldaob were as follows: Airai (34), Ngchesar (33), Ngaremlengui (33), Ngardmau (30), Ngatpang (30), Aimeliik (29), Melekeok (29) than in the northern portion (Ngiwal (22), Ngaraard (22), and Ngarchelong (5). Airai State is the only state of Babeldaob with limestone substrate with limestone islands and plants found only in limestone.

Table 29 Percent Endemism (E/km^2) in Palau's flora for each island type
(The areas for substrate type were provided by USDA Natural Resources Conservation Service)

	Endemic Species	Total Area (km^2)	% Endemics (E/km^2)
Restricted to Volcanic	75	363	21
Restricted to Limestone	31	90	34
Generalist	24	453	5
Total for Palau	130	453	29

Source: Costion, Kitalong and Holm 2009

Southeastern Babeldaob (Ngchesar and parts of Airai) is considered less impacted by human activities in the last few centuries that other parts of Palau (J. Liston, pers. comm. 2007). At least 20% of the land in Palau has been altered by man and it may be as much as 40% (J. Liston pers. comm. 2010). Northern Babeldaob is considered the most impacted by people a few centuries ago. Recent archeological surveys of Ngiwal suggest that an estimated 80% of the land of Ngiwal was altered by people over time (Rita Olsudong pers.comm. 2007). Area is also an important factor as Ngarchelong (10 km^2) and Ngiwal (26 km^2) have the smallest land area compared to other States. Greater endemism tended to be found in states

with both volcanic and limestone soils, less human disturbance, larger area and less accessible upper watersheds with major river systems. These protected watersheds would have surface or subsurface water during severe droughts and be more sheltered from storms. More survey work is needed to determine if there is a significant difference in the distribution of endemics in Babeldaob.

During the 2004-2005 Babeldaob survey only one healthy population of *Parkia parvifoliola* was found within the Ngaremlengui Reserve. *Terminalia crassipes* is restricted to rivers and found along the Tabecheding, Ngerderar, Ngerdorch and Ngerikiil Rivers. *Rauvolfia insularis* were found in small scattered populations in Airai and Melekeok. Less common endemic plants recorded in southern Babeldaob included *Rauvolfia insularis*, *Diospyros ferrea* var. *palauensis*, *Cyrtandra palawensis*, *Manilkara udoido* and *Myrsine palauensis*. Seven of 18 endemic species were restricted to the limestone forests of Koror and Airai and included the palm, *Hydriastele palauensis*, the orchids *Cyclopeltis kingi* and *Malaxis calcarea*, the trees *Garcinia rumiyo* var. *calcicola*, *Maesa palauensis*, and *Melicope palawensis* and the vine, *Peperomia palauensis* C. DC. var. *palauensis*.

A 2008 survey of the native palm, two small stands of *Ponapea palauensis* were found in Koror and is considered critically endangered using the IUCN criteria (Figure 22). In the spring of 2010 one population of *Ponapea* was reassessed. Four mature trees were broken at the trunk and one of two trees with fruit was covered with a white insect that is currently being identified. One tree has immature fruit and the others were younger palms. A revisit to this critical habitat on June 13, 2010 showed no further damage, 4 mature trees were in fruit and flower and 4 young saplings were found. Although no damage was observed in June, propagation of this palm is urgent. The endangered *Cycas micronesica* is found on limestone islands of Airai and Koror and is now threatened by a cycad scale that has infected an introduced ornamental cycad. To date no scales have infected the native species of cycad. Malakal Island is site where *Timonius salsedoi* was found and it is only known from a type specimen (Costion et al. 2009). Malakal Island is heavily developed and a priority area to stabilize steep slopes from landslides (Figures 11 and 22).

Figure 22 Map showing locations of critically endangered *Ponapea palauensis* in close proximity to urban areas of Koror State The map shows landslide areas marked with red dots.

Propagation of endemic plant species, especially critically endangered, endangered, and threatened species is needed to ensure these species are not lost forever. Landscaping with these species rather than introduced species needs to be promoted by the Forestry Office throughout Palau. One of the largest endemic trees in Palau is *Serianthes kanehirae* Fosb.var. *kanehirae,* which grows on volcanic and limestone islands. *Serianthes kanehirae* Fosb. var. *kanehirae* is currently being propagated and used to landscape degraded areas in Melekeok. One sapling was planted at the Belau National Museum Botanical Garden and flowered within 2 years. One known healthy population of *Parkia parvifoliola* (kmekumer) is found near the Ngaremlengui waterfall (Figure 23). One *Parkia* tree was found in Ngiwal. The Nekken Nursery successfully propagated 2 saplings of *Parkia parvifoliola* and provided one to the Belau National Museum Botanical Garden. An IUCN Red list assessment is planned for 2010-2011 that will focus on rare endemic tree species such as *Parkia parvifoliola* and *Timonius salsedoi*.

The BNMBG is currently propagating and planting the endangered palms *Ponapea palauensis* and *Hydriastele palauensis,* the native cycad, *Cycas micronesica* and the endemic trees *Terminalia crassipes, Manilkara udoido, Rauvolfia insularis* and other species of endemic trees and orchids. The BNM botanical garden is working in partnership with the Nekken nursery to propagate and provide seedlings of endemic trees of Palau. The BNM herbarium is coordinating with the National Tropical Garden in Kauai and the New York Botanical gardens and Australia National University to better understand Palau's unique terrestrial ecosystem and document the important uses of plants in our culture.

Koror State is developing a World Heritage nomination for its Southern Lagoon including the Rock Islands as a unique natural and cultural site to be submitted to the UNESCO in 2010. Airai State submitted its application for a Stone Money Quarry Site of one of its Rock Islands as a trans-boundary site with linked with Yap as a cultural site. If accepted, these sites will require more monitoring and protection and effective management to deal with increased number of visitors specifically coming to see World Heritage Sites.

In 2007, Palau conducted a Pacific Asia Biodiversity Transect (PABITRA) training in collaboration with the Palau Natural Resources Council. PABITRA plots are planned for priority watersheds as part of the long term strategy to monitor forest health as biodiversity is an indicator of health. The Council and Belau National Museum are planning to set PABITRA plots within high priority areas as part of the long term strategy to network across the pacific to study terrestrial biodiversity.

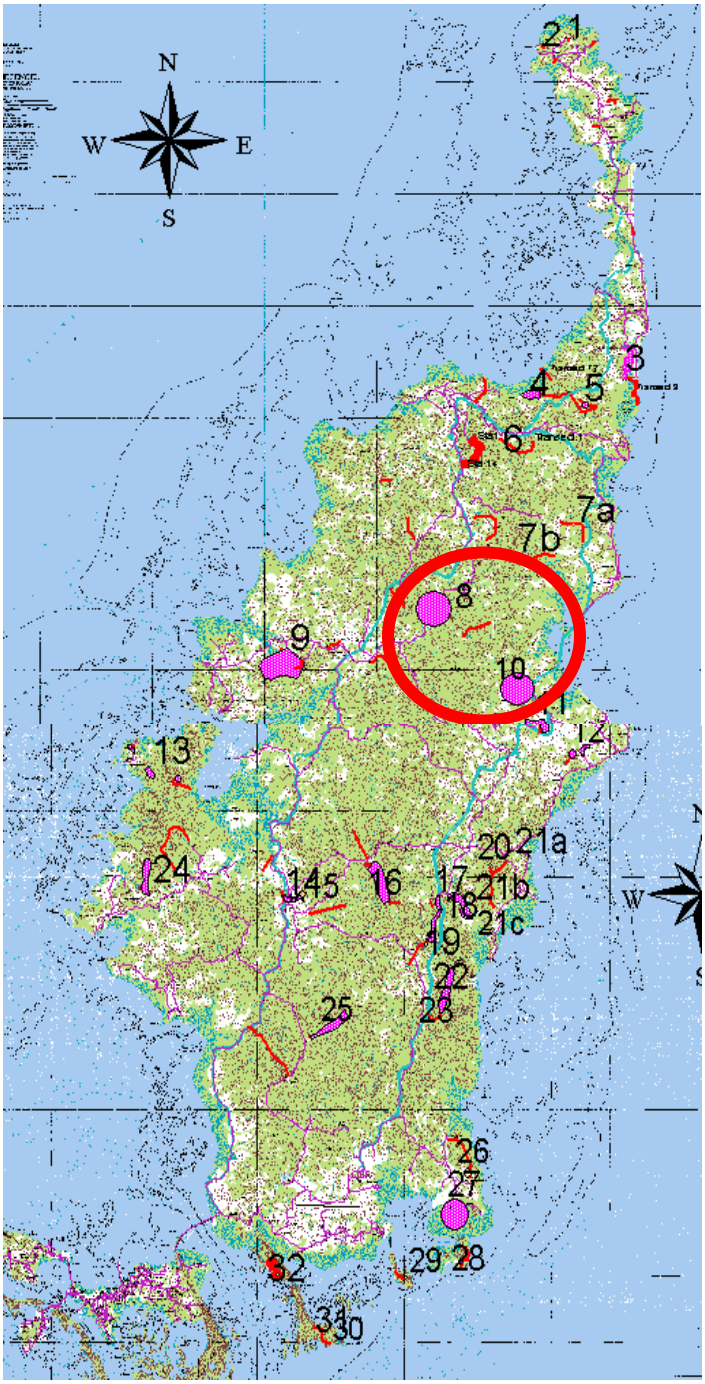

Figure 23 Map of important forest areas in Babeldaob (Costion and Kitalong 2007) shown in lavender. Circled in red are two important areas: the endangered *Parkia parvifoliola* is within the Ngermeskang Watershed near its largest waterfall (8) and the Lake Ngardok Reserve (10) had high biodiversity. These are priority landscapes for conservation and protection in Babeldaob.

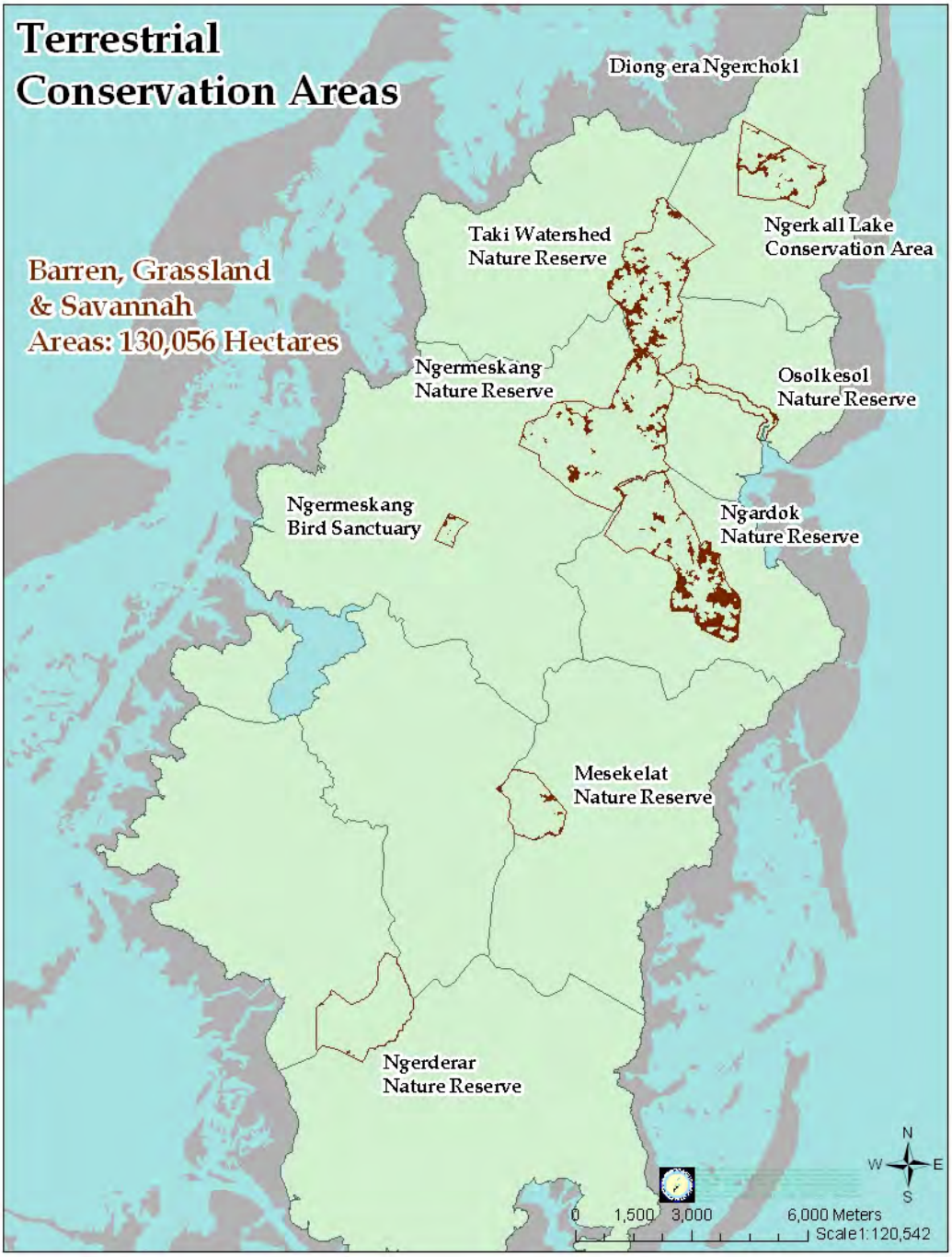

Figure 24 Protected terrestrial areas in Babeldaob. Source: PALARIS

The Ngardok Nature reserve covers 1,250 acres and is the first wetland of International importance to be designated in Palau and Palau's first RAMSAR site (Figures 16 and 24). Palau became party to the Ramsar Convention on Wetlands in 2003. This reserve was designated by Melekeok State in 1997 and is the largest natural freshwater lake in Micronesia. The Ramsar Convention provided technical and financial support to manage this wetland. The lake is part of the headwaters of Ngerdorch River Watershed and the water source for Melekeok State. An interpretative trail, eco-tours and educational tours have been developed with support from the Urban and Community Forestry program.

