STUDY ON THE CHARACTERISTICS OF TERMINALIA AGROFORESTRY IN KOSRAE ISLAND, FEDERATED STATES OF MICRONESIA

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ABSTRACT

Terminalia carolinensis Kaneh. is a wetland species endemic to Kosrae and Pohnpei Island, Federated States of Micronesia (FSM). The tree develops dominant and mixed forests in lowland freshwater wetlands, particularly in Kosrae, where people practice traditional agroforestry on this *Terminalia* land. In one year (1998), *Terminalia* land provided approximately $3.1 million worth of goods and services to the local society (Drew *et al.*, 2005).

The objectives of this thesis project were 1) to quantify and compare the size of *Terminalia* parcels among different municipalities and also among different vegetation/land cover types, 2) to determine trends in important parameters such as average size of parcels and percentage of households who own *Terminalia* parcels, 3) to capture the size and distribution of *Terminalia* forests among different municipalities, and 4) to gain a general understanding of local people on the changes in *Terminalia* population over the entire island. Interviews were conducted with 56 randomly selected households and 6 key informants for obtaining information about the location, role, and management practice on *Terminalia*. The locations, approximate number of *Terminalia* stands, average height and diameter at breast height (DBH) were recorded by observation at 16 parcels.

The result showed that still close to 80% of the households on the island had parcels with *Terminalia*, with no statistical difference observed between the percentages in the current study and that reported by Drew *et al.* (2005) (89%). Most parcels, with an average size of 0.76 ha, were actively used for agriculture. Variation of parcel size was

not statistically significant between different municipalities. However, vegetation/land cover statistically impacted parcel size, with an average size of 2 ha in agroforest, and less than 0.5 ha in swamp forest, upland broadleaf forest, and urban land, respectively.

While half of the interviewees recognized this tree as part of their agroforestry system (providing shade) or serve as part of wetland function (controlling erosion); their traditional usage of *Terminalia* tree as a material for canoe hull seemed to be declining. A majority of the interviewees thought that *Terminalia* population was increasing over the entire island, as a consequence of less demand for a direct use and its successful regeneration. Still, 70% of the interviewees thought that some conservation measures were necessary for the tree. Further dissemination of information on both dense and small patch *Terminalia* forests were recommended. Further studies were encouraged on the *Terminalia* parcels, e.g., a field-based inventory with different aspects in focus.

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CHAPTER 1

INTRODUCTION

Throughout the Pacific Islands, people have developed their own unique traditional farming or agroforestry systems that are well adjusted to their specific environmental conditions over a long period of time (Clarke and Thaman, 1993). Increased understanding of such systems is considered not only beneficial for those people in order to maintain and extend their systems, but it also has implications for the people who have a similar environment, and who seek better ways for a sustainable resource use.

While some traditional agroforestry systems in the Pacific have been extensively documented (e.g., Thaman, 1976; Vergara and Nair, 1985; Raynor, 1989; Clarke and Thaman, 1993), there are still many other systems in different environments that have been less studied. One such system can be found on the island of Kosrae, Federated States of Micronesia (FSM), where people use coastal freshwater wetlands for cultivation. This system, dominated by the overstory species *Terminalia carolinensis* Kanehira (hereafter referred to as *Terminalia*, unless noted otherwise), is considered to have been in use since 1550 to 1350 years BP (Athens *et al.*, 1996), suggesting its long-term sustainability (Chimner and Ewel, 2004; Chimner and Ewel, 2005). Swamp taro (*Cyrtosperma chamissonis* (Schott) Merr.) patches that are usually associated with this *Terminalia* land do not alter hydrological condition, and thus the land maintains the natural condition of the wetland while being used for agriculture, representing a unique situation among the wetlands of the world (Chimner and Ewel, 2004; Allen *et al.*, 2005).

A recent socioeconomic study of *Terminalia* agroforestry showed that it provided $ 3.1 million in a year (1998) worth of goods and services to the local society, primarily from agricultural production (Drew *et al.*, 2005). For 75% of households who were producing soft taro (*Colocasia esculenta* L.), swamp taro, and bananas (*Musa* spp.) on this land, the value of their production corresponded to 44% of the median annual household income in the mid 1990s in Kosrae, which meant a substantial economic value for them.

The objective of this study was to conduct a follow-up study of Drew *et al.* (2005) (hereafter referred to as "1998 survey") and further characterization of *Terminalia* agroforestry. More precisely, the objectives are 1) to quantify and compare the size of *Terminalia* parcels among different municipalities and also among different vegetation/land cover types, 2) to determine trends in important parameters such as average size of parcels and percentage of households who own *Terminalia* parcels, 3) to capture the size and distribution of *Terminalia* forests among different municipalities, and 4) to gain a general understanding of local people on the changes in *Terminalia* population over the entire island. The background and orientation of the objectives are explained in detail in the following chapter.

CHAPTER 2

LITERATURE REVIEW

2.1. Background information on Kosrae and the FSM

Kosrae is a lushly vegetated, high volcanic island in the Eastern Caroline Islands of Micronesia (Merlin *et al.*, 1993), located at 5°19' N and 163°00' E, with an area of 109 km^2 and a population of 7,686 in year 2000 (Kosrae Branch Statistics Office, 2002). The island is characterized by humid tropical environment with high average annual temperature (27 °C at sea level) throughout the year (Merlin *et al.*, 1993), average annual rainfall of 5,050 mm (NOAA Cooperative Weather Station 914395, as quoted by Drew *et al.*, 2005), and relative humidity of between 80 and 90% (Merlin *et al.*, 1993). Some rocks found on the island have been dated at 1.4 million years (Keating *et al.*, 1984). Most of the island is mountainous; approximately 36% is occupied by coastal plain, including mangrove forests and freshwater wetlands (Drew *et al.*, 2005).

Kosrae is one of the four states in the Federated States of Micronesia (FSM). After experiencing a long history of colonial domination by a succession of Western and Asian counties from Spain, Germany, and Japan, to the USA[1] (Merlin *et al.*, 1993), the FSM became an independent country and entered into a Compact of Free Association with the USA in 1986. The country is currently a member of the Small Island Developing States (SIDS) of the Food and Agriculture Organization of the United Nations (FAO)[2], all

[1] After World War II the Caroline Islands (including Palau and the Marshall Islands) were administered by the USA under a United Nations trusteeship.

[2] Small Island Developing States (SIDS) are small island and low-lying coastal countries that share similar sustainable development challenges, including small population, lack of resources, remoteness,

of which are facing many development challenges as they go through social and cultural transition.

The post-war annual population growth for the FSM was until recently over 3 %, one of the highest in the world. However, 2000 census data indicate a downward trend in the annual rate of population growth (1.3 % for the period 1986 to 2000). This is a sharp decline compared to 4.6 % for the period 1973 to 1980, and is attributed to a decline in fertility and an increase in emigration from the FSM. While the rate of population growth is slowing down, the unemployment rate in the FSM is rising slightly, from 15 % in 1994 to 17 % in 2000 (Kosrae Branch Statistics Office, 2002), reflecting the struggling social situation.

Subsistence or non-cash activities (fishing and farming) have been an integral part of Kosraean lives. Non-market production for the entire FSM has stayed around 12 to 14% between 1989 and 1999 (average 13.4%), with some of the state governments claiming as much as a quarter of the economy; due to the creation of income-generating jobs in the country, subsistence economy has declined over the last three decades (Bank of Hawaii, 2000). However, in Kosrae, the number of persons living at the subsistence level[3] almost doubled between 1994 and 2000, from 2.3 % to 4.3 % of the population

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susceptibility to natural disasters, excessive dependence on international trade and vulnerability to global developments. In addition, they suffer from lack of economies of scale, high transportation and communication costs, and costly public administration and infrastructure. There are 51 member States and territories, and they constitute approximately 5% of the global population (Small Island Developing States Network, 2003).

[3] The 2000 census questions classified persons who "sold any" of their produce as "market oriented", and those who don't as "subsistence". The question was applied only one week before the census, thus people who fished and/or farmed for market purposes but did not sell in that week would probably have been counted as subsistence. Kosrae Branch Statistics Office (2002) admits that the result might have been underestimated for some people, such as those engaged in occasional market oriented activities (e.g., seasonal crops, pigs).

(Kosrae Branch Statistics Office, 2002). Subsistence activities are a relevant issue not only to FSM, but also to other SIDS countries (Clarke and Thaman, 1993) and even in some areas in Hawaii (Matsuoka *et al.*, 1998). Subsistence activities are important for food security, safeguard response to natural disaster, cultural identity, and social well being of people.

With the end of the original 15 year Compact period between the FSM and the USA in year 2001, and the launching of the Amended Compact in 2003 for the next 20 years, the FSM is receiving much less financial aid from the USA (Pacific Islands Development Program/East-West Center, 2003), from $13 billion for the past period to $1.8 billion for the coming. The FSM economy and its people are expected to face difficult challenges, including the downsizing of the public sector and the increase of pressure on natural resources with a growing unemployed adult population (Micronesian Seminar, 1997). Likewise in Kosrae, increased dependence on traditional foods as a result of decline in external funding has been projected (Drew *et al.*, 2005).

One hot topic to include here that is taking place in Kosrae is an extension of circumferential road, and its possible impact on the dense *Terminalia* forest at the north western side of the island (still at the planning stage; Appendix A). Kosrae Island Resource Island Authority (known as KIRMA), a state government office in charge with environmental protection of the island, has sought technical consultation from U. S. Department of Agriculture Forest Service, and also conducted one-year educational campaign on the conservation of *Terminalia* forests, mostly targeting children at schools (R. Jackson [KIRMA], pers. comm., 2005).

2.2. Information on *Terminalia*

Terminalia species in Kosrae

The genus *Terminalia* (family *Combretaceae*) is known to include approximately 200 species in the tropical and subtropical areas (Lamb and Ntima, 1971; Whitemore, 1972; Srivastav *et al.*, 1996). Many of these species are used in various ways, such as timber for construction, material for local canoes, medicinal uses, and fodder for silkworm. People sometimes eat their fruit as well. *Terminalia* species also exist in the Pacific Region (Scott, 1993), where some of them are endemic and are becoming a focus of genetic conservation (e.g., *T. richii* in Samoa [Pouli *et al.*, 2002]).

Two *Terminalia* species are known to exist in Kosrae: *T. carolinensis* Kanehira and *T. catappa* L.. *Terminalia carolinensis* is endemic to Kosrae and Pohnpei[4] (Merlin *et al.*, 1992; Merlin *et al.*, 1993). In Pohnpei, most of the trees have been harvested and would be difficult to reestablish as dominant species of wetlands due to considerable disturbance (Merlin *et al.*, 1992). In Kosrae, this species is still considered abundant to the extent that it forms a dominant forest, particularly in the western side of the island. This tree species is also scattered over the entire island of Kosrae, mostly on lowland wetlands where people practice traditional agroforestry. The tree is used for making canoe hulls, cabinet construction, house timbers, and medicinal use (Merlin *et al.*, 1993). *Terminalia catappa* is known as Tropical Almond or Indian Almond tree in English, and is commonly found along coastlines of many Pacific Islands including Kosrae and

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[4] Recently, there has been a claim that T. *carolinensis* might exist in Palau as well (B. Raynor [The Nature Conservancy], pers. comm., 2004). The name also appears both on "A global compendium of weeds" as an introduced species to Western Australia (Randall, 2001), and the flora list of Marquesas Islands with status unclear (Department of Botany, National Museum of Natural History, Smithonian Institution, 2004). Further information on the present status was not obtained.

Hawaii. It does not form dense stands in Kosrae (personal observation). Local people call *T. carolinensis* "*Ka*", and *T. catappa* "*Srifacf*", distinguishing the two species by their different habitats and shapes (Merlin *et al.*, 1993).