The Ngerdorch Watershed and Lake Ngardok and floodplains of the Ngermeskang Watershed and River are important habitats for the water birds including the rare gray duck that uses the native forests to nest and seek shelter. The standard variable circular plot method is not effective in detecting water birds and more secretive very low calling ground doves and the non-vocal Nicobar pigeon. Life history, habitat use and breeding biology are needed for these endangered species.

The Division of Fish and Wildlife Protection is tasked with the enforcement of laws relating to the protection of identified plants and animals including those listed in the Endangered Species Act. Several of Palau's birds are considered either threatened or endangered. Species are considered threatened due to small population size, or small, restricted or fragmented habitats or due to past, current or even perceived future population or habitat decline. A Preliminary 1997 Wildlife Management Plan and recent bird surveys (Gupta 2006) list 10 bird species that are either endangered, threatened or of national concern. (Table 30). Eight areas in Palau were proposed for Important Bird Area Status (Table 31). The Rock Islands and Helen Atoll are fully protected. Ngerutechei in Ngaremlengui is now a Bird Sanctuary. During a one year survey of species richness of birds in an Important Bird Area of Ngaremlengui, 38 species of birds including 30 resident and 8 migratory species. The white breasted woodswallow was sighted on 16 of 26 occasions (Olsen and Eberdong, 2009).

Table 30 Bird species that are listed at either endangered, near threatened or proposed candidates for national concern (Gupta 2006)

Species	Status
Micronesian megapode *Megapodius laperouse*	IUCN Endangered Species, US Endangered Species
Palau ground dove, *Gallicolumba canifrones*	IUCN Near Threatened, US Delisted Monitored
Nicobar pigeon, *Caloenas nicobarica*	IUCN Near Threatened, Proposed candidate for National Concern
Greater white eye, *Megazosterops palauensis*	IUCN Near Threatened
Palau Fantail, *Rhipidura lepida*	US Delisted Monitored. Proposed Candidate for National Concern
Blue faced parrotfinch *Erythrurua trichoroa*	Proposed Candidate for National Concern
Palau owl, *Otus podargina*,	Proposed Candidate for National Concern, US Delisted Monitored
white breasted woodswallow *Artamus leucorhynchus*,	Proposed Candidate for National Concern
Gray duck, *Anas supercilliosa*	Proposed Candidate for National Concern
Common moorhen, *Gallinula chloropus*	Proposed Candidate for National Concern

Table 31 Site, area and birds found in Important Bird Areas (IBAs) of Palau (Gupta 2006)

Site	Area	Bird
Ngeriungs Island	Kayangel	Micronesian megapode
Middle Ridge	Babeldaob	
Western Ridge	Babeldaob	Palau Ground Dove,
Ngerutechei (part of Middle Ridge)	Ngaremlengui	Palau Ground Dove White Breasted Woodswallow
Rock Islands	Koror	Micronesian megapode Palau Ground Dove
Peleliu Island	Peleliu	Palau Ground Dove, Blue faced parrotfinch
Fanna Island	Sonsorol	Sea bird colonies
Helen Atoll	Hatohobei	Sea bird colonies

The Division is responsible to enforce the provisions of Title 24 and 27 of the Palau National Code related to protected sea and land life, illegal methods of capture and to enforce laws related to protected areas in Palau. The DFWP created the Environmentally Friendly Restaurant Program in late 2005 to promote conservation and reduce violations of the laws. The DFWP began a database to track locations of endangered species and works with Bureau of Agriculture to control invasive monkeys with the Palau Animal Welfare Society with technical support from BOA. A qualified wildlife biologist is needed to work at the Division of Fish and Wildlife and collaborate with BOA and Belau National Museum to assess population of endangered populations and their habitats and in the development of management plans. Biologists at the Belau National Museum are working in cooperation with BOA and DFWP. Gavenda et al. 2005 recommended the development of a wildlife habitat management plan for the estuarine crocodiles within the Ngerikiil Watershed that included the re-establishment of a riparian forest buffer along the river to provide critical habitat to the animal and an education program. The Marine Conservation and Protected Areas Program developed a Management Plan for crocodiles and turtles that are in need of funding for implementation. These endangered marine species utilize coastal forests and mangroves for nesting and reproduction. The coastal forests prevent erosion of the sandy habitats as the roots hold the sandy soils. The vegetation also helps camouflage the nests from hunters.

The Belau National Museum Natural History Section has identified areas of high biodiversity for plants, birds and insects. A Bird Reserves has been established in Ngaremlengui because of its exceptional diversity. These areas may be potential for an Assessment of Need for the Forest Legacy Program if under private ownership. There are chronic problems with hunters within the reserve and more enforcement and education is needed. An executive order was just passed in 2010 that designates the Belau National Museum as the center for national monitoring of birds.

Wiles (1991) recommended ecological reserves, bag limits, closed seasons, and restrictions on hunting methods of the fruit bat P. mariannus pelewensis. There is still very little specific information about the breeding phenology and movement of fruit bats in Palau, where they feed and what specific niche they inhabit in forest ecology.

The Marine Conservation and protected Areas Program (MCAP) is working with the Protected Areas Network to identify the most crucial habitat for crocodiles, ideal areas for the relocation of nuisance crocodiles, and to develop regulations regarding public interactions with crocodiles. From 2005 to 2008 a total of 87 surveys were conducted and a total of 178 crocodiles were observed. Crocodile habitat includes the wetlands and swamp forests of the Ngerikiil, Ngerdorch and Ngermeskang Watershed (Nash et al. 2008).

The green turtle (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) nest regularly in Palau. These endangered species have cultural and economic significance. The critically endangered hawksbill turtle nests mainly in the southern lagoon of Koror (Figure 25). The endangered green turtle nests mainly in the Southwest islands (Kitalong, 2005). Coastal erosion threatens the nesting habitat of both turtle species. The hawksbill is especially vulnerable as it uses the roots of native coastal trees and vegetation to hide its nests. Goals for future research and management include the following:

- Identify threats across all critical life stage habitats and to eggs, hatchlings, sub-adults and adults – including from people and climate change
- Understand movements through life stages and during the inter-nesting period
- International collaboration and the opportunity to develop a regional strategy through the Micronesia Challenge.

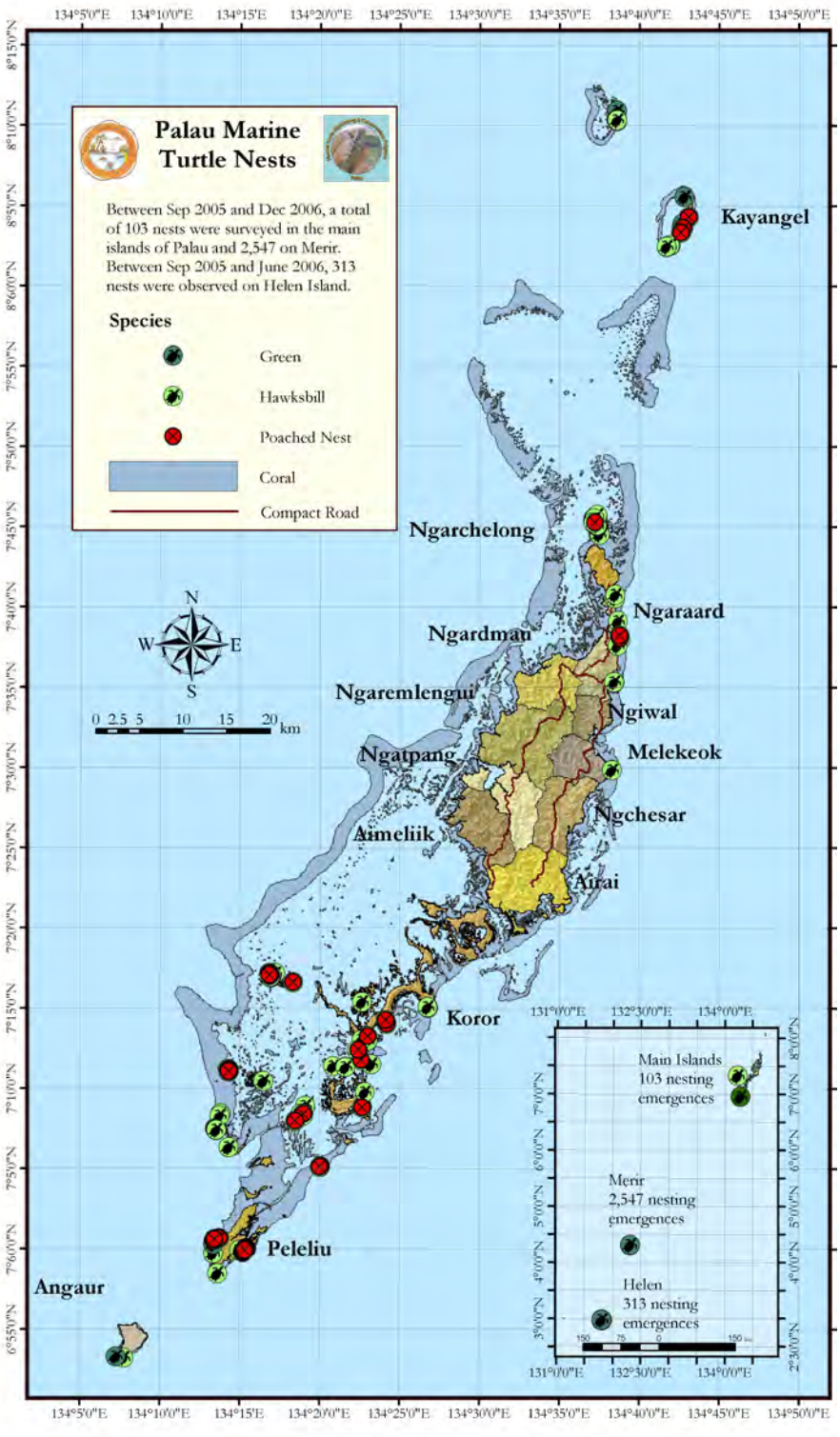

Figure 25 Map of observed turtle nests, 2003-2005.
Source: Bureau of Marine Resources

Figure 26 National highway along east coast of Airai State with *Merremia peltata* vines

Invasive plants are one of the greatest threats to forests, agriculture and natural ecosystems worldwide. It was considered one of the top threats during a meeting of environmental and conservation professionals in Palau during 2008 and during stakeholder meetings for SWARS. Palau Forestry Health Program has developed a 2009-2014 Strategic plan based upon a survey and assessment invasive species. Over the next five years, the Invasive species team plans to control the spread of the worst invasive species in Palau including *Praxelis clematidea*, *Mikania micrantha*, *Imperata cylindrica*, and *Spathodea campanulata*. The Invasive species team plans to assess and control the spread of *Antigonon leptopus*, *Melia azedarach*, *Arundo donax*, *Melaleuca quinquenervia* and *Calamus* species and the Rattan Palm. In the next five years the Bureau will conduct a feasibility assessment for the control of two large invasive trees in the family Fabaceae: *Adenanthera pavonina* and *Falcataria moluccana* originally planted for agricultural purposes (Mayo 1954). These successful invasive trees are members of the Fabaceae family and grow in poor soils because the roots can fix nitrogen. (The Fabaceae Family is the second largest family of plants found in Palau and includes 111 species of which 91 are introduced including 24 invasive species.) *Adenanthera pavonina* was common in Ngarchelong and found in Uruktabel Island, Koror, Melekeok and Ngatpang. *Falcataria moluccana* was common in Ngaremlengui (Figure 14b) where it was planted by Japanese farmers as a shade tree for cacao plantations (Kitalong & Holm 2004, Costion & Kitalong 2006).

Endress (2002) found that *F. moluccana* dominated early successional forest stands in Ngaremlengui, but was not dominate in mid-successional forests and was not found in mature forests. It is important to map, monitor this large tree at other study sites to determine if it has become dominant in mature forests in other parts of Babeldaob or if it is excluded by native trees. Biological and chemical controls can be used if needed as has been done successfully in Samoa. The Bureau will continue its ongoing program to control the native vine, *Merremia peltata* that grows rapidly in disturbed or open areas overgrowing and killing trees within 100 m of the national highway (Figure 26). Community clean-ups have been ongoing o control its widespread distribution. The Bureau plans to assess, map and seek biocontrols for the widespread *Clidemia hirta* in site of Aimeliik with a focus on Nekken Station.

Casaurina equisetifolia is among the most successful colonizers of denuded areas, new surfaces and fresh sand flats. This species has nitrogen-fixing bacterial root nodules and produces carpets of “needles” that exclude other plants. This tree occurs on volcanic and limestone substrate at high and low elevations and on all types of slopes in the Northern Marianas (Mueller-Dombois and Fosberg 1998). *Casaurina* forests covered 451 hectares or 20% of the coral islands of Palau in 1987. Angaur and Peleliu had large stands of this tree as well as the Ngemelis Complex and many rock islands. This successful native pioneer species is commonly found along shore areas that were either settlements in the past or are currently used as temporary shelters. Long term monitoring is needed to determine if this tree may be out-competing other native rock island trees on some rock islands.

Invasive plants are one of the greatest threats to forests, agriculture, and natural ecosystems worldwide. Islands and island countries are especially at risk, and Palau is no exception. Palau has been fortunate in that, while numerous invasive plants have established themselves in the country, most natural ecosystems are still intact. However, the introductions of serious invasive plants such as Mile-a-minute (*Mikania*

micrantha), Cogon Grass (*Imperata cylindrica*), and *Chromolaena odorata* have increased the threat to forests and grasslands. The potential spread of longer-term introductions such as African tulip tree (*Spathodea campanulata*), *Falcataria moluccana* and *Adenanthera* (*Adenanthera pavonina*), and numerous invasive plants used for landscaping, makes it urgent to educate and take preventive action now. An assessment of *Acacia* plantations will be conducted through the Forest Stewardship and Forest Health programs to determine if this species is expanding its range and requires further monitoring and control. The highest frequency of invasive species has been found in Koror (Figure 27). A study of *Falcataria moluccana* was initiated in 2010.

The Forest Health program has had strong community support in Peleliu to control *Mikania micrantha* with support from the National Invasive Species Task Force. *Mikania* is a threat to native trees as it covers and kills trees if not controlled. There is an ongoing program to control the monkey populations throughout Palau through the Palau Animal Welfare Society with technical support from the Invasive Species Program that the Forest Health Program. These programs contribute towards forest health as the monkey is a threat to the agroforests throughout Palau. The forest health program is currently working on a *Falcataria* health assessment in Palau.

The greater sulphur-crested cockatoo, *Cacatua galerita* was introduced to Palau in the 1940's and has established populations in the limestone islands (Engbring 1988). Cockatoos were rare in the Ngerukuid Preserve as only 2 pairs were reported during the 1988 survey. Cockatoos feed on the hearts of endemic palm, *Hydriastele palauensis* and are responsible for killing large stands of these trees. An estimated 5% of the trees surveyed in the Preserve were *H. palauensis* at risk, and the effects of cockatoos on this palm should be reassessed. It was recommended that seeds of this palm be collected for propagation (Birkeland and Manner 1989). The cockatoo has expanded into Babeldaob and its impact on native trees in Babeldaob also needs to be assessed.

Palau has an active invasive plant control program within its Forest Health Program of the Forestry Section of the Bureau of Agriculture, which operates with the support of the National Invasive Species Committee, the Invasive Weeds Committee of the Palau Natural Resource Council, and several partner agencies and organizations. Key species have been targeted for eradication and/or control, and information has been provided to assist Quarantine officers in preventing new introductions. Despite their successes, however, there was an ongoing need for a clear focus, and a strategic plan of action. To meet this need, the Invasive Weeds Committee requested assistance from the United States Forest Service (USFS) Forest Health Program in 2004 to develop a. 5-year strategic plan for invasive weeds. In 2009, the Invasive Plant Program decided to update the plan. This plan was updated by the Invasive Plants Program in the Forestry Section of the Bureau of Agriculture, in cooperation with the Invasive Weeds Committee of the Palau Natural Resource Council, and with the assistance of the US Forest Service. The plan will organize Palau's efforts to combat and prevent plant invasions. It lays out clear goals, objectives, and actions to address key issues related to invasive weeds. All of these will require cooperation and support by the general public; community outreach is therefore a crucial part of this plan. The Forest Health Program under the Forestry Section of the Bureau of Agriculture, within the Ministry of Natural Resources, Environment and Tourism, is the lead implementing agency for this plan, but cooperation and support of other agencies and organizations, and the general public, is essential for successful implementation. Priority areas provided by stakeholders and managers are shown in Table 32. There may be a potential opportunity for an assessment of need for an easement under the Forest Legacy Program.

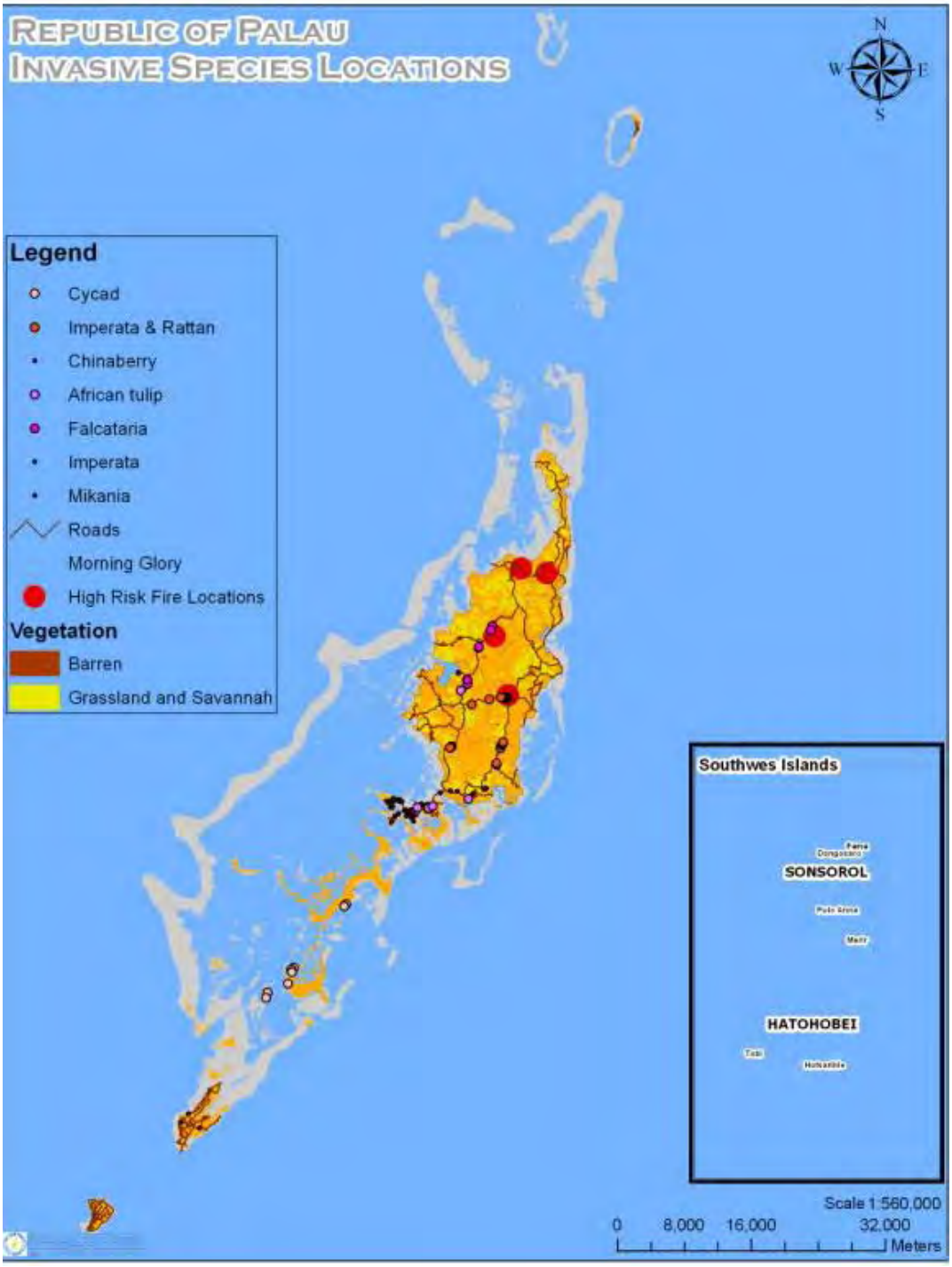

Figure 27 Locations of some invasive species in the Republic of Palau Cycad refers to introduced cycads infested with the cycad scale. Source: PALARIS

Table 32 Priority Conservation Areas ranked during stakeholder meetings and discussions

Rank	Conservation Area
1	Rock island of Ngermid where 2 small populations of critically endangered *Ponapea palauensis* palm tree. Malakal Island where *Timonius salsedoi* is found.
2	Ngaremlengui Reserve and Ngermeskang River System highly diverse flora and bird populations with the only known healthy stand of *Parkia parvifoliola* trees and Bird Reserve
3	Ngerdorch Reserve and River system largest lake of Micronesia and highly diverse in species
4	Ngeremeduu Watershed -Tabecheding River- population of *Terminalia crassipes*
5	Upper Ngerikiil Watershed -population of *Terminalia crassipes* and rare ground dove

Spatial Analysis

A geospatial model was developed to determine the highest priority areas in which Forestry efforts should be directed to protect or enhance potential and existing conservation area. Eleven data layers were used in the model analysis (Table 33) with each layer was weighted by its perceived importance to this issue. The Criteria used for the GIS Analysis is shown in Table 34. The areas highlighted on the map (Figure 27) are areas to reforest within conservation areas in Babeldaob with slopes less than 12%. Private lands within these areas are prime sites for an assessment of need for easements under the Forest Legacy Program.

Table 33 Ranked Layers for Issue 5 Conservation and Protected Areas

Layer Rank	Layer Name	Layer Weight	Available data Layers and weights
1	Protected Areas	16.7	
2	Population	5.0	
3	Contour	5.0	
4	Soil	10.0	
5	Rivers	8.3	Used
6	Forest	16.7	Used
7	Infrastructure	6.7	Used
8	Watershed	13.3	not used
9	Invasive species	5.0	Some- n/a
19	Fire	5.0	n/a

Table 34 Criteria used for the GIS Analysis for the Issue 5 Conservation and Protected Areas

Factor	Conditions	Suitability for Conservation
Protected Areas	*Ponapea* palm habitat of Koror, *Parkia* habitat of	10
	Ngeremeduu, Ngardok Lake Reserve	10
	Tabecheding River & Ngerikiil Upper watershed	5
Watershed Zone	Upper watershed	10
	Lower watershed	5
Population	More than 7-10 buildings/0.5ha	10
	More than 3-7 buildings/0.5ha	5
	More than 0-3 buildings/0.5ha	1
Shoreline	0-1m above sea level	10
	1-5m above sea level	5
	5-10m above sea level	1
Soil	Highly erodible soil types	10
	Less erodible soil types	1
Rivers	Within 100m	10
	More than 100m	1
Forest	Primary Forests	10
	Secondary Forests and Agroforests	5
	Savanna & Bare Areas	1
Infrastructure	0-5 buildings/0.5 ha	10
Directly related	5-10 buildings/0.5ha	5
To population	10 and more buildings/0.5ha	1
Invasive species	No invasive species present	10
	1-5 invasive species	5
	5-10 invasive species	1
Fire	High Fire Risk	10
	Low Fire Risk	1

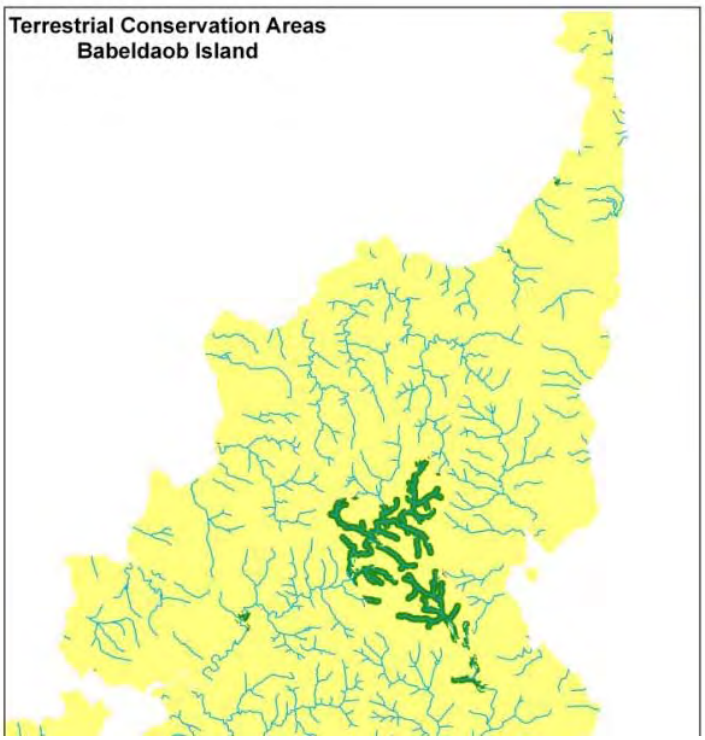

Figure 28 Dark green areas indicate priority areas for reforestation activities for protected areas in Ngaremlengui, Ngerdorch & Ngiwal

Results

Results from the overlay analysis indicate priority areas to establish buffers along streams within conservation sites and potential for tree planting within the protected areas of Babeldaob indicate that there is 130, 056 ha of either barren or savanna areas. Priority buffer areas along streams where it is either barren or savanna are shown in Figure 28 for Ngaremlengui, Ngerdorch and Ngiwal reserves where there are slopes less than 12%. A more complete analysis of other protected areas is in progress. All of the barren savanna vulnerable to fires within protected areas. Other protected areas where the is no compatible spatial data available are the Southern Lagoon of Koror State and its Rock Islands and the island of Fanna in the Southwest Islands. Important bird areas have been identified in all of Palau as well as critical coastal forests for nesting hawksbill turtles. The forest habitats of these endangered animals need protection. States that have laws to protect these habitats need to assess and monitor regularly. The critically endangered *Ponapea* is vulnerable because one of only two small stands is located on a limestone island that is linked by a causeway and already developed area. The invasive tree *Falcataria moluccana* is within the Ngaremlengui Reserve and a risk assessment is needed. If any of these critical habitats are on private land, the habitats may be candidate for an assessment of need for easements under the Forest Legacy Program.

Conclusion

The geospatial analysis of Babeldaob of available data identified 3 primary areas where efforts need to be focused for forest conservation and protection: Ngaremlengui, Ngerdorch and Ngiwal Watersheds (Figure 26). The threatened *Parkia parvifoliola* within Ngaremlengui watershed is captured in this spatial analysis. Data gaps for other important areas including The Rock Islands of Koror and Airai State are not included in this spatial analysis. The critically endangered *Ponapea* found in Koror requires assessment and monitoring at least each year and propagation trials are underway at the BNM and BOA. The *Hydriastele* palms within the Ngerukuid National Preserve is threatened by Sulphur crested cockatoo

(Kitalong, 2008). Forest habitats of critically endangered, endangered and threatened species of birds and nesting turtles also require protection.