Ecological studies on *Terminalia*

Terminalia carolinensis was scientifically described in 1932 (The New York Botanical Garden, 2004). It often dominates lowland freshwater wetlands in Kosrae, usually below 80m elevations, along with *Horsfieldia nunu* Kaneh., another endemic tree species to Kosrae locally known as "*Nunu*" (Merlin *et al.*, 1993). During Japanese Colonial period between 1914 and 1945, T. *carolinensis* was heavily logged and used on the island as construction material, or shipped to Japan. No official record was kept regarding how much of this particular tree was shipped during the period, nor of the use of the tree once in Japan. Some of the trees were presumably used as materials for making wooden slippers (or footwear called "*geta*") in Japan (Nanyo Boeki Co., 1942; S. Iwatani [Nanyo Boeki Co.], pers. comm., 2003). After World War II, *Terminalia* forests were permitted a full recovery, as there was no significant exploitation of the resources in the last half of the 20th century (Dahl, 1993).

According to a vegetation map of Kosrae (scale: 1:20,000), there are 345 ha of freshwater forested wetlands (labeled as "swamp forests") that corresponded to 5% of total forest (7,066 ha) or 3% of total land area (11,186 ha) (Whitesell *et al.*, 1986). Also, 175 ha are delineated as a mixture of "swamp forest" and "secondary vegetation", thus there are a total of 520 ha of swamp forests and swamp forest/secondary vegetation.

Some "agroforest" areas, corresponding to 5% of the island, have been originally freshwater forested wetlands (Laird, 1983; Allen *et al.*, 2005).

One of the largest segments of the freshwater forested wetland is Yela *Terminalia* forest at the north western side of the island, 77 ha of which has been recommended for inclusion in the United Nations Environmental Programme World Conservation Monitoring Centre's Protected Areas and World Heritage Programme (UNEP-WCMC, 2001; Allen *et al*, 2005). The same area has been identified as one of 14 "Areas of Biological Significance" in the FSM by The Nature Conservancy (The Nature Conservancy, 2003).

Suitable soil types for *Terminalia* are 1) Inkosr (occupying 526 ha or 5% of total land area), 2) Nansepsep (571 ha; 5%), 3) Sonahnpil (105 ha, 1%), and 4) Ngerungor (69 ha; 0.6%) (Laird, 1983). All soil types are poorly drained with slopes of 5% or less. Nansepsep soils are considered to be most suitable for agriculture among these soil types (Laird, 1983), as they have lower water tables than other three soil types (Allen *et al.*, 2005). The total area combining swamp forests and suitable soil types is 1,555 ha.

With different degree of anthropogenic influence, the average height and diameter at breast height (DBH) of this species differ in different sites, although growing on the same soil types. For example, both growing on Inkosr soils, average height and DBH of *Terminalia* stands in Yela were 32m and 59 cm, while those in Yewak (eastern side, more developed) were 17 m and 23 cm, respectively (Chimner and Ewel, 2005). Also, in comparison of *Terminalia* forests on 3 soil types of Inkosr, Nansepsep, and Sonahnpil, *Terminalia* regeneration was successful only on Inkosr soils, which had the highest water tables (Allen *et al.*, 2005). The same researchers indicated *Terminalia* forests on Nansepsep soil might be facing the greatest risk of land conversion into other uses.

Swamp taro patches, one of the major crops usually found in *Terminalia* land and traditional practice, are considered to have little impact on the land and thus sustainable, because the cultivation does not alter the natural hydrological condition of the wetland, water chemistry, soil temperature, decomposition rates, and soil respiration (Chimner and Ewel, 2004). Besides, the patches are left fallow periodically for a few years, allowing natural regeneration of the land (Chimner and Ewel, 2004). The land on which *Terminalia* or swamp taro grows is categorized as peatland, and the process of peat accumulation has been studied as well (Chimner and Ewel, 2005), showing an interesting example of carbon sequestration in the tropical area.

The total volume of *Terminalia* in 1983 was 19,000m^3: 2,000 m^3 in upland forest and 17,000 m^3 in swamp forest, respectively (MacLean *et al.*, 1988). This inventory did not include *Terminalia* on the areas of agroforest and secondary vegetation.

Socioeconomic and awareness survey on *Terminalia*

A socioeconomic and ecological awareness survey conducted in 1998 and involving 10% of all households in Kosrae showed that 89% of the interviewees owned some *Terminalia* land, and that most grew agricultural products either in or immediately adjacent to *Terminalia* stands (Drew *et al.*, 2005; this sub-chapter is cited from this reference unless otherwise noted). Based on the interview results, a total annual economical value from *Terminalia* land was calculated as $3.1 million, or $4 million together with the goods harvested from the adjacent mangroves (Naylor and Drew, 1998).

This latter value was equivalent to 60% of annual household income in Kosrae in mid 1990s (Drew *et al.*, 2005).

The average cultivated *Terminalia* land owned by a household at this time was 1.42 ha, suggesting a total of 1,264 ha on the entire island. Eighty percent of the interviewees owned less than 2 ha. As for harvesting of *Terminalia*, nearly half of the interviewees (45%) had harvested the tree to clear the land for agriculture (64%) in the previous year 1997, rather than to build canoes (36%) or to obtain timber (18%) and firewood (11%).

In regard to the ecological role of the *Terminalia* forest in the landscape, people were aware of its importance in erosion control and improving water quality. However, only 30% thought that the freshwater wetlands might be affecting downstream mangrove forests. *Teriminalia* forests are proven to be hydrologically connected with outer mangroves (Drexler and Ewel, 2001; Drexler and de Carlo, 2002), however, majority of their interviewees did not see the connection of two ecosystems. Almost all (98%) interviewees believed *Terminalia* forests were very to moderately important to the island. They were optimistic about its provision of natural services (76%), yet the opinion on the future *Terminalia* population was equally divided in two. Eighty-three percent of the interviewees thought some kind of management plan to govern use of *Terminalia* forests was necessary.

2.3. Summary of the literature review and formation of the objectives

In summary, *Terminalia* forests in Kosrae have been documented as a part of general vegetation studies on the island, or they have been studied mostly from the standpoint of natural wetland functions. The study by Drew *et al.* (2005) holds an interesting position; 1) it showed the present day *Terminalia* forests as a traditional agricultural production system, which might have been the first to document it, and 2) it also served as an appreciation of the value of natural wetlands, exhibiting a uniqueness of this system. Natural wetlands and agricultural production are usually not associated in developed countries (Drew *et al.*, 2005), but their work showed such system existed on an island. Their work was successful in presenting an overview of *Terminalia* agroforest; however, because their focus was mostly on the economic evaluation, biophysical characteristics of the system, including distribution of *Terminalia* agroforest, number of crop species, and roles of dominant species were not fully studied yet. Consequently, their evaluation of the system might have been only partial.

The current thesis project was therefore designed to fill in some of the gaps. Due to the time constraint, only small aspects about this system were able to study. One of the questions were whether there was any factor that differentiated *Terminalia* parcel size greater or smaller than 2 ha; for this question, difference of *Terminalia* parcel sizes among different municipalities and among different vegetation/land cover types were selected to examine further. Also, determination of some of the parameters, e.g., average size of parcels and percentages of households who owned *Terminalia* land were thought to be important to see the temporal change. Another important information lacking from the previous study was information about the dominant species *Terminalia*, such as number and size of the trees in each parcel, and how people have managed *Terminalia* in their systems (i.e., if most people were intentionally keeping the tree or rather leaving it naturally growing). Therefore collection of such information was included as part of this study. Lastly, Drew *et al.* (2005) reported that people's opinion was equally divided in two about the future of *Terminalia* forests; how people view the temporal changes of *Terminalia* population at this point was considered important in determining whether conservation was an urgent issue for most of the *Terminalia* forests.

CHAPTER 3

MATERIALS AND METHODS

Households for the interview were randomly selected from the four municipalities, Lelu, Malem, Utwe, and Tafunsak (Figure 3.1), in proportion to the size of their population, using a housing list for the 2000 census (Kosrae Branch Statistics Office, 2002). A total of 56 interviews were conducted: 21, 14, 7, and 14 from Lelu, Malem, Utwe, and Tafunsak, respectively. This corresponded to approximately 5% of all households on the island. Two interviewees reported that they participated in the 1998 survey. Answers from these interviewees were included in the results.

Questions were asked about the interviewees themselves (e.g., age, occupation), their households (number of residents, their age classes), parcels (ownership, location, crops and other plants grown in the parcel), and information pertaining to *Terminalia* (number, age, role, origin, and harvesting practice) (appendix B and C). Names of major crops, trees, and varieties were cited from Merlin *et al.* (1993). Questions were also asked about their understanding of the temporal change in *Terminalia* population over the entire island, and whether the interviewees thought conservation of this tree was necessary. All interviews were conducted orally in Kosraean and recorded in English, with the help of two local interpreters (one male and one female). In addition to the household interviews, 6 key informants who were knowledgeable about *Terminalia* were interviewed to obtain more information on the species, such as its spatial distribution and population change.

After the interviews, we visited 20 *Terminalia* parcels with permission from the interviewees, and recorded their locations with eTrex Legend (Garmin International Inc., Olathe, KS, USA), a Global Positioning System (GPS) device. During the site visits, the Assistant State Forester recorded the approximate number, average height and DBH of *Terminalia* trees in the parcels by observation. Both interviews and site visits took place between mid March to April 2005. Additionally, approximate center coordinates of the parcels were obtained from the Division of Surveying and Mapping, Department of Agriculture, Land and Fisheries, Kosrae State, in order to cross check the locations of parcels visited, and for the overlay analysis with vegetation- and soil maps.

Information was incorporated in a Geographic Information System (GIS) using ArcGIS ver. 9.0 (ESRI, Redland, CA, USA). All maps were projected on the World Geodetic System (WGS) 1984 Universal Transeverse Mercator (UTM) zone 58 N. Official parcel size records were obtained from the Land Court, Kosrae State, and Division of Surveying and Mapping. For the GIS analyses, vegetation map (Whitesell *et al.*, 1986) and soil map (Laird, 1983) in digital forms were obtained from The Nature Conservancy Micronesia Program Office and U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), respectively. Location (municipality), vegetation/land cover- and soil type of the parcels used for the analyses is summarized in Appendix D.

The observed average DBH was later used to estimate the stem volume of *Terminalia* on the agroforestry lands. Equation for the stem volume was cited from Chimner and Ewel (2005) as follows:

$$\text{Stem volume } (m^3 \text{ tree}^{-1}) = 0.25 * \exp(\text{DBH} * 0.044474) \quad (R^2 = 0.66).$$

For the GPS recordings, 6 reference points were arbitrarily selected and GPS readings were repeatedly taken there for determining locational accuracy (Appendices E and F), as Kosrae did not have any GPS stations for differential correction on the island. The largest standard deviations in both UTM northing- and easting directions (± 2.68 m at Tradewind Motel [eastern side of the island] and ± 5.69 m at the Airport [north-western side], respectively) were considered small and negligible for the overlay analyses of parcel locations and other maps.

As for statistical analyses, for the percentage of households owning *Terminalia*, the Z test for comparing two proportions was conducted using the current data and that of the 1998 survey. Descriptive statistical analysis and analysis of variance (ANOVA) were conducted for comparisons among four municipalities for the parcel size, stand density, observed average height and DBH, and stem volume of *Terminalia*. Similar statistical analysis was conducted to determine if there were statistical differences in the parcel size among different vegetation/land cover types regardless of their location within municipalities. For ANOVA, all data sets were transformed to log base 10, as the great variability was observed in the original data sets. Normality of each data set, both before and after log transformation, was checked by error component calculation, Bartlett's test for homogeneity of variances, and examination of the independence of means and variances (data not shown). Mean separation was conducted using Least Significant Difference (LSD) test.