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Table 35 Strategy matrix for Issue 5 Conservation and Protected Areas

Long Term Strategy	Priority Landscape Areas	2^0 Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/ Required to Implement	Measure of Success	Supports National Objectives
Protect the integrity of our ecosystem Over 5 years, control & if possible eradicate Palau's top priority invasive plants and build capacity on management of priority landscapes	*Ponapea* populations of Koror *Cycas micronesica* populations in Koror & Airai	Climate Change (CC) Population Growth & Urbanization (PG) Water Quality & Quantity (WQ) Sustainability of Forest Resources (SF) Urban Forest Sustainability (UF)	Urban & Community Forestry (UCF) Forest Health (FH) Forest Stewardship (FS) Conservation and Education (CE) Forest Legacy (FL) Cooperative Fire (CF)	Communities of Koror	Technical assistance & personnel from: BOA, BNM TEI, DFW BWA, TNC, PCS, PAN, OERC, NRCS, UOG Vehicles /funds for: boat rental, fuel, equipment supplies, multi-spectral imagery, wildlife and terrestrial ecologist	Assess health of *Ponapea* palm annually Set permanent plots for long term monitoring by 2011 Control damage to *Ponapea* by 2010 Completed report on Report on health of *Cycas micronesica* each ye One terrestrial & one Wildlife ecologist is hired by 2012. Two staff certified to set and monitor forest plots by 2011.	Conserve 1.1 1.2, Protect 2.2 Enhance 3.4, 3.5 3.6 3.7
	Rock Islands with *Hydriastele* palms			Communities of Airai & Koror		Report of assessment of health of *Hydriastele* palm & extent of damage from Sulfu Crested Cockatoo by 2015	
	Reserves & Protected Areas			Communities of Palau		Report on IUCN red list assessment report for Palau's rare & threatened endemics including *Parkia* & *Timonius* to meet the CBD target by 2012	
	Ngaremlengui & Ngardok Preserve			Communities of Ngaremlengui & Melekeok		Report on status of *Parkia parvifoliola* stand by 2012. Annual Report on survey of threatened & endangered plants Certify 2 staff & 2 community members to survey. Acres surveyed of top invasive species. *Praxelis* controlled by 2011	
	Ngaremlengui & Ngardok Preserve Ngarchelong Rock Islands					Number of acres surveyed & mapped one educational poster and 1 booklet for *Adenanthera pavonina* by 2011; one pilot contro project by 2012	

Long Term Strategy Issue 5 Conservation Continued	Priority Landscape Areas	2^0 Issues Addressed	Program Areas that Contri-bute	Key Stake-holders	Resources Available/ Required to Implement	Measure of Success	Supports National Objectives
Protect the integrity of our ecosystem Over 5 years, control & if possible eradicate Palau's top priority invasive plants Build Capacity for Conservation Management	Nekken Forestry Station Ngaremlengui & Ngardok Preserve	Climate Change (CC) Popula-tion Growth & Urban-ization (PG) Water Quality & Quantity (WQ) Sustain-ability of Forest Resources (SF) Urban Forest Sustain-ability (UF)	Urban & Communi Forestry (UCF) Forest Health (FH) Forest Steward-Ship (FS) Conser-vation & Education (CE) Forest Legacy (FL) Cooperati Fire (CF)	Community in priority areas	Technical assistance & personnel From BOA, PALARIS BNM, TNC PCS, BWA Personnel, vehicles /Funds for boat rental, fuel, equipment supplies, geospatial databases terrestrial ecologist	Assess, map & develop educational material and seek biocontrols agents for top invasive plants by 2012 Monitoring plots for the control of *Falcataria moluccana* by 2010. Permanent monitoring plots with control plots annually Report on assessment of need for easements of critical ecosystem on Private land. Hire a terrestrial ecologist for BOA	Conserve 1.1 1.2, Protect 2.2 Enhance 3.4, 3.5 3.6 3.7
	Nekken Station					Assess, map & develop educational material & set up pilot control site and seek biological contr for *Clidemia* by 2012. Monitor & set up more control sites annually	
	Nekken Ngaremlengui &Ngardok Preserves Ngarchelong Airai					Assess, map & control of spread of *Merremia peltata* Monitor & set up more control sites annually 2 staff trained in Geospatial analysis	
	Nekken Ngaremlengui & Ngardok Preserve Ngarchelong Airai of large Infestations					Assess, map & control the spread of *Mikania macrantha, Antigonon leptopus*; *Melia azedarach*; *Arundo donax*annually	
	Ngerderar River Aimeliik			Aimeliik Community		Assess and control Rattan (*Calamus*) species) by 2015	
	Nekken			BOA		Develop a standard method to report, survey & monitor by 2011	

Issue 6 Sustainable Use of Forests Resources

Forests have provided Palauans with trees for food, homes, canoes, bamboo rafts, tools, utensils, medicine, compost and a unique aesthetic landscape for centuries. The Republic of Palau has mandated the Bureau of Agriculture through the Nekken Agriculture Station in Aimeliik to ensure that Palau's forests are sustained for each generation (Figure 29 and Table 36). The Nekken station was opened in 1938 under the Japanese Administration covering an area of 15 ha. The facilities were destroyed during World War II. Over time Aimeliik has reclaimed a majority of the land for conservation and crop and livestock production. Today the Station covers an areas of 262.5 ha that consists of conservation areas, forestry demonstration areas, a tree nursery and several large stands of mahogany and smaller stands of fruit trees. The main objectives of the Nekken Station are to 1) operate as a focal demonstration center for sustainable agroforestry and forestry and includes a tree nursery, native species propagation area, tree farm models, agroforestry model, composting and traditional agriculture; 2) provide a location to support increased food security and sustainable livelihoods; 3) function as a training center and 4) produce and distribute planting materials.

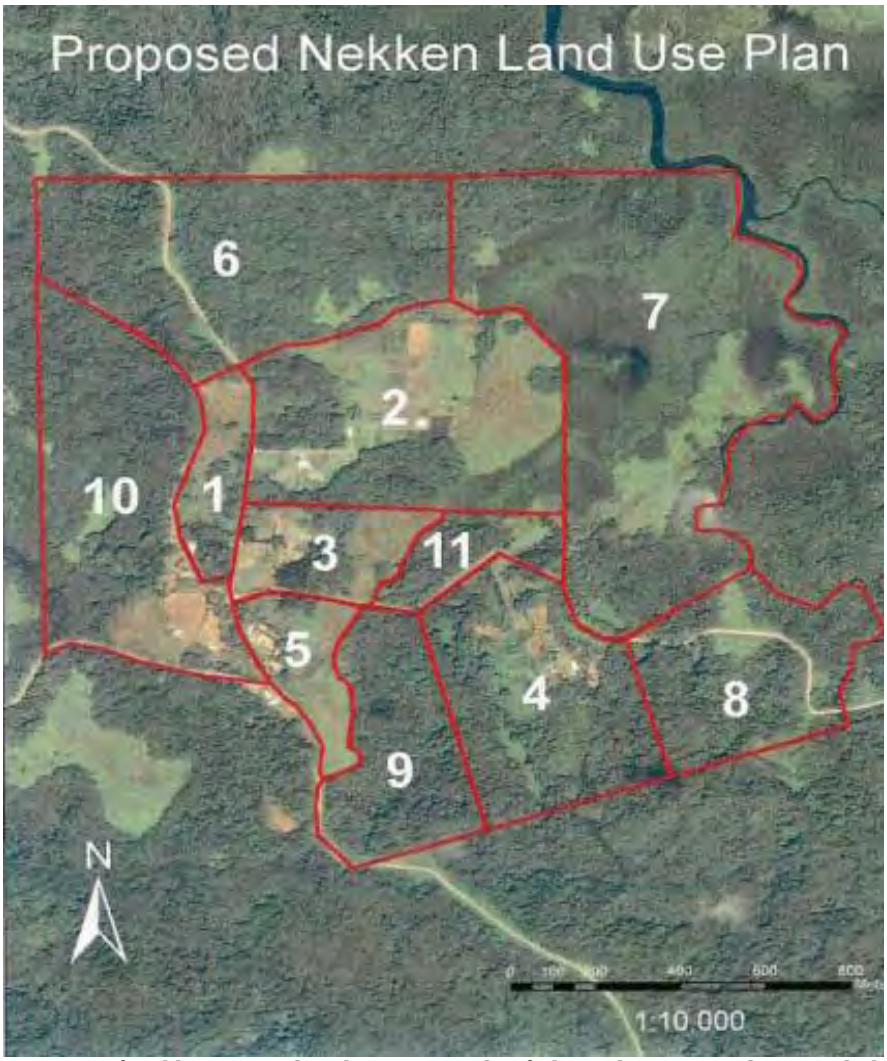

Figure 29 Map of Nekken Agricultural Station, Code of plots, plot name and area and plot use.
Source: Nekken Agriculture Station Plan 2005.

Table 36 Plot number, name, area and use at Nekken Agricultural Station (Refer to Figure 27)
Source: Nekken Agriculture Station Plan 2005

Area No.	Land Use	Area (m^2)	Specific use
1	Plant experiment & multiplication plot, poultry hatchery unit, dorms, offices and facilities	67,011	➢ Trial plot for new varieties of root crops & vegetables ➢ Plot for reproducing plant materials for distribution ➢ Poultry hatchery facility
2	Taiwan Technical Mission Demonstration Plot	347, 756	TTM demonstration farm for training and trails
3	Sublek Farm	95, 715	Formerly occupied by the Ministry of Justice
4	OISCA Farm	256, 608	OISCA Training Center for students
5	Fruit tree production plot & TTM Facilities	75,536	➢ Plot for fruit tree experiments & production ➢ Facilities for TTM to produce and market food products
6	Small ruminant experiment and production plot	386,498	➢ Watershed protection ➢ Ecotourism ➢ Buffer zone demonstration
7	Water buffalo grazing plot	632,598	Planned for water buffalo production
8	Native Forest Protection	200,068	➢ Watershed protection ➢ Ecotourism, ➢ Buffer zone demonstration
9	Native Forest Protection	169, 197	➢ Watershed protection ➢ Ecotourism ➢ Buffer zone demonstration
10	Native Forest and Watershed Protection	329,297	➢ Watershed protection ➢ Ecotourism, ➢ Buffer zone demonstration
11	Fruit trees and forest plot	64,861	Demonstration timber & fruit plots for sustainable harvest
Total Area = 2, 625, 145 square meters			

Palau has been administered by foreign administrations that introduced dozens of plants to Palau for timber, food and medicine. Plantations of coconut trees, pineapple and cocoa occurred throughout Babeldaob. Mayo (1954) surveyed the Japanese Agricultural Station in Koror and commercial planting sites and relocated and recorded over 88 species of trees and plants of the originally recorded 157 planted. During 1922, the South Seas Industrial Experiment Station began the introduction and propagation of economic and subsistence plants. Pineapple production peaked in Ngaremlengui during 1939 when 473 hectares were cultivated by 468 Japanese families. The second most important crop was cassava (*Manihot esculenta*). In 1938, 113 tons of cassava was produced on 8 hectares of land. In 1936, cacao production began on 500 hectares of leased land in Ibobang, Ngatpang that resulted in a decade of profit.

The shade tree, *Falcataria moluccana* was planted with cacao and Mayo reported that it was doing well in 1954. *Adenanthera pavonina* was planted in 1924. Several of the dominant trees planted during this time period included *Calophyllum inophyllum*, *Cananga odorata*, *Casuarina equisetifolia*, *Ceiba pentandra*, *Cocos nucifera*, *Coffea arabica*, *Diospyros blancoi*, *Ficus elastica*, *Garcinia mangostana*, *Hibiscus tiliaceus*, *Intsia bijuga*, *Mangifera indica*, *Metroxylon sagu*, *Pterocarpus indicus*, *Swietenia macrophylla*, and *Terminalia catappa*. *Swietenia macrophylla* grew well during this time period and became

the preferred tree for reforestation in 1954 and is still planted today. Cole et al. (1987) identified two separate vegetation types for *Casuarina* Forest. Earlier efforts to reforest with *Casuarina* are still evident today. Casuarina forests are prevalent in Peleliu (404 ha), Angaur (47ha) some of the Rock islands. *Casuarina* is good for firewood and there is concern that this may be an invasive species (Kitalong, 2008). There may be a potential sustainable firewood industry for *Casuarina*.

Coconut

Cole et al. (1987) identified a separate and larger vegetation type for Coconut Plantations that covered 100ha. Efforts to reforest with *Cocos* continue today. *Cocos nucifera* has been in Palau since thousands of years before the present and considered a native tree in Palau. Coconut plantations were developed in Palau during the German administration from 1899 to 1914. Copra was the top industry in Palau until the 1970's when the tuna fishery was top industry and recent years the tourism industry has taken top ranking economically. Agro-tourism is being initiated in recent years. The coconut is marketed globally by the tourism industry as a symbol of an idyllic paradise. The taste of coconut is found in many tropical foods served to visitors in Palau. Coconut is a keystone species for Palau with over 40 documented uses. Parts of this tree can be used as food, shelter, clothing, medicine and art – all aspects of traditional culture (Kitalong et al.2009). It is recommended that coconut plantations be assessed to determine the health of the trees and the potential for replanting a mixture of agroforest trees at these locations.

The percent of the total areas (in acres) of each State covered with coconuts shows that the northeast coasts of Ngarchelong and Ngaraard have the highest percent of coconut (Figures 30 and 31 and Table 37). The southwest islands consist of 375.3 ha of land area at mean high tide of which 64.5 ha or 17% of the land is coconut t forest and 42.5 ha or 11.3% of the land is coconut and mixed forest. A total of 28.3% of the land in the southwest islands is coconut or coconut and mixed forest habitat. At Hatohobei 30.4ha or 40.5% of the island is covered in coconut forest. At Merir Island 5.6 ha or 5.6% of the island is coconut forest. In Pulo Anna 35% of the island (13.3 ha) is coconut forest. In Sonsorol 11.5 ha or 9.5% is coconut forest and 42.5 ha or 35% is coconut and mixed forest. The island of Ngercherur is 13% (4.1ha) coconut forest. The island of Ngerekeklau is considered 100% coconut/mixed forest (6.2ha). The island of Ngcheangel is 72% coconut forest (72 ha), and the southern island of Ngedebus is 66% (59ha) coconut forest (Table 37).

The Institute for Sustainable Living (SIUL) has initiated the Tree of Life project in Palau. This project has one goal: to revitalize coconut oil production in Palau to reduce Palau's carbon footprint; avoid potential conversion of land to a higher impact use; and create employment and entrepreneurial opportunities in rural communities of Babeldaob by improving current coconut oil production and stimulating the demand for coconut oil and its by-products. The institute leased land from Polycarp International Enterprises in Ngchesar and built a micro-mill plant to demonstrate an appropriate technology for dispersed small-scale oil production in the villages of Palau; and is developing secondary industries. The mills started at low production. A fully operational mill can produce 10 gallons a day, 6 days a week, which will bring up the gallons per month at 240. The size of coconuts also determines production. Only 12 Large coconuts from Koror are needed compared to 14 nuts sourced from Babeldaob where the coconuts are very small. Many of the coconuts are spoiled and are averaged into the production requiring 16coconuts/gallon. The Japanese administration conducted the last study of coconut plantations using the Tochi-Daicho maps. At that time, Babeldaob sustained up to 95 coconut mills when it was at its peak production at 452,000 gallons/yr. If a very conservative 10% of those original 813 hectares are productive, Palau can potentially support 9 mills/yr if they reach full production (Patricia Leon pers. comm. 2010). Table 38 shows annual projections for coconut oil production. There is a need to conduct an assessment and survey of existing coconut plantations.

Table 37 State, location, total hectares and percent of total land area that is covered by either coconut plantations or coconut trees with mixed forest

State	Location	Total hectares of coconut (coconut /mixed forest)	Percent of total land area
Kayangel			**42.0**
	Ngcheangel Island	72	72
Ngarchelong		**146**	18.96
	Ngerekeklau Island	6.2	100
	Ngercherur Island	4.1	13
Ngaraard		**158**	5.12
Ngiwal		25.6	0.69
Melekeok		2.1	0.09
Ngchesar		2.95	0.07
Aimeliik		9.65	0.17
Airai		9.10	0.14
Peleliu			5.30
	Ngedebus Island	59	66
Sonsorol			11.4(11.7)
	Sonsorol Island	11.5 (42.5)	9.5 (35)
	Pulo Anna Island	13.3	35
	Fanna Island	3.7	9.3
	Merir Island	5.6	5.6
Hatohobei			**38.9**
	Hatohobei Island	30.4	40.5
		559.4 (42.5)	

Table 38 Coconut Oil Production projections for small coconut oil mill in Ngchesar

Months	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Gallons	64	64	80	80	96	96	120	120	120	120	136	160
Liters	**243**	**243**	**303**	**303**	**364**	**364**	**455**	**455**	**455**	**455**	**515**	**606**
No. of Coconuts	3396	3396	4245	4245	5094	5094	6367	6367	6367	6367	7216	8490
No. of Coconuts	3,849	3,849	4,812	4,812	5,774	5,774	7,218	7,218	7,218	7,218	8,180	9,624

Source: Institute for Sustainable Living (SIUL) 2010.

There are at least five known insect pest that threaten the health of *Cocos nucifera*: long horned grasshopper, *Segestes unicolor*, the coconut scale, *Aspidiotus destructor*, the coconut leaf beetle, *Brontispa palauensis*, the red coconut scale, *Furcaspis oceanica*, the coconut mealybug, *Nipaecoccus nipae* (maskell) and the coconut rhinoceros beetle, *Oryctes rhinoceros*. The rhinoceros beetle also feeds on betel nut palms. A virus disease of the rhinoceros beetle, called *Rhinoceros baculovirus* was imported from Samoa in 1983 and released in different locations in Palau. In 2003, the virus was applied to healthy beetles in Sonsorol (Esquerra and Del Rosario 2007). A collaboration effort between agriculture and forestry and the College of Research and Extension at Palau Community College and the communities is needed to assess the effectiveness of the virus and overall health of coconut plantations throughout Palau.

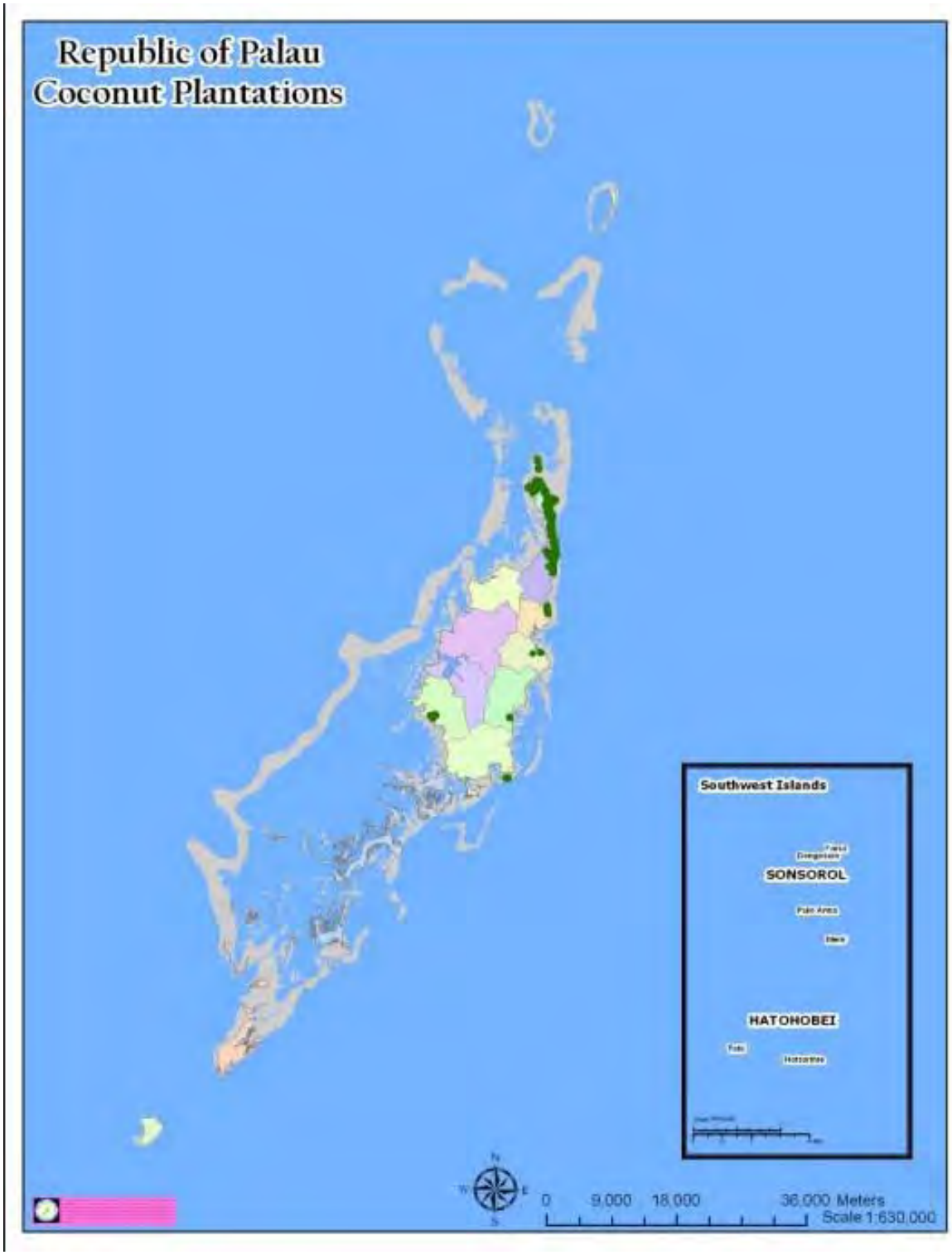

Figure 30 Coconut plantations in the Republic of Palau

Figure 31 Coconut plantations in Babeldaob

Mahogany

Several large mahogany plantations are located at the Nekken Station. Recently 161 *Swietenia macrophylla* were measured with a total basal area of 2.79 ft^2 and a total volume of 2, 763 ft^3 that were valued ranging from $132,896 to $265,768. These values are based upon a value of $4-$8/board feet. The raw data provided by Pua Michael, Acting Head Forester in 2010. Sustainable harvest of existing mahogany at Nekken could provide funding for the Forest Stewardship Program. Mahogany plantations have been established in over 100 locations (Figure 35). During the 1980's 40,000 to 60,000 tree saplings were propagated and distributed annually. During the 1990's 10,000 saplings of *Acacia* and mahogany were propagated and distributed annually. In the 2000's production has been the same with larger distributions (1,000-5,000 saplings) to private landowners in Airai, Aimeliik, Ngchesar, and Ngatpang. In 1994, there was a demand for mahogany tree that were 20-36" in diameter at a price of $100/tree in the construction of the Airai View Hotel. A 35-year old tree was selling for $100.00/tree. *Swietenia macrophylla* is fast growing and valuable timber with an average price of $1,300.00/$m^3$in the United States. Mahogany reaches commercial size in 30 to 120 years. It is heavily exploited with few natural populations in the wild. However establishing plantations should not jeopardize native forests (Costion 2004).

Currently Blue Moon Exotic Wood company processes and exports *Swietenia mahogani* or Cuban Mahogany and the native *Calophyllum inophyllum* (btaches) or Alexandria laurel. Their plantation is located in Ngchesar State and covers 100 acres with an additional 200 acres for expansion (http://www.bluemoonexoticwood.com). The company is processing logs in country.

"The forest resources are an unexplored economic asset for Palau. But it needs careful assessment to devise a lasting and sustainable management for timber resources on Palau. Are you working on this project for the National Government? I'm asking because the National Government does not own land in Palau. Each States owns about 80% of land in Palau and Individual Clans owns about 15% and Individual private land ownership is accounted for about 5%. I think you should take these facts as you proceed with your project. I think you should work closely with each states, clans and private land owners. They are the ones that would have the greatest interest in your project. They own the land therefore any strategy for forest management should include them along the way to clarify any legal difficulties that may arise. I will be open to partner with any States or Private Land Owners to promote and help market their timber products.

Tropical tree is a viable forest resource that can be managed and sustainable harvested for good income for States and private land owners. Local tree species are not readily marketable in the international timber market as they are not known yet. But can be introduce to international market in a later date when proper management program can be devised. Mahogany tree is a marketable timber product in the international market. There are two species of mahogany tree introduced in Palau. Swietenia mahagoni is more valuable than Swietenia macrophylla, the other introduced species. Mahogany pricing is based on "stump price" of $.40 per board foot. An average size of 20" diameter and 20 feet or more bole length of the tree would be worth about $200 and $300. Mahogany trees will be matured for harvest in 20 to 25 years."

We stopped the operation for couple years due to shipping problem not import problem. I shipped green lumber and after 9/11 shipping into port of Los Angeles took so long for inspection and I did not want the lumber in the hot container to be damaged. I resumed operation in 2007. I will harvest again to replenish the lumber stock as needed. I have been harvesting 10 trees at a time ever since we started sustainable harvesting operation. The key for successful small scale sustainable harvesting of tropical timber product is to stay away from the big multi-nation logging operation. Palau does not have enough timber products and besides big companies will pay almost to nothing to get timbers. ..

I am the contact person for our sustainable harvest operation. All my brothers in Palau are helping out during the harvesting and sawing process. I fly home when I need to replenish lumber supply. I control and manage sawing process to make sure we get the best lumber yield and grade in order to maximize highest price possible. I will be interested in cooperating with other land owners. But they need to practice sustainable harvest management program. They need to be willing to do a lot of tree planting to replace ones harvested and to expand their groves. I have import license to bring in to the US timber

products. That is the first and most important step in timber import business. Please keep me posted."`- Toribiong Basilius, Ngchesar State, January 2009.

Figure 32 *Swietenia macrophylla* 25-30 yr old Plantation Stand Nekken Station, Aimeliik State

Figure 33 *Garcinia mangostana* (mangosteen) orchard at Nekken Station, Aimeliik State.

Figure 34 Nekken Station nursery at Aimeliik State

A Draft Forest Management Plan (Bell 1994) lists the top species used locally for construction including *Calophyllum* spp. *Pterocarpus indicus*, *Serianthes kanehirae* var. *kanehirae*, and *Lumnitzera littorea*. *Intsia bijuga* is preferred and found in the limestone forests. *Horsfieldia irya* (chemeklachel) is good wood but hard to harvest as it is found in swamp forests. Other trees harvested for their wood include *Campnosperma brevipetiolata*, *Gmelina palawensis*, *Manilkara udoido*, *Vitex cofassus*, *Rhizophora mucronata* and *Sonneratia alba*. Bell states that 50.1% of Palau's forests are within steep or highly erosive soils with severe problems for use of heavy equipment. No logging was recommended in these areas. The draft plan further recommends that buffers strips of 130m wide (65m on either side) be left in fully forested states along all perennial streams to protect stream channels and act as sediment traps. A minimum of 50m on either side was recommended in Issue #3. These buffers would remove 17% more of all land from "production" forestry base. In addition, about 7% of the forest should be left as a visual buffer around roads villages and scenic attractions such as waterfalls and cultural sites. This would leave about 35% of the forest base available for selective harvest or about 1, 000 m^3 y^{-1}. In reality about 50% of the harvestable timber is accessible so that leaves about 500 m^3 y^{-1}. However with the national highway open access to more forests. Draft Forestry legislation (House Bill No. 5-132-5) recommended that no more the 50% of the basal area of mature trees on any harvesting site or acre be logged and that state permits be required for all cutting.