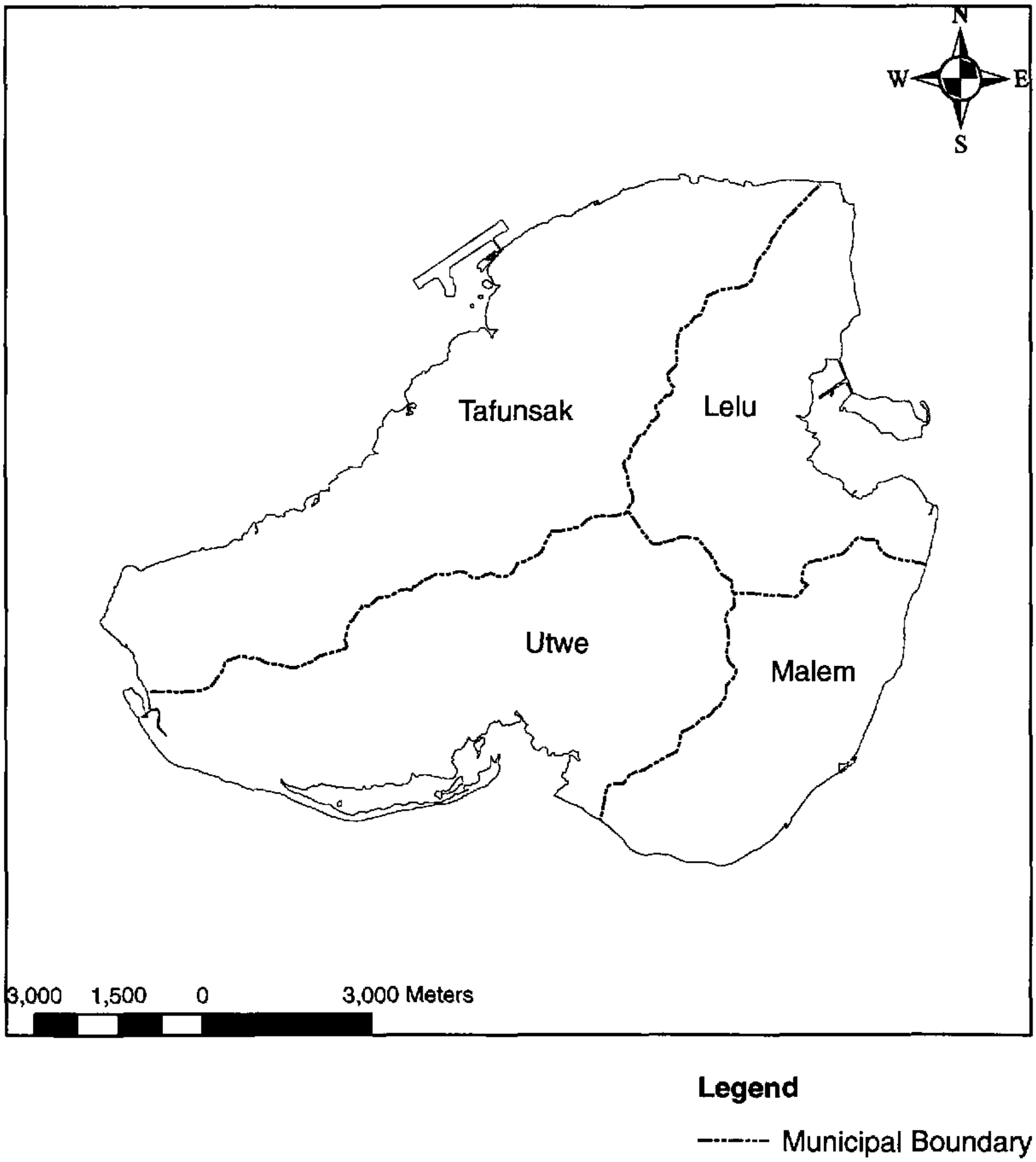


Figure 3.1. Four municipalities in Kosrae.

CHAPTER 4

RESULTS

4.1. Demographic features of the interviewees and households

Average age of the interviewees was 49, ranging from 20 to 76 years old. Eighty-eight percent of the interviewees were male, most of whom were the heads of the household. The selection of the interviewees was slightly influenced by a recommendation from a statistical official that it was usually men who practiced farming in Kosrae (S. Taulung [National Department of Economic Affairs], pers. comm., 2005). However, in some of the households we visited, women were as knowledgeable about farming as men, because they would work together in their parcels. The interviewers thus usually asked for a person for the interview who was either the head of the households or someone who was engaged in farming, regardless of their gender. As for occupation, 22% of the interviewees were employed in the public sector, 38% had jobs in the private sector, 4% were retired, and 11% were unemployed.

Total household members were 472, representing 6% of the population of Kosrae based on the 2000 census (Kosrae Branch Statistics Office, 2002): 44% were children (age 0 – 17 years old), and 56% were adults (18 years and older). The average number of children and that of adults (including senior) per household were 3.7 and 4.7, respectively. In 16% of the households, no family member was formally employed.

4.2. Characteristics of parcels

Most interviewees (85%) owned their parcels, and the rest were leaseholders regardless of the presence or absence of *Terminalia* tree (Appendix C). Seventy-nine percent of the households owned one or two parcels with *Terminalia* trees. The percentage of households who owned (or leased) parcels with *Terminalia* was not significantly different ($\alpha = 0.05$) from that of the 1998 survey (89%), regardless of the participation of the two interviewees who received both surveys (Appendix H).

The average *Terminalia* parcel size was 0.76 ha (detransformed mean; mean of the original data was 1.39 ha) (Table 4.1), with 80% of the parcels less than 2 ha. No statistical difference was found in the parcel size among the four municipalities (Appendix G). On the other hand, vegetation/land cover types had significant effect ($\alpha =$ 0.01) on the parcel size (Figure 4.2). Average parcel size in agroforest (2.09 ha) was statistically different from all the other vegetation/land cover types (less than 0.5 ha) except secondary vegetation (0.69 ha), which was not different from any of the vegetation/land cover types.

Most parcels with *Terminalia* were actively used for agriculture, and more than half of the households (57%) cultivated at least half of the parcels. On average, three family members were engaged in farming, and they worked either bimonthly (14%), once a week (29%), or twice to three times a week (20%). Thirty-two percent of the interviewees reported their parcels had been farmed for a long time (years not specified), 16% more than 50 years, and another 16% for 20 to 29 years. Seventy-two percent reported their parcels were either forests or wetlands prior to the agricultural use. Most households (84%) had a *Terminalia* parcel in the same municipality as their residential municipality. Their cropping system was described as either "mixed cultivation" or "with no specific seasonal cycle", implying most crops were available all year around. Piggeries were included in the parcels owned by 14% of the interviewees, while 64% of them reported passage of wild animals across their parcels including wild pigs and freshwater eels.

Terminalia parcels visited during this study were in the vicinity of housing areas, or easily accessible. We did not visit dense forests such as Yela area. Among 20 parcels visited, both coordinates and parcel sizes for 16 parcels were obtained. Of these 16 parcels, 5 parcels fell on the swamp forests in the vegetation map (Whitesell *et al.*, 1986), 3 on the upland broadleaf forest, 4 on the secondary vegetation, 2 on the agroforest, 1 on the mangrove forest, and 1 on the urban land, respectively (Table 4.2; Figure 4.1). As for the soil type, 3 parcels were on Inkosr and another 3 on Nansepsep, and the rest were on less suitable soil types (Appendix D).

4.3. *Terminalia* in the parcels

Most of the interviewees identified *Terminalia* properly based on its shape, structure, size and shape of its leaves, seeds, flowers, softness of the bark, and its habitat. However, during our site visits, we found out that some interviewees from Lelu had mistaken *Terminalia* for *Elahk* (*Campnosperma brevipetiolata* Volk.), another common tree in the lowland and upland forests in Kosrae (Merlin *et al.*, 1993).

Ninety-six percent of 44 interviewees with *Terminalia* reported that this tree had been present in their parcel as long as they could remember, and only one interviewee (2%) planted it later. Locations of *Terminalia* stands varied, and were either scattered throughout the parcels (34%), located at the edge (32%), or in the center (23%). The number and age of *Terminalia*, as reported by the interviewees, were also different through the parcels: 37% reported that the number of the trees was no more than 10, another 37% between 11 and 50, and 11% between 51 and 100. Average size of *Terminalia* was categorized as "big (10m or taller)" by 78% of the interviewees. Its average age was reported as "10 to 19 years" by 32%, followed by "20 to 49 years" (21%), and "50 to 100 years" (18%). No one could tell exactly how many years an average *Terminalia* would live. Regeneration of *Terminalia* in their parcels was observed by 52% of the interviewees, and 84% reported that they did not make any effort to keep the tree in their parcel. Transplanting of this tree from other places was practiced only by 2 interviewees (4%). Among the households with *Terminalia*, 46% considered this tree as part of the agroforestry system; 68% agreed it served as shade for other crops, and 25% thought it might be important for erosion control.

Based on the site visit results, no statistical difference was observed in the sizes of the parcel, approximate stand density of *Terminalia,* observed average height and DBH, and estimated stem volume among the four municipalities (Table 4.1; Appendix G). Grand mean for the stand density, observed average height and DBH, and stem volume were 21 trees ha^{-1}, 13m, 45cm, and 43 m^3 ha^{-1}, respectively. Overall, stand density showed a great variability (CV of 28% [transformed data]; Appendix G) with Tafunsak and Utwe having denser *Terminalia* stand density (48 trees ha^{-1} and 36 trees ha^{-1}, respectively) than Malem (20 trees ha^{-1}) and Lelu (3 trees ha^{-1}), although statistically nonsignificant. In Lelu, the most developed municipality among the four, many of *Terminalia* stands are assumed to have been cut down without allowing natural regrowth.

Malem had the least variability between the sites in *Terminalia* stand density, average height and DBH, and stem volume.

4.4. Use and harvesting practice of *Terminalia*

Generally, *Terminalia* was used to build canoes (reported by 93% of the interviewees), or used as lumber (55%) and firewood (43%). However, 55% of the interviewees also reported that they themselves had never harvested *Terminalia*. Of those who had harvested *Terminalia*, 18% reported they did once in 3 years or within past 3 years, and 7% once in 4 to 10 years. In the two municipalities of Tafunsak and Malem, one more question was asked about the means of transportation; 88% of the interviewed households owned cars, 12% owned motorboats, and only one household (2%) owned a canoe.

When asked about what part of the tree was commonly harvested for use, 30% of the interviewees reported that they would cut it down and use the whole tree. Some interviewees (9%) reported that they would burn the tree to clear the land.

More than half of the interviewees (68%) felt there was some difference in the quality of *Terminalia* wood when compared to the wood of other tree species. However, there was no consensus regarding the relative merits of different woods for canoe building, lumber, and firewood. Some interviewees suggested breadfruit (*Artocarpus altilis* (Parkinson) Fosb.) for making canoe, and mangrove trees for firewood as substitute trees for *Terminalia*.

4.5. Major crops and plants grown in the parcels

The interviewees were asked to report crops and other plants grown in the parcels (Appendix I). Seven interviewees had two *Terminalia* parcels, and these interviewees provided a list of crops and plants grown in the multiple parcels. The interviewees with *Terminalia* parcels reported a total of 22 crops and other plants. Swamp taro was grown by 91% of the interviewees, followed by breadfruit (84%), bananas (82%), coconut (*Cocos nucifera* L.) (77%), and noni (*Morinda citrifolia* L.) (77%). Swamp taro is sometimes referred to as famine food on some Pacific Islands (Merlin *et al.*, 1993), however, people in Kosrae regard it as staple food and like it as much as soft taro (L. Livaie [KIRMA], pers. comm., 2006). No difference was found in the number of crops and trees between households with or without *Terminalia* in their parcels (22 and 21, respectively). Out of 82 varieties of swamp taro, banana, soft taro, sugarcane, and breadfruit, households with *Terminalia* parcel reported a total of 76 varieties, while those without reported 45 varieties. However, this difference was attributed to one household with *Terminalia* parcel: without this household's answers, households with *Terminalia* parcel reported 45 varieties, the same as that of households without *Terminalia*. In addition to these comparisons, there was no statistical difference in the responses of male and female interviewees in the number of crops reported (mean of 8.9 and 10.0, respectively).

No statistical difference was found among the four municipalities in the number of crop species grown in parcels with *Terminalia* (Table 4.1; Appendix G). However, number of swamp taro varieties was significantly different (Table 4.1; Appendix G), with parcels in Tafunsak having the highest numbers. This was partially understandable from the fact that Tafunsak had the largest total swamp forest and swamp forest/secondary vegetation area (281 ha) than other municipalities (34 ha, 77 ha, and 126 ha in Lelu, Malem, and Utwe, respectively).

Eleven other plants were reported by the interviewees (Appendix J). Nunu was by far the most common species (91% in parcels with *Terminalia*), followed by false sandalwood (*Adenanthera pavonina* L.) (18%), Barringtonia (*Barringtonia racemosa* (L.) Sprengel) (16%), and tree hibiscus (*Hibiscus tiliaceus* L.) (16%). Further questions were asked about nunu, a tree traditionally used as lumber; two-thirds of the interviewees answered that nunu had been in their parcels for a long time. Close to half of them reported that they had "many", or 10 to 50 nunu stands. Forty-four percent of them reported a decrease of its population, 38% an increase, and the rest of them did not see any noticeable change over the years. Some interviewees who reported a decrease added that they deliberately clearcut the tree.

4.6. Perception of the change in *Terminalia* population and necessity for conservation measures

Thirty-nine percent thought that *Terminalia* population was increasing over the entire island, while 29% thought the opposite, and 11% viewed it as stable. One of the explanations for its increase was that people were relying more on imported goods such as cars. Those who thought the population was decreasing attributed this to either overexploitation of the tree for making canoes and for lumber, or land clearing for agriculture or houses.

Most of the key informants supported the view that *Terminalia* was increasing in number and size, because of less demand from local people and successful regeneration of the seedlings. Also, one key informant pointed out that there is only one sawmill on the island, remaining of four operating in the early 1980s. Both the sawmill and its owner are getting old, and people were not sure how long this last sawmill would continue. As a consequence, people have been less inclined to cut down large trees (L. George [canoe builder], pers. comm., 2005). The State Forester had a slightly different view than other key informants, and commented that *Terminalia* population might be fluctuating. He listed several threats to this tree and to freshwater wetlands in Kosrae, such as road construction, land conversion into agriculture or housing (e.g., in Innem and Tofol in Lelu), and encroachment of invasive species (e.g., invasive vine species, *Merremia peltata* (L.) Merr.) (E. Waguk [State Forester], pers. comm., 2005).

Although there was no consensus among all the interviewees on the change in *Terminalia* population, 70% of the total interviewees agreed that some conservation measures were necessary for this tree. Thirty-eight percent of them were aware of KIRMA educational campaign on the conservation of *Terminalia* forests conducted in the previous year, 2004. Most actions suggested were public awareness including school education, and establishment of protection laws and their enforcement. Key informants did not agree with this view, but different management practices were suggested, e.g., selective cutting or planned thinning of *Terminalia* in an agricultural parcel, rather than burning them all or removing small size *Terminalia* trees (E. Waguk [State Forester], pers. comm., 2005; G. Joel [canoe builder], pers. comm., 2005).

In regard with the difference in the response from male and female interviewees, male interviewees tended to be more affirmative towards the questions about the trend of *Terminalia* population and conservation measures; within the male interviewees, 45% reported *Terminalia* population was increasing, and 76% thought conservation measures necessary. Approximately 16% were uncertain (i.e., they answered "I don't know") for both questions. On the contrary, female interviewees seemed to be unaware, uncertain, or would not like to express their opinion about such issues; within the female interviewees, 57% reported that they "don't know" for the first question and 67% for the second question, respectively.

4.7. Different practices and attitudes among municipalities

Several key informants addressed different practices and attitudes among municipalities in the selection of tree species for canoe hulls. Ceremonial or racing canoes, suitable for 6 to 10 passengers, have been made from *Terminalia* in all municipalities, but the canoes for daily use, suitable for 3 to 4 passengers, were not necessarily made from *Terminalia* (A. Tilfas [canoe builder and instructor for traditional skills], pers. comm., 2005). People in Utwe would use *Terminalia* for canoes needed for daily use, while people in other municipalities tended to use breadfruit tree for such purpose. A key informant from Utwe commented that people in Utwe would like to save breadfruit tree for fruit production, and *Terminalia* of suitable size for canoes were more abundant in the vicinity and more easily accessible for them than for people in other municipalities (T. Waguk [tour guide], pers. comm., 2005).

Another key informant from Malem reported that people in Malem might not be as knowledgeable about canoe construction as those in Utwe. This person also reported that people in Malem brought a *Terminalia* tree from the Okat area (in Tafunsak) to construct a racing canoe in the previous year, implying no *Terminalia* stand of a suitable size for a racing canoe was available in Malem (G. Cornelius [Department of Agriculture, Land and Fisheries], pers. comm., 2005).

The key informants disagreed about the longevity of canoes made from different trees. According to the State Forester, however, generally a canoe used daily would last for 2 to 3 years.

Table 4.1. Characteristics of *Termialia* parcels among four municipalities (n = 42). †

	Total	Municipality			
		Lelu	Malem	Utwe	Tafunsak
Size, ha	0.76	0.83	0.48	0.98	0.95
Terminalia in the parcel					
Mean stand density, trees ha^{-1}	21.4	3.2	19.5	36.3	47.9
Mean height, m	13	12	14	12	14
Mean DBH, cm	45	56	41	39	47
Mean stem volume, m^3 ha^{-1}	43	11	31	54	102
Number of crop species (mean)	7.8	9.5	6.7	8.6	7.4
Number of crop species (total)	22	18	17	18	18
Number of swamp taro varieties (mean) ¶	2.6	1.9a	2.7ab	1.7a	3.5b

† All variables were transformed to log base 10 and detransformed back to the original scale.

¶ Means followed by the same lowercase letter for the number of swamp taro varieties are not significantly different at the 0.05 probability level.

Table 4.2. Vegetation category, area, stand density, average height and DBH, and stem volume of *Terminalia* in the 16 parcels visited.

Vegetation/Land cover category	Number of parcels	Total area	*Terminalia* ¶			
			Mean stand density	Mean height	Mean DBH	Mean stem volume
		ha	trees ha^{-1}	m	cm	m^3 ha^{-1}
Swamp forest	5	2.0	84	14	38	119
Upland broadleaf forest	3	2.4	24	16	50	55
Secondary vegetation	4	6.4	11	11	51	32
Agroforest	2	5.7	8	15	53	27
Other (Mangrove forest, urban land)	2	6.1	7	10	38	8

† Out of 20 parcels visited, 4 parcels (3 parcels on swamp forest and one on upland broadleaf forest) did not have official parcel size record. Data from those four parcels are therefore not inluded in the table.

¶ All variables for swamp forest, upland broadleaf forest, and secondary vegetation were transformed to log base 10 and detransformed back to the original scale.

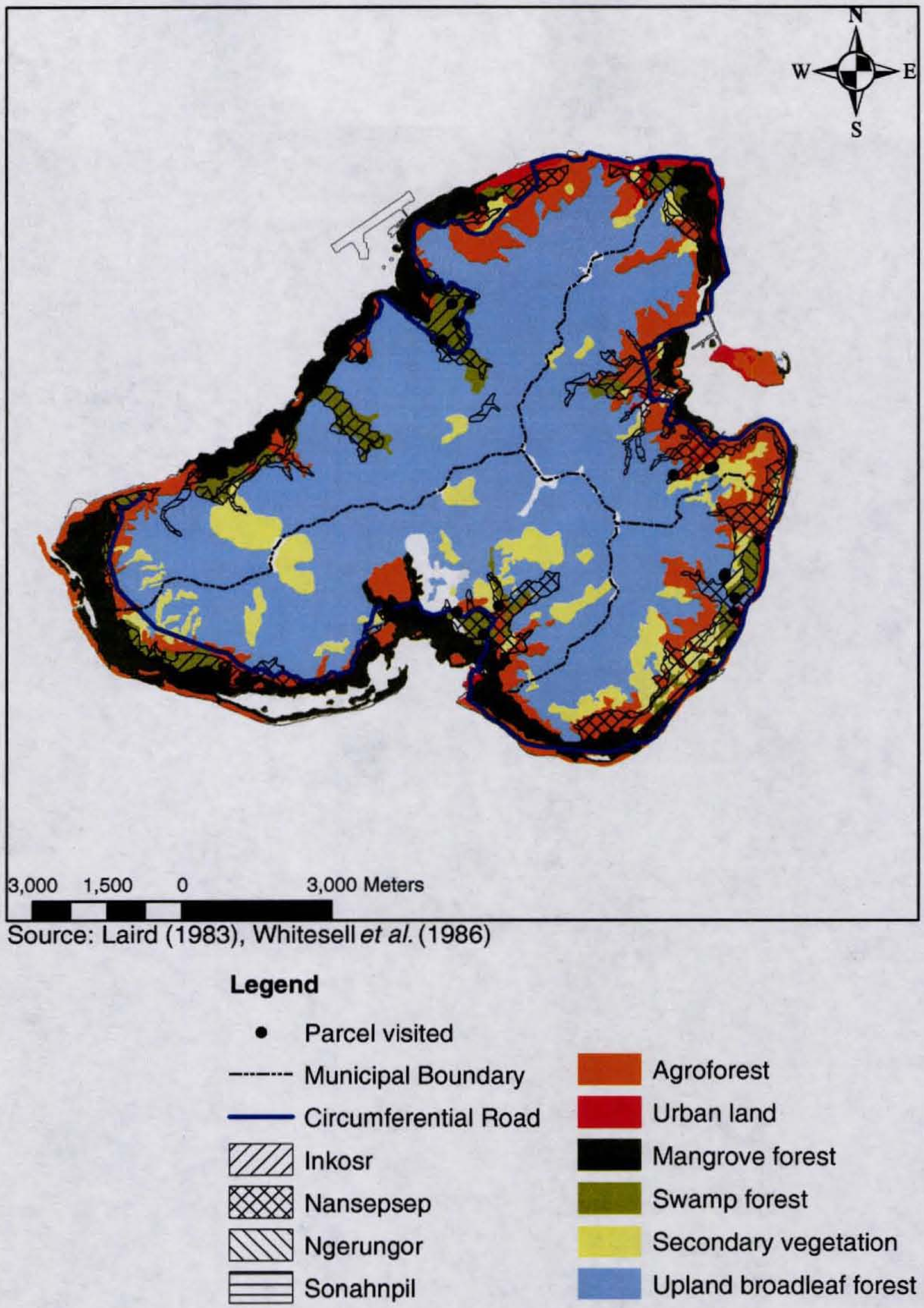
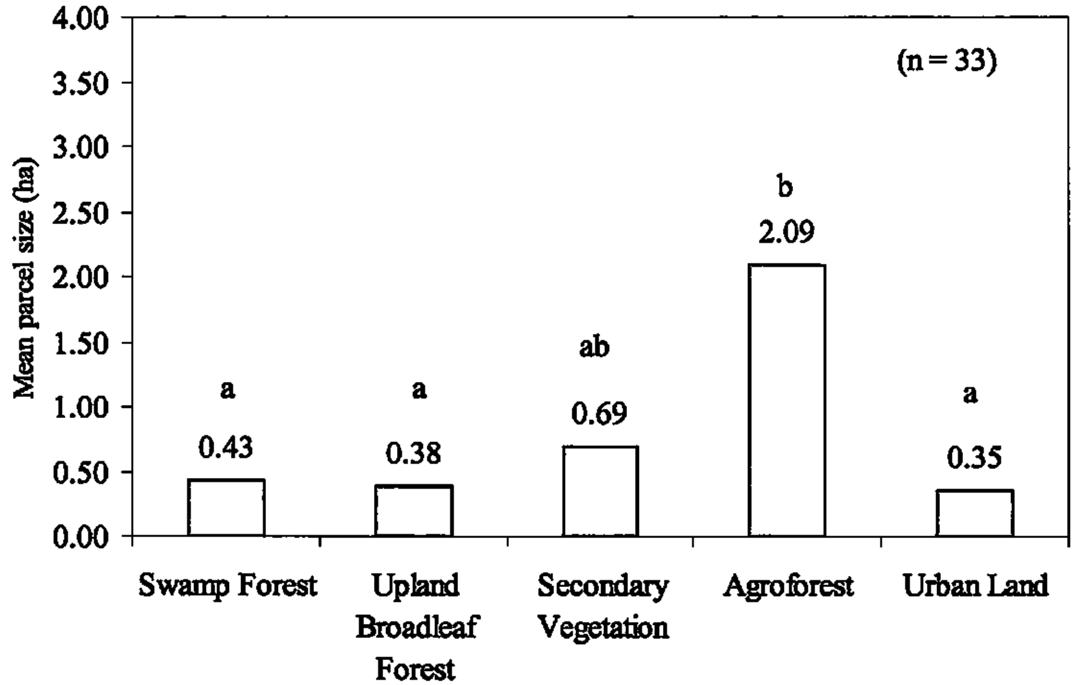


Figure 4.1. Location of parcels visited, soil types, and vegetation/land cover categories.