Currently the Forestry Division is conducting a survey within Aimeliik to determine the density of timber trees especially *Gmelina palawensis* as a hotel is requesting 200 trees for construction. Aimeliik state is

concerned that the demand is greater than what the State can sustainably harvest. The need for local timber is not well documented – yet many local community centers, the traditional abai and summer rest houses use local wood that are durable and lasting. State inventories for sustainable harvest and propagation of native timber is needed in each State.

During 2004, Craig Costion with the Forestry Division staff developed a tree planting guide was developed for *Nephelium lappaceum* (rambotang), *Garcinia mangostana* (mangosteen), *Annona muricata* (sausab), *Citrus mitis* (kingkang) *Mangifera indica* (iedel), *Persea americana* (bata), *Calophyllum inophyllum* (btaches), *Intsia bijuga* (dort), *Serianthes kanehirae* (ukall) *Swietenia macrophylla* (big leaf mahogany) and *Pterocarpus indicus* (las). *Garcinia mangostana* is a delicious and unique fruit that is thought by some to be one of the world's best-flavored fruit (Figure 33). It is difficult to cultivate and no successful widespread commercialization is known. We recommend more production of this fruit trees as part of a healthy diet for school lunches in Palau.

During 2005 to 2009 preliminary data from Forestry indicates that a total of 79,384 saplings were produced and distributed at Nekken State Nursery to over 133 landowners (Figures 32- 34). Available data for 68 people in 8 states of Babeldaob who received 59, 376 trees covering more than 133 acres or 54 hectares. The top saplings distributed were *Morinda citrifolia* (ngel or noni) (50, 532 saplings) and *Swietenia macrophylla* mahogany (8,804 saplings). The landowners who requested the most mahogany resided in Ngardmau, Ngatpang, Ngarchelong and Ngaremlengui. Landowners living in Ngaremlengui, Ngarchelong and Ngiwal requested the more *Morinda* saplings than other states (Table 39). Other saplings produced and distributed included *Areca catechu* (buuch) or betelnut (10,988 saplings) and *Nephelium lappaceum* or rambotang (1,391 saplings). In 2009 more native trees were propagated than in previous years including 500 saplings of *Ixora casei* (kerdeu) and 169 saplings of *Trichospermum ledermanni* (chelsau). The distribution of *Morinda citrifolia* (ngel or noni) and mahogany trees is shown in Figure 34.

Table 39 Sapling Distribution of *Swietenia* sp. or mahogany and *Morinda citrifolia* (ngel) from 2005-2009 from the Nekken Nursery.

State	Number of Landowners	Scientific name	Common name	total	acre	Hectare
Ngardmau	3	*Swietenia* sp.	mahogany	2,450	5.68	2.3
Ngatpang	4	*Swietenia* sp.	mahogany	2,150	8.25	3.3
Ngarchelong	2	*Swietenia* sp.	mahogany	1,486	3.45	1.4
Ngaremlengui	5	*Swietenia* sp.	mahogany	1,358	2.41	1
Melekeok	2	*Swietenia* sp.	mahogany	900	4.1	1.6
Ngiwal	2	*Swietenia* sp.	mahogany	400	1.32	0.5
Aimeliik	2	*Swietenia* sp.	mahogany	100	0.33	0.13
Subtotal				8,844		10.23
Ngaremlengui	9	*Morinda citrifolia*	ngel	13,400	33	14.3
Ngarchelong	14	*Morinda citrifolia*	ngel	11,170	21	8.5
Ngiwal	4	*Morinda citrifolia*	ngel	9,100	12.38	5
Ngaraard	6	*Morinda citrifolia*	ngel	5,900	16.83	6.8
Ngatpang	7	*Morinda citrifolia*	ngel	5,587	11.8	4.8
Aimeliik	5	*Morinda citrifolia*	ngel	3,800	8.16	3.3
Melekeok	2	*Morinda citrifolia*	ngel	825	2.73	1.1
Ngardmau	1	*Morinda citrifolia*	ngel	750	1.62	0.6
Subtotal				50,532		30.1
Total	68			59,376	133.06	54.63

Spatial Analysis

A geospatial model was developed to determine the highest priority areas in which Forestry efforts should be directed to sustain forest resources. Twelve data layers were used in the model analysis (Table 40). Each layer was weighted according to its perceived relative importance to this issue. Soil type is critical for determining types of resources that will grow. The criteria for each layer are given in Table 41. For the spatial analysis five layers were used and equally weighted because other layers either had insufficient data or when used did not contribute significantly to the analysis to help prioritize landscapes.

Table 40 Ranking of layers for issue 6 Sustainable Use of Forest Resources

Layer Rank	Layer Name	Layers Identifie & Weighted	
1	Vegetation	25	20
2	Infrastructure	20	20
4	Slope	10	Not used
5	Soil	10	20
6	Priority watersheds	10	Not used
7	Riparian buffers	10	20
8	Public Drinking water	10	Point data not used
10	Protected Areas	5	20
11	Invasive species	5	Not used
12	Fire	5	Not used

Table 41 Criteria used for the GIS Analysis for the Issue 6. Sustainable Use of Forest Resources

Factor	Condition	Suitability for harvest
Vegetation	Mahogany, Coconut Casaurina and other tree plantations	10
	Native secondary forests & savanna	5
	Native primary forests	1
Infrastructure	More than 1000m from infrastructure	10
	Within 500-1000m	5
	Within 0-500m	1
Slope	Less than 12 degree slope	10
	More than 12 degree slope	restricted
Soil	Less erodible soil types	10
	Highly erodible soil types	restricted
Priority watersheds	Upper watersheds	restricted
	Lower watersheds	10
Riparian buffers	10-100 m from stream	10
	0-10m from stream	Restricted
Public Drinking water		Restricted
Protected Areas	No take areas	Restricted
	Surveyed areas for sustainable harvest	10
	That can include no take areas for comparison	
	Un-surveyed areas for sustainable harvest	1
Invasive species	Invasive Tree species	10
Wildfire		Restricted

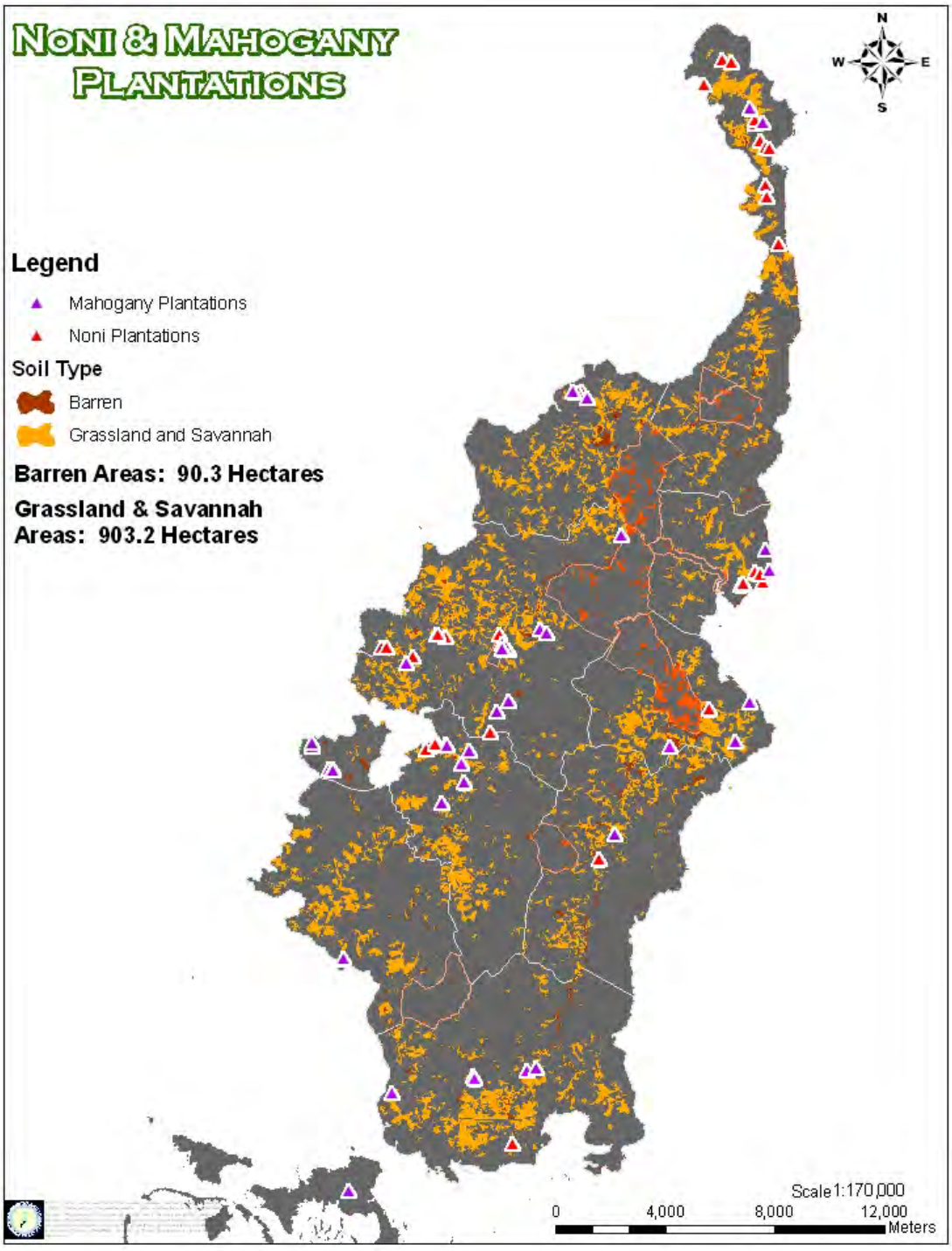

Figure 35 Locations of plantations on private lands of mahogany and noni (*Morinda citrifolia* or ngel) Data provided by the Forest Stewardship Program and Nekken Nursery Bureau of Agriculture

Results

Plantations on private land are eligible for Forest Stewardship technical assistance including the development of forest management plans. The sizes of these plantations need to be measured in order to do a spatial analysis. Currently forestry only has point locations of plantations that cannot be analyze with the other layers. These plantations consist mainly of coconut, mahogany and noni trees and a variety of other trees. Coconut plantations are mapped however the health of these plantations needs to be assessed under the Forest Health Program. Priority areas for either reforestation are bare areas and grasslands with highly erodible soils, vulnerable coastal areas subject to flooding where coconuts and other low lying coastal shrubs grow well (Figure 35). Reforesting with native timber within the secondary buffer zone and areas with slopes are less than 12% or the soil are highly erodible and urgently need tree vegetation is a cross linked issue with water quality. The current Administration is advocating the revitalization of coconut plantations throughout Palau. The existing plantations require assessment and forest plans on private lands through the Forest Stewardship Program and public lands through Urban and Community Forestry program. Establishment of agroforest including coconuts, timber trees and fruit trees is an ongoing process at forestry. Focusing these efforts in top priority watershed areas is important. Mature mahogany stands at Nekken and elsewhere can be sustainably harvested and funds generated used to support local community programs. Fruits from mature stand of rambotang and mangosteen can be propagated and distributed. Falcataria, Adenanthera and Casaurina and Coconut can also be assessed for biomass utilization.

Conclusion

The geospatial analysis identified primary areas in which future efforts should be concentrated within the Nekken Station, Koror, Airai and villages throughout for reforestation with economically important trees. Existing plantations can need to be assessed and sustainably harvested as markets have been and are being developed for local uses. The coconut has the most uses and a viable market for its products already exists. Casuarina forests can be sustainable harvested for firewood as is being done in Peleliu. Fruit trees and important native timber tree are being propagated. Through existing forestry programs, ongoing tree planting efforts should be well reported, mapped and monitored to ensure successful revegetation and production in areas that need to be reforested in priority areas both in poor soils and in areas with good potential for reforestation.