Note: means with the same lowercase letter are not significantly different at the 0.01 probability level.

Figure 4.2. Mean *Terminalia* parcel size according to vegetation/land cover types.

CHAPTER 5

DISCUSSION

5.1. Characteristics of the sample group in the households

The average numbers of children and adults (over 18 years old) in the households interviewed (3.7 and 4.7, respectively) were similar to those (3.9 and 4.4) reported in the 1998 survey. The percentage of households in which no family member was formally employed (16%) was consistent both with that of the 1998 survey (23%) and with that by Naylor and Drew (1998) (19%) in the 1996 survey for mangrove study.

The percentage of children and adults (44% and 56%) showed a slightly higher percentage in adults than that in children when compared to the 2000 census (52% and 48%). This may be attributed to the fact that census uses different age groups than the current survey (20 years and older are counted as adults). In addition, approximately 30% of the total population fell within the age group of between 10 to 19 years in the 2000 census, implying a large segment may be in the age group between 15 to 24 years in 2005. The proportions of children and adults are thus considered as almost equal, and the sample represented the whole population of Kosrae fairly well.

As for gender, a majority of the interviewees (88%) was male, most of whom were the heads of the household. Gender roles vary in the Pacific Islands depending on many factors, including geographic locations and social and cultural norms and values (UNIFEM, 1998; Seniloli *et al.*, 2002). In Kosrae, it is usually men who are involved in farming, as explained earlier; women are more involved with near-shore fishing in regard with subsistence activities (Des Rochers, 1990; personal observation). Distance of farming (far) and fishing (closer) areas from the house might have affected this gender role differentiation in Kosrae, as women usually stay closer to their house due to house chore and childbearing responsibilities (Raynor, 1989; Seniloli *et al.*, 2002). In our case, some women reported they worked together with men in their parcels, and number of crops reported by male and female interviewees did not show any statistical difference. The gender of the interviewees thus did not seem to have greatly affected their responses about the parcels. However, when asked about more general issues or their opinion, such as *Terminalia* population on the island or conservation issue, different tendencies were observed between male and female interviewees, which might have affected the result. Interpretation of the results about conservation issues thus may need a little more caution than other results.

5.2. Mean *Terminalia* parcel size and percentage of households with *Terminalia* parcels

The average size of home garden units is around 0.1 to 0.5 ha worldwide (Fernandes and Nair, 1986; Kumar *et al.*, 1994; Trinh *et al.*, 2003). Mean *Terminalia* parcel size in Kosrae (0.76 ha) was a little larger than that in other countries, but much smaller than parcels of agroforestry lands in Pohnpei (4.9 ha) (Raynor, 1989). *Terminalia* agroforest is dependent on the soil type and the hydrologic condition, as can be seen in Figure 4.1 and based on the interview results. Therefore the wetland areas are likely to have been fragmented in smaller sizes so as to allow the use of wetlands by many people.

However, it might not be the case with the traditional agroforest in Pohnpei, which are considered a managed landscape, with no pattern in species composition that are dependent on elevation, soil types, or particular region (Raynor and Fownes, 1991). Many of the examples of home garden units cited above were from countries with population densities of 300 people/km^2 or higher, as opposed to those of less than 100 people/km^2 in the Pacific Islands (e.g., Pohnpei and Kosrae). If *Terminalia* agroforest were more of a managed landscape (i.e., free from natural conditions of the land), the average parcel size might have been closer to that of Pohnpei, as a large piece of land may still be available towards the inner side of the island. In this regard, *Terminalia* parcels in agroforest, with the mean parcel size more than 2 ha, may rather share characteristics with the agroforest in Pohnpei; for example, these parcels might have different dominant species (e.g., breadfruit tree), or the actual cultivation area might be small e.g., due to the steepness of the area. Consequently, the economic values coming from these larger parcels might somewhat differ from those coming from smaller parcels in other vegetation types. It should be noted, however, that the vegetation map on which the analysis was based on was published almost 20 years ago, and the current vegetation/land cover might have deviated from the map. When the vegetation map is updated, this analysis should be revised.

Average parcel size in all municipalities derived as arithmetic mean (1.39 ha) was quite similar to that reported from the 1998 survey (1.42 ha: as there was no note in Drew *et al.* (2005) about how they derived the average parcel size, it was assumed that they showed the arithmetic mean). The methods for obtaining the parcel sizes were different, with the current study assumed to be more accurate (being based on official parcel size records). Similar average parcel size estimates between the two studies implies that the previous method (field measurement) was fairly accurate, and it further suggests that the interviewees were honest and accurate in determining their parcel boundaries. The detransformed mean derived from this study (0.76 ha), which was supposed to give more weight to the smaller variates (Little and Hills, 1978), were much smaller, however. In estimating total *Terminalia* land, it might have been more conservative and close to the reality to use such detransformed mean from a data set that had a great variability and when a majority of the parcels were in small sizes.

The percentages of households with *Terminalia* in 1998 (89%) and in 2005 (79%) were not statistically different, implying relatively unchanged conditions during 7 years. Some land conversion from *Terminalia* land to other uses has been reported by Allen *et al.* (2005), however, such as traverse of an extended road through small *Terminalia* forests into a previously isolated village in the southwestern part of Kosrae. In addition, one-third of the households in the 1998 survey, and 9% of the households in the current survey reported that they either harvested or burned the tree for the purpose of clearing lands. It would be of further research interest how much of these cleared lands were permanently converted into other uses, and on what part of the island they are happening most frequently.

5.3. Size and distribution of *Terminalia* stands

Based on the interview results, almost all *Terminalia* stands in the parcels of the interviewees turned out to be of natural origin, or remnant of *Terminalia* forests. Stand densities (ranging from 3 to 48 trees ha^{-1} in each municipality) were smaller, average heights (12 to 14 m) were shorter, DBH (39 to 56 cm) were larger, and stem volumes (11 to 102 m^3 ha^{-1}) were smaller than those in Yewak, Malem (250 trees ha^{-1}, 17 m, 23 cm, and 187 m^3 ha^{-1}, respectively; Chimner and Ewel, 2005), which were approximately 50 years old. Due to the time constraint, the method for capturing *Terminalia* sizes across the entire island was still qualitative. However, some tendencies were observed from the collected data, such as the great variability of *Terminalia* stand densities in each parcel. Considering these data as a preliminary data set, a real measurement of *Terminalia* should be taken in future studies about its size distribution.

Areas and stem volume of *Terminalia* owned by 79% of the households on the entire island were calculated as 895 ha and 30,562 m^3, respectively, based on the number of parcels in different vegetation/land cover types, and mean parcel size and stem volume for each vegetation/land cover type (Table 5.1). The estimated *Terminalia* area is approximately 70% of that calculated by Drew *et al.* (2005) (1,264 ha), and the estimated stem volume is 1.6 times the volume of timber reported by MacLean *et al.* (1988) (19,000 m^3).

In order to further capture the current distribution of *Terminalia* clusters over the entire island, a spatial analysis using recent satellite imagery was undertaken. Some of the dense *Treminalia* forests delineated as "swamp forest" in the vegetation map were visually recognized on a Quickbird satellite image. Preliminary work on the image classification is included in Appendix K. The results obtained this time did not provide enough data to determine whether the area of *Terminalia* clusters was increasing or decreasing compared to Whitesell *et al.* (1986).

5.4. Crops and plants in *Terminalia* parcels

The 1998 survey reported that most households grew multiple crops on *Terminalia* land, documenting 4 major crops and 3 other plants/plant groups (breadfruit, coconut, and various kind of citrus). With the current survey, the list extended to include a total of 33 crops and other plants, and 76 varieties of swamp taro, soft taro, bananas, sugarcane (*Saccharum officinarum* L.), and breadfruit. The number of species was much less than in the agroforest in Pohnpei (127: Raynor, 1989), or other homegardens in the Pacific (53: Barrau, 1961). This could be because wetlands usually have more stressful (waterlogged) conditions than the upland and many agricultural crops may be poorly adapted to these conditions.

Breadfruit and coconut had higher occurrence than they were expected from the 1998 study. Although stand densities of these plants in each parcel were not checked in this study, potentially they may add more economic value to the *Terminalia* land. Noni is another common plant from which fruit extract has been sold recently (personal observation). Further inventory in the field is desirable to examine how many more economically valuable crops and trees exist in *Terminalia* land.

An actual inventory of crops and varieties from the field is also encouraged, with a focus on nutritional values of crops. A recent analysis of local banana and swamp taro varieties, some of which samples had been taken from Kosrae, showed that these crops contained high levels of β- and α- carotene, substances that could help alleviate Vitamin A deficiency (VAD) in the FSM (Engelberger *et al.*, 2003a; Englberger *et al.*, 2003b). In the current study, Tafunsak had more varieties of swamp taro than Utwe and Lelu. The State Forester was supportive of the finding that Tafunsak would have many varieties of swamp taro, referring to a past agricultural survey that showed the same municipality had many varieties of breadfruit and coconut. Furthermore, some of the old varieties of swamp taro might be preserved particularly in the freshwater wetlands in Tafunsak and Utwe (unfortunately, some areas in Utwe have already been converted into other uses since then), implying the significance of these areas as storage for local crop varieties (E. Waguk [State Forster], pers. comm., 2006). Home gardens are considered to serve as refuges for crops and varieties, and they have a large potential for on farm or *in situ* conservation of a wide range of plant genetic resources (Eryzaguirre *et al.*, 2001; Trinh *et al.*, 2003). Based on our finding and comments from the local expert, *Terminalia* land, particularly those in Tafunsak, has quite a high potential in such role. Not all interviewees were familiar with names of varieties, however, probably less so in younger generation (K. Isisaki [Assistant State Forester], pers. comm., 2005). Further studies pertinent to different crop varieties should still cover all four municipalities.

Many other species can be looked at from different perspectives. For example, false sandalwood, one of the species listed in the current study, may have a potential to serve as nitrogen fixer (Raynor and Fownes, 1991; Dr. J.B. Friday [University of Hawai'i], pers. comm., 2005). Valuation of goods and services from *Terminalia* lands is still a challenging task, as not all items can be converted directly into monetary terms. Taking the above examples into account, however, the values from these forests may be higher than that reported by Drew *et al.* (2005).

5.5. Timing of follow-up study and some notes on economic estimate

Another issue noticed while comparing the results from the 1998 and the current survey was that the number of canoes owned by households might vary depending on the time of the year, or even between years. While the 1998 survey reported that 47% of the households owned canoes, the current survey found only one interviewee (2%) who owned canoes in two municipalities (Tafunsak and Malem). The difference might have been attributed to the fact that interviewees in Utwe were not asked this question in the current survey (this municipality is more associated with canoes than other municipalities). The interview results obtained this time were not able to clearly show how often a typical household in Kosrae would construct a canoe, which species of tree would be used most, and also whether there was a particular period for construction, e.g., right before the canoe race event in September. A large canoe race may not be held every year (personal observation), and different municipalities may prefer different wood. The economic estimate from the 1998 may have led to an overestimation in this area. Further consultation may be necessary to determine the frequency of canoe construction and species preference by a typical household on the island.

5.6. Distance of people from traditional skills and their land

Terminalia's uniqueness, particularly its dense forests, has surely attracted the interest of people outside the island, mostly from the aspect of biodiversity. On the contrary, local people's attention towards this tree, particularly its direct use as their daily resource (i.e., for canoe material or lumber), seems to be declining. Decline in the traditional usage of materials is occurring not only for *Terminalia*, but also for other trees. Nunu, another endemic species common in most *Terminalia* parcels and a traditional source of lumber, was perhaps once the most important timber tree (Merlin *et al.*, 1993). As more people started to purchase imported lumber, its value declined to the extent that some people even see it as a nuisance. As Drew *et al.* (2005) pointed out, endemicity of these species, usually highly valued in developed countries, does not seem to be valued by local people.

Greater departure of people from their traditions, including traditional usage of materials and skills, and consequently, from their land, may be progressing in Kosrae (Des Rochers, 1990), a phenomenon also acknowledged in many other places in the world. In the FSM, a survey regarding passing down five traditional skills across three generations demonstrated that all the skills were less conserved in the youngest generation (Lee *et al.*, 2001). This study also indicated that younger Kosraeans did not show interest in learning traditional canoe construction.

5.7. Need for the dissemination of information on *Terminalia* land

Interviewees for both the 1998 and current survey addressed the need for management or conservation plans to *Terminalia* forests (83% and 70%, respectively). In addition to the fact that the local people have been aware of the importance of *Terminalia* forests (based on the result of 1998 survey), these answers could have been influenced by the recent discussion on the further extension of circumferential road and its possible impact on Yela *Terminalia* forest, and the consequent educational campaign by KIRMA. Based on the interview results of the current survey, smaller *Terminalia* patches (i.e., perhaps containing many of the *Terminalia* agroforests) may not need urgent management or conservation actions, as 40% of the household interviewees and a majority of the key informants in the current survey thought that the *Terminalia* population was increasing. Dense forested areas and other *Terminalia* lands need to be discussed separately. Perhaps what local people need at the moment is dissemination of information pertinent to both types of *Terminalia* forests. Consideration should be also given in the selection of target groups so that female adults are not left out.

Coupled with the socioeconomic study result by Drew *et al.* (2005), The result of this study can be used to show an overview of *Terminalia* agroforestry, including approximate number of *Terminalia* stands in different municipality and vegetation/land cover types, and number of crops and plants grown in the land. This will help local people to visualize *Terminalia* agroforest and where the estimated economic values come from. Another study on the different soil types and regeneration patterns of *Terminalia* (Allen *et al.*, 2005) may lead people to reconsider their present practice of removing

Terminalia trees. Falanruw (1993) emphasizes the importance of addressing the "why" of traditional agroforestry, in order to discover principles to extend the system. Also, information on the nutritional value of swamp taro should not be ignored. While the Yela *Terminalia* forest is becoming more internationally known (Appendix A), new concepts such as endemicity could be introduced as part of an education package, as well as "biodiversity", a term less recognized by local people (in association with *Terminalia*) in the 1998 survey. Through touching on the information on *Terminalia* land, some people may reconsider the importance of their traditional skills and values in their resource use, and reconnect themselves to the land again.

Table 5.1. Estimated areas and stem volume for each vegetation/land cover type.

Vegetation/land cover category	Parcel		Corresponding number of households	Mean parcel size	Estmated area	Stem volume per hectare	Estimated stem volume
	Number	Ratio					
				ha	ha	$m^3\ ha^{-1}$	m^3
Swamp forest	7	0.21	177	0.43	75	119	8,947
Upland broadleaf forest	7	0.21	177	0.38	67	55	3,678
Secondary vegetation	7	0.21	177	0.69	122	32	3,854
Agroforest	9	0.26	227	2.09	475	27	12,874
Other (mangrove forest, urban land)	4	0.12	101	0.35 †	155	8	1,208
Total	34	1.00	859 ¶	-	895	-	30,562

† Only the mean parcel size for the urban land is shown due to the protection of private information.

¶ Number of households corresponding to 79% of the total households (1,087) in Kosrae based on 2000 census.

CHAPTER 6

CONCLUSION AND FURTHER STUDY OPPORTUNITIES

This study aimed at further characterization of *Terminalia* agroforestry following the report by Drew *et al.* (2005) with primary focus on the parcel size, size and distribution of *Terminalia*, number of crops and other plants grown in the parcels, and people's perception of *Terminalia* population over the entire island. Both *Terminalia* parcel sizes and *Terminalia* stands exhibited great variability. Parcels in agroforest on the vegetation map turned out to be larger than those in most of the other vegetation/land cover types. As for crops, swamp taro occurred most frequently in *Terminalia* land, and the number of its varieties in Tafunsak was significantly more than those of Utwe and Lelu. Further studies were encouraged for a more detailed inventory of *Terminalia* land, incorporating different focus such as nutritional value of crops.

Close to half of the interviewees and most key informants viewed *Terminalia* population increasing, due to the decline in its direct use and successful regeneration. The dense *Terminalia* forests and smaller patches including most *Terminalia* agroforests were recommended that they be discussed separately, and the latter did not seem to need urgent conservation measures. At this stage, further dissemination of information on both forests was recommended.

Many study opportunities still exist around this *Terminalia* agroforestry, including those not necessarily stemmed from this study results. Some of the topics worth studying further are the effect of mixed stands of naturally occurring species and introduced ones on the wetlands; whether different stand densities of *Terminalia* will affect the agricultural productivity of other crops in positive or negative way (as noted by Drew *et al.*, 2005); and whether species/variety composition is shifting upon the needs of local people and any biophysical change is brought to the wetlands. Also, whether regeneration of *Terminalia* is really progressing towards the regrowth of the forest on different soil types would make an important monitoring study. *Terminalia* tree is definitely one of the key species on the freshwater wetlands in Kosrae, therefore development of some kind of monitoring study for *Terminalia* stands can also serve as a wetland monitoring programs. Connectivity of freshwater wetlands with other ecosystems, and how much more the society benefits by preserving different ecosystems, should be another interesting direction for the studies, as coastal areas in most developed countries already lost the connectivity of coastal and upland vegetation through road construction.

Many Pacific Islands grow swamp taro in the shade of other trees (Falanruw, 1990; Clarke and Thaman, 1993). Also, *Terminalia* freshwater forests are found among some of the islands as well (e.g., *T. richii* in Samoa [Pouli, 2002], *T. canaliculata* in Papua New Guinea and *T. brassii* in Solomon Islands [Scott, 1993]), although the degree of mixed cultivation in these forests is unknown. As Drew *et al.* (2005) noted, further studies on *Terminalia* agroforestry on Kosrae may give implications to places with a similar environment, and also to other places that seek the way of balancing the use and conservation of wetlands.

APPENDIX A.
ARTICLES PERTINENT TO YELA *TERMINALIA* FOREST AND ROAD EXTENSION
(Source: Pacific Magazine online edition)

(October 2003)

Kosrae
Last Ka Forest Under Threat

A major portion of Kosrae's 250 inches of annual rainfall drains through the Yela basin, an area of land that comprises a large portion of the island's total land mass, and contains what many scientists consider to be the world's last remaining intact stand of Terminala Carloninensis trees. The tree is more commonly referred to as Ka on Kosrae, and it is the predominant species found in the freshwater swamps, acting as filters and purifiers between the upland mountains and the mangroves, sea-grass beds and reefs. The ongoing circumfrential road project is now less than a mile away from the Yela drainage and environmental groups, American and Japanese scientists from the U.S. Forest Service, and other concerned citizens are looking for ways to keep the forest, and its pristine watershed, away from the effects of heavy road-building machines and encroachment.

Simpson Abraham, Director of the Development Review Commission; Richard Creed, Civil Engineer; Bruce Howell, Director of Public Works; Moses Palik, DRC Environmental Impact Assessment Specialist and Marcel Jonas of Survey and Mapping discuss the various scenarios associated with putting a road through the Yela Ka Stand, the last forest of its kind in Micronesia. Photo courtesy Olivier Wortel

The Terminalia forests were once common on both Pohnpei and Kosrae, but heavy logging during the Japanese era, and farming, development and settlement in the ensuing years has left the Yela Ka stand as the last of its kind globally. The government has been sending personnel from various agencies into the massive swamp to ascertain the most viable route, both in financial and environmental terms. Simpson Abraham, the director of the Development Review Program, the environmental and permitting arm of the government, has been spearheading efforts to bring awareness to what he considers to be "an area of particular concern" on Kosrae.

Along with Bruce Howell, the director of Public Works, Abraham recently brought in Richard Creed, a retired civil engineer who resides most of the time in the woods of Northern Idaho, but over the last decade has become well known in environmental circles for his solid work on roads in Yap, Guam, Hawaii and Palau. According to Abraham, the forest is of major biological, ecological, aesthetic and economic importance to the island and the people. His major priority at this point, he says, is to get together with the main landowners and try to come to a consensus on the value of saving rather than cutting the area. If you are visiting Kosrae, make the effort to get a boat ride into the area for a hike. The towering trees, with their huge wall roots and canopy of nearly perpendicular branches, are about as tropical as one can get.

-Olivier Wortel

http://www.pacificislands.cc/pm102003/pmdefault.php?urlarticleid=0015

(February 2004)

Kosrae

Road Danger Warnings

Katherine C. Ewel, a senior scientist with the U.S. Forest Service and the Institute of Pacific Islands Forestry, has warned of the dangers to a pristine forest area in Kosrae if a new round-the-island road is completed. She issued a report to the Development Review Commission on Kosrae that describes the Yela forest area as one of Micronesia's greatest treasures that includes one of the few remaining Ka trees in the world. The Yela Ka swamp was listed as one of 14 "areas of biological significance" during a recent assessment of biodiversity in the Federated States of Micronesia, undertaken by The Nature Conservancy.

Blair Charley of the Kosrae Island Resource Management Authority wades knee-deep at the upper reaches of the Yela Ka swamp, said to be

one of the most pristine forests in the Micronesian area that is in danger from a new road project.
Photo: Olvier Wortel

"The Yela watershed is the largest and perhaps the most valuable intact landscape remaining in Kosrae," Ewel says. "Left undisturbed, it will continue to provide a supply of firewood from its mangrove forest and fish from its offshore waters. With the largest remaining stand of Terminalia carolinensis in the world, the natural beauty of a wild and undisturbed wetland will attract tourists, even if seeing it requires hiking for some distance from the ends of the existing roads." If landowners agree to not allow access to their lands for the new road project, Ewel urges the government to reward them for "serving a common good."

Conservations are worried that any road will bring with it garbage, pigpens, and the introduction of invasive vines, grasses, and weeds that could eventually choke the Yela watershed area.

-Olivier Wortel

http://www.pacificislands.cc/pm22004/pmdefault.php?urlarticleid=0044

APPENDIX B.
INTERVIEW SHEETS

<u>Questions for the interview with randomly sampled households (Confidential part)</u>

NOTE: THIS PAGE WILL BE KEPT CONFIDENTIAL AND DESTROYED AT THE END OF THE RESEARCH.

1. Personal information on the interviewee

1-1 Interviewee's name: ______________________________

1-2 Age: ________ years old

1-3 Sex: M / F

1-4 Occupation/title (if any): ______________________________

1-5 Address (Municipality, Kumi-no):______________________________

____

1-6 Phone:___________

2. Information on the household (later summarize nos. in non-confidential sheet)

2-1 Number of household members (+ their ages, sexes, occupation)

2-2: see Non-Confidential Part

3. General information on the farm/agricultural parcel

3-1: See Non-Confidential Part

3-2: See Non-Confidential Part

3-3 Parcel no.

10. Other

10-4 Can I visit your parcel (preferably with the interviewee) and take photos of the place? I can come back for other days as well.

Questions for the interview with randomly sampled households (Non-confidential part)

NOTE: IF REQUESTED BY INTERVIEWEES, ANY INFORMATION IN THIS SECTION MAY BE KEPT CONFIDENTIAL AS WELL (SPECIFY).

1. Personal information on the interviewee: see Confidential Part

2. Information on the household (summary)

2-1 * Later summarize ONLY numbers

(Numbers)

Male adults (working age) –
Female adults (working age) –
Children -
Senior (over 60 years old) -

2-2 Number of household members usually working on the farm/agricultural parcel (or among the listed household members, how many adults works on the parcel, and how often?)

3. General information on the farm/agricultural parcel

3-1 Location (if multiple locations, please list all)

3-2 Acreage

3-3 See Confidential Part

3-4 Ownership

a. The family owns the land and cultivate it themselves
b. Leased by other people and the family cultivate on it
   from: Relative / Non-relative
c. Other (specify)
d. Don't know exactly

4. History of the parcel

4-1 How long has the place been in use as an agricultural parcel?

4-2 Do you know anything about the previous land use / land cover of the parcel? (e.g. forest)

4-3 How much of this parcel has been planted deliberately? If there is a periodic cycle for the use of the parcel (e.g. fallow- and cultivation period), please explain it briefly.