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Table 42 Strategy Matrix for Issue 6 Sustainable Use of Forests Resources

Long Term Strategy	Priority Landscape Areas	2[0] Issues Addressed	Program Areas that Contribute	Key Stakeholder	Resources Available/ Required to Implement	Measure of Success	Supports National Objectives
Develop and Implement a Nation Policy Framework & Best Practices for Forests as guidance for States & Raise awareness about the value of forests	The entire Republic of Palau	Climate Change (CC) Popula-tion Growth & Urban-ization (PG) Fire Water Quality & Quantity (WQ) Conservation (C) Urban Forest Sustain-ability (UF)	Urban & Commun-ity Forestry (UCF) Forest Health (FH) Forest Stewardship (FS) Conservation & Education (CE) Cooperative Fire (CF)	All members of Palau's community	Technical assistance and personnel from: State Governments BOA, DFR DFW, BTA, PV BNM, TEI, PICRC, SIUL, Didil Belau, Inc. & Seeds of Promise South Pacific Commission /funds for equipment and supplies fees for a policy expert and facilitator geospatial data & analysis	A National Forest & Mangrove Policy ratified by Congress by2012 Annual Forest Sympos to share information & review policy & guidelines Number of Key stakeholders from each state	All: Conserve Protect Enhance
Develop sustainable forests sources of livelihood (i.e. ecotourism, agroforestry, & sustainable tree harvest) through specific programs and capacity building	Nekken Station			Public and Private Landowners with mahogany plantations		Demonstrate the harves of 10 mahogany trees Number of landowners assisted. Number of species Propagated & planted Number and size of demonstration agroforest plots Number of trees planted Number of forest Stewardship Plans Acres of important forest resource areas Acres of sustainably Managed forest Resource areas Hire 1 urban forester or arborist 5-yr UCF Plan	
	Mahogany Plantations in Ngchesar Aimeliik, Airai					Produce guidelines for sustainable forest management by 2012 2 certified staff to harvest, process & market of trees 2 certified staff to develop Forest Stewardship plans assess10 mahogany plantations/yr Assist 10 owners. Set up 1 harvest processing & marketing Training at Nekken each year. Plantation Cooperative by 2013	Enhance 3.4 Maintain & enhance the economic benefits & values of trees & forests

Table 42 continued Strategy Matrix for Issue 6 Sustainable Use of Forests Resources

Long Term Strategy	Priority Landscape Areas	2^0 Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/ Required to Implement	Measure of Success	Supports National Objectives
Develop sustainab forests based sources of livelih –i.e. eco tourism, agroforestry , & sustainable tree harvest	Coconut Plantations in Babeldaob Hatohobei, Sonsorol, Kayangel, Angaur & Peleliu	Climate Change (CC) Population Growth & Urbanization (PG) FIRE Water Quality & Quantity (WQ) Conservatio (C) Urban Forest Sustain-ability (UF)	Urban & Community Forestry (UCF) Forest Health (FH) Forest Steward-Ship (FS) Conservation & Education (CE) Cooperative Fire (CF)	Communities in priority landscape areas	Technical assistance & personnel from: BOA, DFR,DFW, BWA, BTA, PVA CRRF, SIUL, PNRC Blue Moon Exotic Woods SPC /funds for equipment & supplies & LIDAR SAR Imagery	Model management plan for coconut plantations that includes surveys, maps & trees marked for sustainable rotational harvest & inspected for the *Rhinoceros* beetle by 2012	Enhance 3.4 Maintain & enhance the economic benefits & values of trees & forests
	Casaurina Plantations			Public and Private Landowners of *Casaurina* plantations and wild populations		Plantations and wild Populations of *Casaurina* surveyed & trees marked for sustainable rotational harvest by 2014 Spatial analysis of *Casaurina* using Aerials & IKONOS, LIDAR & SAR by 2015	
	Aimeliik Mahogany forests for sustainable harvest demo project			Plantation owners of Aimeliik		Demonstration project for plantation owners to show rotational harvest of marked trees	
	Ngerikiil, Ngerdorch & Ngermeduu Watersheds			Communities in priority landscape areas		sustainable harvest buffers in priority landscapes using native trees valued for constructi by 2014.	

Issue 7 Urban Forest Sustainability

Trees and forests in urban areas represent valuable natural and cultural resources. Traditional valuation was based on the cost to replace a tree. Today, new software enable valuation based upon functionality. Functional values include air pollution removal, energy savings, storm water runoff, carbon sequestration and storage, real estate value, recreation, health benefits, psychological well- being and aesthetic appeal. The Palau Urban and Community Forestry Council's seven goals link with two national themes: Enhance Public Benefits and Protect Forests from Harm (Table 43).

Table 43 Urban and Community forest goals that link with national themes

Urban and Community Forest Goals	National Theme
Enhance & organize planting of trees	Enhance Public Benefits
Protect the integrity of our ecosystem	Protect Forests from Harm
Develop forest-based sources of livelihood	Enhance Public Benefits
Gather & share information & assist communities	Enhance Public Benefits
Raise awareness of the value of trees	Enhance Public Benefits
Foster self-reliant communities	Enhance Public Benefits
Promote the connection between trees & our culture	Enhance Public Benefits

Figure 36 Ecotour in Ngaremlengui State

The council seeks to establish and improve community forests and sustain the vital interconnection between peoples' forests and culture. Since its inception in 1997 the Urban and Community Council has supported over 17 projects to meet its goals (Table 44, Figures 42-43). The projects include assistance with the development of eco tours in Melekeok, Ngaremlengui, Ngarchelong, Airai, Ngardmau, Ngiwal, Ngchesar and Aimeliik (Figure 36). The Council has support the development of educational materials (posters, videos and books) and programs about the importance of trees. State nurseries, tree planting activities within communities and restoration of urban landscapes in Koror and Airai are other projects supported by the Council. The council is working with Ngarameliwei to help in the restoration of a traditional urban landscape (Figure 37).

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Table 44 Urban and Community Forestry Projects over the past 10 years

	Project Name	Year	Organization	Description	SWARS Issue(s)	
1	Koror Interpretive Mini-Forest	2000	Belau National Museum	Mini forest beside BNM.	7	Urban Forest Sustainability/Agroforestry
2	Community Forest Inventory	2000	The Environment Inc.	Tree survey with 7th and 8th graders in Koror and Airai.	7	Urban Forest Sustainability/Agroforestry
3	New Mindszenty High School Beautification	2001	Mindszenty High School	Beautification and native tree planting on grounds of new Mindszenty High School	7	Urban Forest Sustainability/Agroforestry
4	State Nurseries	2002	Forestry	State nurseries in Airai, Ngchesar, Melekeok, Ngiwal, Ngaraard, Ngarchelong, Ngardmau, Ngaremlengui, Ngatpang, and Koror	1 2	Climate Change Population Growth and Urbanization
5	Palau Plants - A Photographic Database	2003	Ann, Tarita, Robin	Photographic database of Palau plants	6 5	Sustainability of Forest Resources/Agroforestry Conservation
6	Ngardok Lake Trail Project	2004	Ngardok Lake Board	Construct trail and boardwalk at Ngardok Lake	6	Sustainability of Forest Resources/Agroforestry
7	Palau Plant Field Guide	2005-2007	Ann, Tarita, Robin	Native Plants of Palau - book	6 5	Sustainability of Forest Resources/Agroforestry Conservation
8	Ngatpang Trees for Life Garden	2005	Ngatpang State	Beautification and native tree planting in Ngatpang	7	Urban Forest Sustainability/Agroforestry Population Growth and Urbanization
9	Community-based Healthy Forest Initiative	2006	Ngarchelong Bngala Klikm Association	Kebeas clean-up in Ngarchelong state	6	Sustainability of Forest Resources/Agroforestry
10	Project to control the spread of *Merremia peltata* vine	2006	Ngarchochado Men's club	Kebeas clean-up along Compact Road in Ngiwal state.	6	Sustainability of Forest Resources/Agroforestry
11	Ngetkib Path improvement Phase1	2005-2006	Ngarameliwei	Improvement of the Traditional path in Ngetkib	7	Urban Forest Sustainability/Agroforestry
12	2nd Phase Ngetkib Path improvement	2008-2009	Ngarameliwei	Improvement of the Traditional path in Ngetkib	7	Urban Forest Sustainability/Agroforestry
13	Ngardmau Waterfall Trail Project	2009	Ngardmau State	Improvement of trail to waterfall in Ngardmau	3	Water Quality and Quantity
14	Tree Awareness & connectivity with Palauan Culture by Restoring "Euatel" in Ngerbau	2009	Ngarchelong Bngala Klikm Association	Restoration of Euatel	5	Conservation
15	Ferns, Orchids and Herbs of Palau - A Field Guide	2009	Ann and Tarita	Fern and orchid field guide	5	Conservation
16	Tree planting in Ngerubesang, Melekeok State	2009	Ngerubesang Men's Club	Community beautification projects in Melekeok state	2 7	Population Growth & Urbanization Urban Forest Sustainability/Agroforestry
17	Ngiwal State Botanical Conservation Area	2009	Ngiwal Botanical Garden	Establish Ngiwal Botanical garden	5	Conservation

The Urban and Community Council funded a 2001 survey of 90 homes in the urban states of Koror and Airai. A total of 859 trees representing 64 species and 37 families were identified and measured (Kitalong, 2001). A total tree volume of 596 m^3 was calculated or 0.016 m^3 $m^{-2.}$ Eight plants represented 74% of the total volume: *Mangifera indica* (76 trees, 30% of total volume), *Areca catechu* (222 trees, 10%), *Cocos nucifera* (100 trees, 10%), *Terminalia catappa* (24 trees, 15%), *Swietenia macrophylla* (9 trees, 3%), *Spondias pinnata* (27 trees, 2%), *Plumeria obtuse* (22 trees, 2%), and *Artocarpus altilis* (11 trees, 2%). Other important trees and shrubs were *Musa* spp., *Persea americana*, *Syzygium aqueum* and *Nephelium lappaceum*. Less common trees included *Carica papaya*, *Citrus* spp., *Psidium guajava*, *Annona muricata*, *Premna serratifolia*, *Averrhoa carambola*, *Muntingia calabura* and *Bambusa vulgaris*. Decorative bushes and plants included *Gardenia jasminoides*, *Hibiscus rosa-sinensis* and *Cordyline fruticosa*. Large trees included *Serianthes kanehirae* Fosb. var. *kanehirae*, *Falcataria moluccana*, *Cananga odorata*, *Samanea* sp. and *Campnosperma brevipetiolata*. *Rhizophora mucronata* and *Calophyllum inophyllum* were found near homes adjacent to the mangroves and coasts.

Figure 37 Restoration of traditional urban landscape along a traditional stone in Ngetkib Village, Airai.

The students listed a total of 26 uses for 56 plant species. Food, shade and decoration were most frequently cited. Plants were also used for lumber, medicine, drink, firewood, housing, chewing, furniture, flower leis, spice for soups and food, spears, animal food, holding the soil, wrapping materials for "bilum," making brooms, filling for pillows, clothing, slingshots, shelter, benches, income, glue and basket weaving. The coconut tree was listed with the most uses. This study provides an inventory of trees to propagate at the State nurseries and Nekken for urban forests. The council is working with the Palau Community Action Agency, Palau Conservation Society, the Natural Conservation and Resource Service, Didil Belau, Inc. a local women's group and the Seeds of Promise, a local group working with youth and health to initiate a green garden program to promote urban forests in Airai State (Figure 38)

Figure 38 Didil Belau Inc. green yard project supported by Seeds of Promise, PCS, PCAA, NRCS, UCF and a home owner in Airai

Since 2006, a collaborative ethnobotanical study of Palau's plants by the Belau National Museum in partnership with the New York Botanical Gardens has documented uses of over 300 species of plants (Fig.39). Permanent collections include the names of each person who provided information about the uses of a plant with its uses to ensure that knowledge is protected and archived. This study was conducted in Oikull, Airai State and Ibobang, Ngatpang State, The Republic of Palau. A total of 43 interviews were conducted; 27 interviews in Oikull (17 women, 10 men) and 17 interviews (8 women, 9 men) in Ibobang. A total of 200 plant species were recorded with uses, 171 species in Oikull and 127 in Ibobang. Reported uses included medicine (70 species), construction (41 species), food (27 species) and toys (22 species). Men were more knowledgeable about plants used for construction, tool making, firewood, fishing and canoe making. Women were more knowledgeable about plants used for medicinal uses for the first birth. Both men and women know the plants used for food, recreation, art, and medicine for primary care. A total of 190 voucher specimens were collected in Airai and 82 voucher specimens were collected in Ngatpang. The palms *Cocos nucifera* (39 uses) and *Areca catechu* (19 uses) had the most uses. The ethnobotanical program at the Belau National museum goal is to conservation of plant diversity, integrate traditional knowledge and practices in the educational programs and promote culture thorough local, regional and international activities to ensure that Palauan culture will survive into the next millennia (Kitalong et al. 2009).

Figure 39 Rubeang Hiromi Nabeyama observing processing of voucher specimen by Van Ray Tadeo of BNM-an ethnobotanical project supported in part by UCF.

Traditional agroforestry has been ongoing for centuries in Palau (Fig. 40). Trees used for all purposes are cultivated with taro or *Colocasia esculenta.* These tree gardens are part of a complex system to control and conserve freshwater. Demonstrations and technical assistance to sustain this taro-forest system is critical for preserving Palau's living culture. Traditionally, women cultivated their gardens with assistance from men for clearing large trees. Taro and the trees grown nearby are used for funerals, first birth ceremonies, marriage, and celebrations upon receiving a traditional title. Twenty years ago, McCutchen (1985) observed a trend towards more substitution of imported starches, reclamation of taro patches for homes and less community participation in traditional agroforestry. In recent decades, male laborers from the Philippines and Bangladesh are being used by women to work in their gardens as they

Figure 40 Agroforest at higher elevation in Airai ate.

Figure 41 Didil Belau Inc. rehabilitation of agroforest-taro farm: note double barrier filled with coconut husks to prevent sea water intrusion from higher tides in this converted swamp forest from Climate Change

pursue professional careers. This trend continues as more customary celebrations substitute rice for taro and plastic containers and wrap for palm fronds and plant leaves to for hold and preserve food. People practices create habitat mosaics by moderate and repeated disturbance that can increase biodiversity at species, habitat and landscape levels. An objective of the Nekken Station is to demonstrate traditional agroforestry including composting, water management, crop rotation, and pest management in collaboration with PCC and BNM to preserve agro biodiversity and actively use the knowledge and skills within Palau's unique landscape. The council works with Didil Belau, Inc. a local women's group to mitigate the impacts of sea level rise in lowland agroforest-taro systems (Figure 41).

Spatial Analysis

Eight layers were identified and weighed by the technical team (Table 45). A geospatial model was developed to determine high priority areas to direct to urban forest sustainable activities. The team set criteria for each layer (Table 46). During a series of generated analyses, two maps were needed. One analysis showed where good soil existed for tree planting (Figure 42) using layers and weights shown in Table 45. A second analysis prioritized landscapes in urban areas with poor soils using three layers as follows: infrastructure (weight= 40%), soil (weight =35%) and forests (weight =25%) shown in Figure 43. No spatial data exists to distinguish between barren and un-barren or disturbed and undisturbed savanna and agroforest.

Table 45 Ranking of layers for issue 7 Urban Forest Sustainability

Layer Rank	Layer Name	Identified & weighted layers	Layers used with weight
1	Infrastructure	20	25
2	Forest	20	25
3	Priority Watershed	15	15
4	Soil Type	10	25
5	High Fire Risk	10	Point data/not used
6	Current UCF projects	10	Point data not used
7	Rivers and Streams	10	10
8	Cultural Sites	5	Not used

Table 46 Criteria used for the GIS Analysis for the Issue 7 Urban Forest Sustainability

Factor	Condition	Suitability for urban reforestation
Infrastructure	Within 0-5m	Restricted
	Within 5-10m	5
	Within 50-100m	10
Forest	Barren	10
	Disturbed Savanna & Disturbed agroforest	5
Priority Watershed	Ngerikiil & Ngerdorch	10
	Ngeremeduu & Diongradid	5
	Ngerbekuu	1
Soil Type	Good Agroforest soils	10
	High Erodible	7.5
	Low erodible soils	5
High Fire Risk	Ngerikiil & Ngetkib	10
	Ngatpang & Ngardmau	7.5
	Ngaraard-Ngarchelong	5.0
Urban & Community Fores	Within protected areas	10
projects	Outside protected areas	5
Rivers and Streams	Within 0-10	Restricted
	Within 10-50m	10
Cultural Sites	Within 10-50 m	10
	Within 5-10m	5
	Within 0-5 m	Restricted

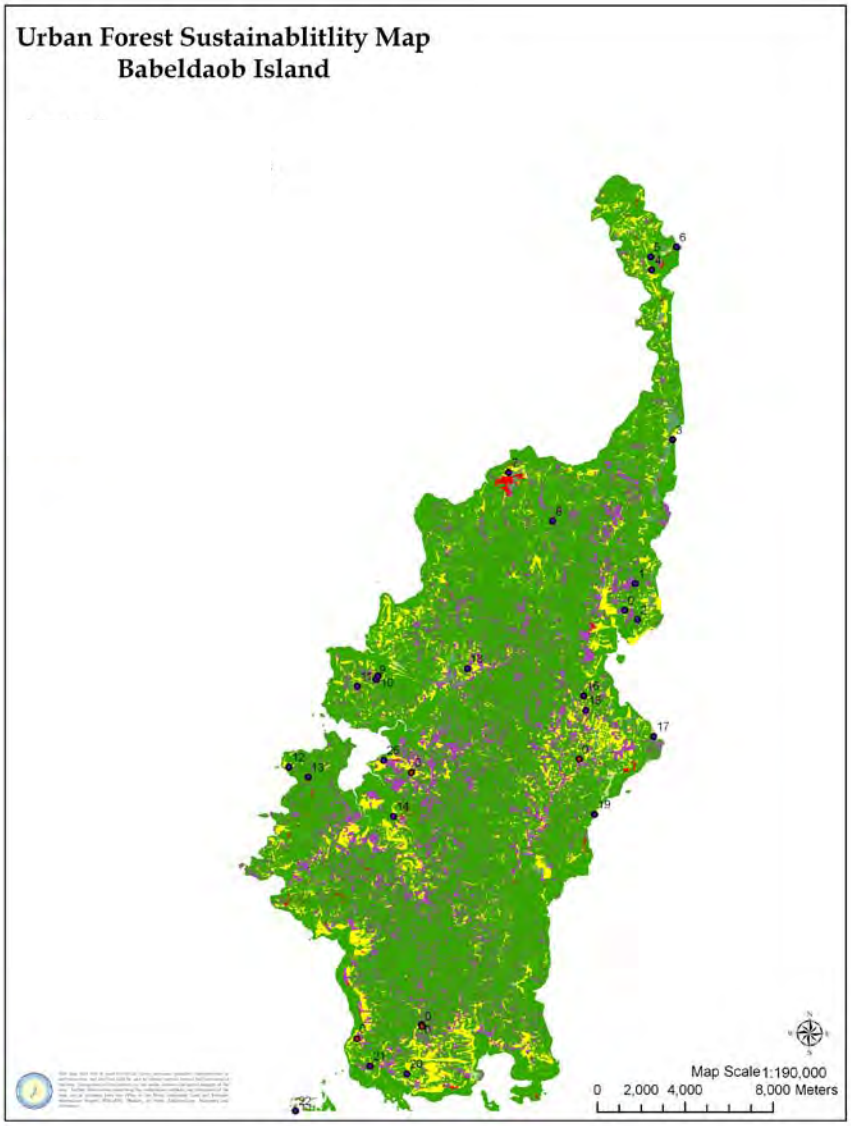

Figure 42 Map showing locations of urban community forest projects.
Refer to table below for color codes for forest types and reforestation suitability

Color	Forest Type and reforestation suitability
Light green	Agroforest
Red	Secondary forest- good soil for reforestatic
Pine green	Wetland
Yellow	Infrastructure or bare areas
Lavender	Suitable for reforestation
Green	Forest

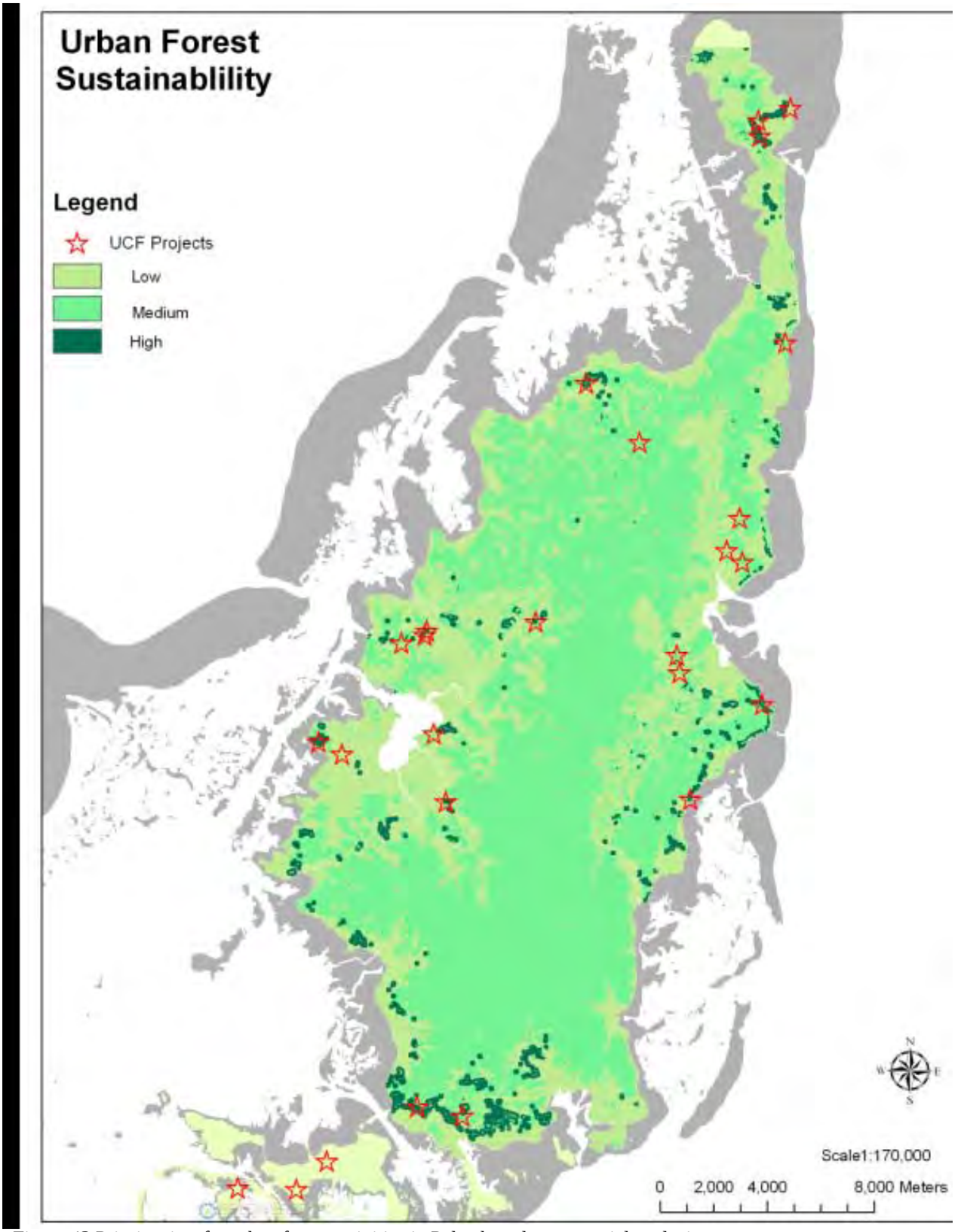

Figure 43 Priority sites for urban forest activities in Palau based upon spatial analysis
High priority is dark green, medium priority is light green and lower priority is yellowish green with urban projects as red stars.

Results

Results from the spatial analysis are shown in Figure 43 over 500,000 potential areas suitable for agroforest. Priority areas for reforestation activities are shown in red and lavender in Figure 43. The results so that many of the Urban and Community forest project are near infrastructure or areas that are bare. A second spatial analysis using only three layers- infrastructure, vegetation and soil show the highest priority areas for reforestation in urban areas and locations of urban projects (Figure 44). Many projects are in priority areas. The analysis is focused on Babeldaob. There is also an even greater urgency to forest with Koror State where population densities are the highest and the forests are more threatened as shown in Figures 11 and 22 under the issues of Climate Change and Population Growth which are cross cutting issues with Urban Forest Sustainability. Urban forests cover at least 2, 102 acres of land. Yellow depicts area where there is infrastructure and potential areas for landscaping with trees for homes and businesses. Much of Koror has potential as the map under the issue of population shows how dense the populations are in Koror. Urban areas such as housing developments in the Ngerikiil Watershed where there are highly erodible soils and a nearby river are prime areas for tree planting to landscape homes and roads. Additional analysis is needed within the priority landscapes of Airai and Koror and urban areas to prioritize areas for planting.

Conclusion

Two primary areas in which future efforts for reforestation are needed are the Ngerikiil Watershed of Airai and other urban areas of Airai and Koror. Best practices for tree propagation and maintenance within the urban landscape that build upon the traditional landscapes is needed. Traditional landscapes incorporated proper storm water management and selection of trees for different parts of the landscape that better hold the soil in place along streams and slopes. Integration of traditional urban landscapes with modern urban landscapes that have a higher percentage of impervious surfaces and more storm water drainage is needed.

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Table 47 Strategy Matrix for Issue 7 Urban Forest Sustainability

Long Term Strategy	Priority Landscape Areas	2^0 Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/ Required to Implement	Measure of Success	Supports National Objectives
Enhance & organize planting of trees Foster self-reliant communities	Koror & Airai Villages with 5 homes /0.5ha or more	Climate Change (CC) Popula-tion Growth & Urban-ization (PG) FIRE Water Quality & Quantity (WQ) Conservatio (C) Forest Sustain-ability (FS)	Urban & Commun-ity Forestry (UCF) Forest Health (FH) Forest Steward-Ship (FS) Conser-vation & Education (CE) Cooperative Fire (CF)	Communities in Koror & Airai and villages with 5 homes/0.5ha or more	Technical assistance and personnel from: BOA, BNM, PVA, PCS, BWA, Didil Belau, Inc., Seeds of Promise Communities in priority areas /Funds for vehicles, increase staff, equipment, supplies, fuel, printing, & video production rental of meeting venue and supplies geospatial analysis and collection of geospatial data	Establish 6 urban gardens annually in priority site Annual field trip to project sites	Conserve 1.1, 1.2, Enhance 3.6
Develop forest-based sources of livelihood Foster self-reliant communities	Lake Ngardok Ngiwal Ngardmau Waterfall Ngetkib Airai Nekken Station			Staff and communities a priority landscape areas, PVA, BTA, MOE, visitors and tourists, BWA, PCS		Eco tours developed at priority sites by 2015 Annual Forestry meeting & field trip to assess projects geospatial data collected & analysis annually	Conserve 1.1, 1.2 Enhance 3.4

Table 47 continued. Strategy Matrix for Issue 7 Urban Forest Sustainability

Long Term Strategy	Priority Landscape Areas	2^0 Issues Addressed	Program Areas that Contribute	Key Stakeholders	Resources Available/ Required to Implement	Measure of Success	Supports National Objectives
Gather & share information & assist communities Raise awareness of the value of trees and forests	Koror & Airai State & Village with densities of 5 homes per 0.5ha or more	Climate Change (CC) Population Growth & Urbanization (PG) FIRE Water Quality & Quantity (WQ) Conservation (C) Urban Forest Sustainability (FS)	Urban & Community Forestry (UCF) Forest Health (FH) Forest Steward-Ship (FS) Conservation & Education (CE) Forest Legacy (FL) Cooperative Fire (CF)	Communities in priority landscape areas	Technical Assistance and Personnel from: BOA, PVA, BTA, MOE, PCS, TNC, & communities In priority areas /funds for vehicles, equipment, supplies, fuel, printing costs, video production costs	1 book on orchids & ferns, 1 video about tree value, planting & propagation	Conserve 1.1 Enhance 3.6
						Annual community meetings (4) to raise awareness on tree value 1 Booklet on trees, people & culture each year One video on trees by 201 1 calendar/yr 1 poster/yr Bibliography of Palau's forest literature by 201	Enhance 3.6
						Annual site visits by council to assess projects Direct future projects in priority areas	Enhance 3.4
Promote the connection between trees & our culture				Communities of Ngiwal, Ngatpang Airai BTA, PVA		Ngiwal & BNM Botanical Gardens Brochures & Display Conduct an assessment of need for easements	