5. Plants in the parcel and rotation

5-1 Do you have *Ka* tree in your parcel?

a. Yes: How many? a-1: No.s (could be approximate no.s) ______________
a-2: Don't know how many

b. No

c. Don't know: c-1 I don't know how the tree looks like
c-2 I know how the tree looks, but am not sure if we have it in the parcel

5-2 What are crops that you grow in the parcel (including different varieties)?

a. Giant taro (or *Pahsruhk*): (var.) 1) *Ebon*, 2) *Tepat*, 3) *Wasrwasr*, 4) *Siminton*, 5) *Kihrngihsi*, 6) *Mokil*, 7) *Nukor*, 8) *Pahsruhk kac*, 9) *Ikinlahs*, 10) other variety [mark if the interviewee has the variety]

b. Soft taro (or *Kuhtak*): (var.) 1) *Kohsroh*, 2) *Ikinmuhla*, 3) *Fahluhl*, 4) *Filac*, 5) *Nukor*, 6) *Pingelap*, 7) *Saipan*, 8) *Hawaii*, 9) *Palau*, 10) *Ruk*, 11) *Kosroh kwekwe*, 12) other [mark if the interviewee has the variety]

c. *Onak* (*Alocasia macrorrhiza* – wild taro)

d. Banana (or *Usr*):

Cooking bananas

(var.) 1) *Apact*, 2) *Apact fusus*, 3) *Usur wac*, 4) *Kaclfoni*, 5) *Kuhlahsr*, 6) *Sentoki*, 7) *Kuhlontohl*, 8) *Inyacir*, 9) other

Eating bananas

(var.) 1) *Kuhfahfah*, 2) *Fiji*, 3) *Taiwang*, 4) *Lakuhtan*, 5) *Pucnluc*, 6) *Kihriac*, 7) *Usr ruk*, 8) other

[mark if the interviewee has the variety]

e. Sugar cane (or *Tuh*)

(var.) 1) *Eir*, 2) *Eseng*, 3) *Ponol*, 4) *Tuh sal* or *Tuh srolsroal*, 5) *Tuh in Kos* or *Tuh Kosra*, 6) *Tuh srac*, 7) *Tuh fasrfasr*, 8) *Tuh Pohnpei* or *Aiwanik*, 9) *Tuh tihng*, 10) *Tuh pahlahng*, 11) other

[mark if the interviewee has the variety]

f. Tapioca

g. Other (specify)

5-3 Please name all plants (e.g. trees, other than crops) that you deliberately grow for certain use.

a. Breadfruit (or *Mos*):

Mos yohlahp (rough-skinned breadfruit varieties)

(var.) 1) *Puhtaktuck*, 2) *Puhtaktuck foksruhsrak*, 3) *Ikinyacsrihk*, 4) *Puhtaktuck nurem*, 5) *Oahkahs*, 6) *Foksruhsrack*, 7) *Fok kuhracn*, 8) *Sra waseng*, 9) *Fok kwekwe*, 10) *Inohl oa*, 11) *Inohl wet*, 12) *Fok fasr*, 13) *Ikin pe*, 14) *Fucsr*, 15) *Muhnyepuhng*, 16) *Yoarkuhn*, 17) *Sruf*, 18) *Nuuhsr*, 19) *Fok kohloh*, 20) *Inpuhlah*, 21) *Mos in Kosra*, 22) other

Mos fwel (smooth-skinned breadfruit varieties)

(var.) 1) *Ikunloal nurem*, 2) *Musunwac*, 3) *Sra fohn*, 4) *Popol*, 5) other

[mark if the interviewee has the variety]

b. Tangerine

c. Lime

d. Noni

e. Coconut (or *Koacnu*)

f. Other (specify)

5-4 Is there anything that you notice about the quality of the crops (e.g. taste) that you notice between those grown in an agricultural parcel with *Ka* tree and those without this tree?

a. Yes (specify)

b. No

c. Don't know

5-5 Could you name some of the other plants that you recognize in the parcel, which you do not know how to use? (including weeds)

5-6 Do you have *Nunu* (*Horsfieldia nunu*, another endemic tree in the secondary vegetation) in your parcel?
(Note: this question is for the case only when people haven't mentioned Nunu in 5-4.)
  a. Yes -> How many? How long has it been there? Increasing/decreasing?
  b. No
  c. Don't know

5-7 Do you raise any animals in the parcel?
  a. Yes
  b. No, but wild animals come and go (specify the animals)
  c. Don't know

5-8 Can you briefly describe the farming cycle in your parcel, if you have fallow period, or practice rotational farming system? (Note: This cycle does not necessarily have to associate with *Ka* tree)

6. Information on *Ka* tree (location, origin, age and other information) in the parcel
*** If 5-1 (do you have ka tree in your parcel?) is "Yes", then ask following questions. If not, pass the whole section.**

6-1 Was *Ka* tree there from the start, or planted later?
  a. It was (they were) there from the start
    a-1: Originally cleared the forest for agricultural use, but kept some for providing shades
    a-2: Originally cleared the forest for agricultural use totally, and later Ka tree grew back
  b. Planted later: by who, and when? (specify)
  c. Don't know

6-2 Do you know the difference between *Ka*, *Srifacf*, and *Elahk*?

(* *Ka*: Terminalia carolinensis, *Srifacf*: T. catappa, *Elahk*: Campnosperma brevipetiolata)

a. Yes: How do you specify?
b. No
c. Don't know for sure but I guess it's *Ka* tree that I have in the parcel

6-3 Where is *Ka* tree located in the parcel?

a. Edge of the parcel
b. Center
c. Scattered throughout the parcel
d. Don't know

(Ask a simple sketch where Ka tree exist, in relation with the parcel entrance, roads, etc)

6-4 How big (tall, large) is *Ka* tree? Do you know how old the tree is?

6-5 Have you seen *Ka* tree regenerate in the parcel?

a. Yes: Please briefly explain where, when or how often.
b. No
c. Don't know

6-6 Are you trying or have you (or any other family members) tried to keep *Ka* tree in the parcel?

a. Yes, and I'm successful: -> How?
b. Yes, but I failed: -> How many trees are left now?
c. Never thought of it
d. Don't know

6-7 Would you consider *Ka* tree as a regular component of Kosrae's common farm?

a. Yes
b. No
c. Don't know
d. Other (specify)

7. Use of *Ka* tree and harvesting practice

7-1 What is/are the major use(s) of *Ka* tree among your family? (Mark all that apply)

[Alive Ka tree in the parcel]

a. Shade for other crops
b. Erosion control
c. Provision of structure for other crops
d. Fence (show border between parcels of other families)
e. Other (specify)

[Ka tree as a product]

a. Firewood
b. Making canoes: Ceremonial / Daily use
c. Making other handicrafts (specify)
d. Medicinal use
e. For commercial sale (woods? Or other use?)
f. Other (specify)

7-2 How often do you harvest *Ka* tree?

7-3 What part do you use? Please explain briefly your harvesting practice. If the practice has changed over time, please address all methods you have taken. Also, if you have heard of your parents' or grandparents' practice, please include that as well.

a. Cutting down the whole tree, use the whole material
b. Usually Leave the stem, and only take branches
c. Other (specify)

7-4 Is there any difference in the quality of wood (or product) between *Ka* tree and other trees that you are particularly aware of?

7-5 Can you name some of the trees that can be substituted the use of *Ka* tree, both in agricultural plot and the product?

8. Association with other place(s) where *Ka* tree stands can be found (e.g. forests)

8-1 Do you know how where the nearest forest/place is that you can find *Ka* tree?

8-2 Do you or have you ever collected *Ka* seeds from the forested area or someone's agricultural parcel, and tried to grow in your parcel?

a. Yes: a-1. Regrowing successfully -> Seeds from where?
a-2. Tried, but failed -> Seeds from where?
b. No, never collected and introduced on my parcel
c. Other (specify)

9. General recognition on the trend of *Ka* tree

9-1 From your view, is *Ka* tree in Kosrae increasing, decreasing, or stable in amount?

a. Increasing
b. Decreasing -> Since when is it decreasing?
c. Stable
d. Don't know

9-2 Do you know about the conservation campaign on *Ka* tree conducted by KIRMA last year (2004)?

a. Yes
b. No

9-3 Do you think *Ka* tree needs some kind of conservation measure?

a. Yes -> Any suggestion as for area or method?
b. No
c. Don't know

9-4 Have you been interviewed about *Ka* tree before?

a. Yes -> By who?
b. No
c. Don't remember/Don't know

10. Other

10-1 What other plants or resources are you concerned most, if any?

10-2 (Note: this question is for interviewees who don't grow taros themselves only) Do you eat taros, particularly giant taro and soft taro? Where or from who do you get it, and how often?

a. Yes, daily -> where/who
b. Yes, weekly -> where/who
c. Yes, once in two weeks to monthly -> where/who
d. Yes, only occasionally (e.g. at parties)
e. No

10-3 Could you name anyone that might be knowledgeable about *Ka* tree?

10-4: See Confidential Part

<u>Questions for the interview with key informants</u>

1. Personal information on the interviewee

1-1 Interviewee's name: ______________________________

1-2 Age: ______ years old

1-3 Sex: M / F

1-4 Occupation/title (if any): ____________________________

1-5 Address (Municipality, place name):______________________________

____

1-6 Phone:__________

2. Questions

2-1 Main activity(s) practiced by the interviewee that is related to *Terminalia carolinensis* or *Ka* tree

2-2 Spatial distribution of the tree (where to find *Ka* tree)

2-3 Trend (increase/decrease in the forests or agroforestry stands, change in usage, etc)

2-4 Classification between other similar species (e.g. with *Terminalia catappa* or *Srifacf*)

2-5 Other information

APPENXIX C.
SUMMARY OF THE HOUSEHOLD INTERVIEW RESULTS

1. Information on the parcels of interviewees.

1) Ownership

Category	Total	% answers (n = 58)
Family owns the land	49	84.5
Leased by other people	7	12.1
Other (half owned by the family, half by the government)	1	1.7
Don't know	1	1.7

2) Number of households with and without *Terminalia*

Category	Total	% answer (n = 56)
Households with *Terminalia*	44	78.6
Households without *Terminalia*	11	19.6
Don't know	1	1.8

3) Portion of parcel used/cultivated

Category	Total	% answers (n = 44)
All or most of the parcel	12	27.3
More than half	5	11.4
Half	8	18.2
One-tenth to less than half	11	25.0

4) Frequency of farming

Category	Total	% answers (n = 44)
Once a week	13	28.6
Twice to three times a week	11	19.6
Bimonthly	5	14.3

5) Age of parcel

Category	Total	% answers (n = 44)
Older than 50 years	7	15.9
40 - 49 years	6	13.6
30 - 39 years	4	9.1
20 - 29 years	7	15.9
10 - 19 years	2	4.5
0 - 9 years	4	9.1
Long time in use for farming (years not specified)	14	31.8

6) Previous use/land use of parcel

Category	Total	% answers (n = 44)
Swamp	16	36.4
Forest	15	34.1
Used for farming as long as the interviewee remembered	7	15.9
Other uses	2	4.5

7) Animals in parcel

Category	Total	% frequency (n = 44)
Deliberately keeping animals inside the parcel(s)	12	27.3
(Pigs in pig pens)	(6)	(13.6)
Wild animals passing	28	63.6
(Wild pigs)	(25)	(56.8)
(Freshwater eels)	(2)	(4.5)

* Question (3) to (7) include answers from the households with *Terminalia* only.

2. Information on *Terminalia* in the parcels.

1) Origin of *Terminalia*

Category	Total	% answers (n = 44)
Existed originally in the parcel(s)	42	95.5
Planted later	1	2.3

2) Location of most *Terminalia* in the parcel

Category	Total	% answers (n = 44)
Scattered throughout the parcel(s)	15	34.1
Edge	14	31.8
Center	10	22.7

3) Number of *Terminalia* in the parcel

Category	Total	% answers (n = 57)
1-10	21	36.8
11-50	21	36.8
51-100	6	10.5
More than 100	1	1.8
Many (numbers not specific)	3	5.3

4) Size of average *Terminalia*

Category	Total	% answers (n = 44)
Big (10m or taller)/Old	35	79.5
Medium (5-10m, medium-aged)	4	9.1
Small (smaller than 5m)/Young	2	4.5

5) Age of average *Terminalia*

Category	Total	% answers (n = 44)
More than 100 years	1	2.3
50-100 years	8	18.2
20-49 years	9	20.5
10-19 years	14	31.8
Less than 10 years	1	2.3

6) Regeneration of *Terminalia* recognized in the past

Category	Total	% answers (n = 44)
Yes	23	52.3
No	5	11.4

7) Any efforts made to keep *Terminalia* in the parcel

Category	Total	% answers (n = 44)
Yes	4	9.1
No	37	84.1

8) Any efforts made to transplant Terminalia in the parcel?

Category	Total	% answers (n = 56)
Yes	2	3.6
No	52	92.9

9) Consider *Terminalia* as an agroforestry component?

Category	Total	% answers (n = 44)
Yes	20	45.5
No	12	27.3
Don't know	10	22.7

10) Role of *Terminalia* in the parcel

Category	Total	% frequency (n = 44)
Shade for other crops	30	68.2
Erosion control	11	25.0
Fence (show borders between parcels)	3	6.8
Fertilizer (provide nutrients)	2	4.5
Keep soil wet	1	2.3
Bird's nest	1	2.3
Beautifiaction	1	2.3
No use	6	13.6

3. Use of *Terminalia* and harvesting practice.

1) Use of *Terminalia* as products

Category	Total	% frequency (n = 56)
Canoe	52	92.9
Lumber	31	55.4
Firewood	24	42.9
Handicraft, furniture (table)	12	21.4
Medicinal use	3	5.4
Food (fruit edible)	3	5.4
Commercial use (any part for selling)	1	1.8

2) Frequency of harvesting *Terminalia*

Category	Total	% answers (n = 56)
Once in 3 years (or within past 3 years)	10	17.9
Once in 4-10 years	4	7.1
Once in 11-20 years	3	5.1
Just one time to clear for agriculture (period not specific)	1	1.8
Never harvested	31	55.4

3) Parts for harvesting

Category	Total	% answers (n = 56)
Cut down and use the whole tree	17	30.4
Just burn the tree (for clearing)	5	8.9
Usually leave stems, only take branches	1	1.8

APPENDIX D.
SUMMARY OF PARCELS USED FOR THE ANALYSES

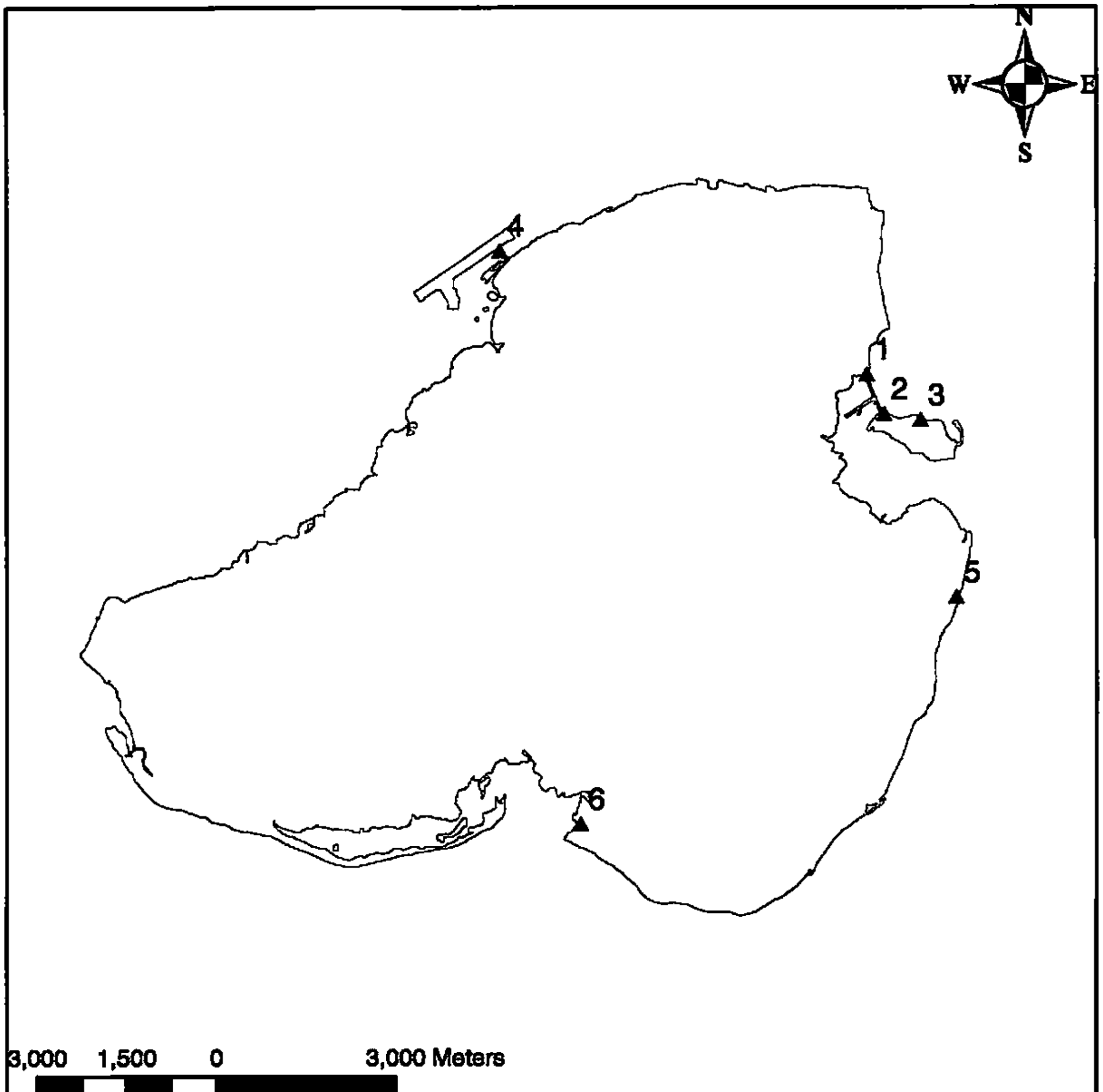
No	Municipality	Vegetation / land cover type †	Soil type ¶	Site Visit	Used for the analysis among municipalities	Used for the analysis among vegetation types
1	Lelu	SF	Ngerungor		x	x
2	Lelu	SV	Fomseng	x	x	x
3	Lelu	SV	Fomseng	x	x	x
4	Lelu	AF	Inkosr		x	x
5	Lelu	AF	Tolonier	x	x	x
6	Lelu	AF	Fomseng		x	x
7	Lelu	DD	Tolonier		x	x
8	Lelu	(unknown)	(unknown)		x	
9	Lelu	(unknown)	(unknown)		x	
10	Lelu	(unknown)	(unknown)		x	
11	Lelu	(unknown)	(unknown)		x	
12	Malem	SF	Naniak	x	x	x
13	Malem	SF	Inkosr	x	x	x
14	Malem	UBF	Fomseng	x	x	x
15	Malem	UBF	Fomseng	x	x	x
16	Malem	UBF	Inkosr		x	x
17	Malem	UBF	Nansepsep		x	x
18	Malem	UBF	Nansepsep		x	x
19	Malem	UBF	Nansepsep		x	x
20	Malem	SV	Fomseng		x	x
21	Malem	SV	Fomseng		x	x
22	Malem	AF	Nansepsep		x	x
23	Malem	DD	Ngedebus		x	x
24	Malem	(unknown)	(unknown)		x	
25	Malem	(unknown)	(unknown)		x	
26	Tafunsak	SF	Inkosr	x	x	x
27	Tafunsak	SF	Inkosr		x	x
28	Tafunsak	SF	Inkosr	x	x	x
29	Tafunsak	UBF	Nansepsep	x	x	x
30	Tafunsak	AF	Naniak		x	x
31	Tafunsak	AF	Naniak	x	x	x
32	Tafunsak	AF	Tolonier		x	x
33	Tafunsak	AF	Nansepsep		x	x
34	Tafunsak	AF	Nansepsep		x	x
35	Tafunsak	DD	Ngedebus	x	x	x
36	Tafunsak	(unknown)	(unknown)		x	
37	Tafunsak	(unknown)	(unknown)		x	
38	Utwe	SF	Nansepsep	x	x	x
39	Utwe	SV	Nansepsep	x	x	x
40	Utwe	SV	Fomseng	x	x	x

No	Municipality	Vegetation / land cover type †	Soil type ¶	Site Visit	Used for the analysis among municipalities	Used for the analysis among vegetation types
41	Utwe	SV	Fomseng		x	x
42	Utwe	MF	Fomseng	x	x	
43	Utwe	(unknown)	(unknown)		x	
44	Utwe	(unknown)	(unknown)		x	
45	Utwe	(unknown)	(unknown)		x	
	Total			16	45	33

† Abbreviations for the vegetation/land cover types are SF, Swamp Forest; SV, Secondary Vegetation; AF, Agroforest; UL, Urban Land; UBF, Upland Broadleaf Forest; MF, Mangfove Forest. Vegetation/land cover types are cited from Whitesell *et al*. (1986).

¶ Names of soil types are cited from Laird (1983).

APPENDIX E.
REFERENCE POINTS FOR GPS CALIBRATION



Legend

▲ GPS Reference point

1	Causeway Bridge (north end)
2	Causeway Bridge (south end)
3	Tradewind Motel
4	Airport
5	Lelu-Malem Municipal Boundary
6	Utwe Harbor

APPENDIX F.
GPS CALIBRATION DATA

1) Causeway Bridge - North end

No	Date	Time	UTM58N (m) N	UTM58N (m) E
1	03/20/05	16:45	590692	280501
2	03/22/05	16:45	590691	280506
3	03/25/05	17:12	590690	280503
4	03/27/05	16:45	590692	280504
5	03/30/05	16:45	590691	280506
6	04/05/05	16:47	590691	280501
7	04/08/05	16:42	590691	280503
8	04/15/05	16:45	590690	280506
9	04/21/05	16:43	590684	280506
10	04/24/05	16:44	590690	280506
11	04/25/05	16:44	590690	280503
12	04/26/05	16:45	590690	280501
Mean			590690.2	280503.8
SD			2.08	2.12

2) Causeway Bridge - South end

No	Date	Time	UTM58N (m) N	UTM58N (m) E
1	03/20/05	16:30	590031	280790
2	03/22/05	16:30	590032	280788
3	03/25/05	16:56	590028	280793
4	03/27/05	16:30	590032	280790
5	03/30/05	16:30	590029	280788
6	04/05/05	16:36	590032	280790
7	04/08/05	16:27	590030	280791
8	04/15/05	16:27	590031	280791
9	04/21/05	16:26	590030	280788
10	04/24/05	16:28	590031	280793
11	04/25/05	16:30	590032	280791
12	04/26/05	16:30	590030	280791
Mean			590030.7	280790.3
SD			1.30	1.72

3) Tradewind Motel

No	Date	Time	UTM58N (m) N	UTM58N (m) E
1	03/20/05	17:30	589925	281410
2	03/22/05	17:12	589931	281414
3	03/25/05	17:34	589928	281417
4	03/27/05	17:10	589932	281415
5	03/30/05	17:08	589931	281410
6	04/05/05	17:09	589930	281409
7	04/08/05	17:08	589928	281410
8	04/15/05	17:10	589927	281412
9	04/21/05	17:10	589927	281410
10	04/24/05	17:10	589935	281409
11	04/25/05	17:10	589929	281410
12	04/26/05	17:08	589930	281412
Mean			589929.4	281411.5
SD			2.68	2.58

4) Airport

No	Date	Time	UTM58N (m) N	UTM58N (m) E
1	04/05/05	14:20	592754	274347
2	04/14/05	14:20	592749	274358
3	04/20/05	14:20	592752	274347
4	04/26/05	14:25	592751	274346
Mean			592751.5	274349.5
SD			2.08	5.69

5) Lelu-Malem Municipal Boundary

No	Date	Time	UTM58N (m) N	UTM58N (m) E
1	04/05/05	13:45	586968	282010
2	04/14/05	13:45	586969	282017
3	04/20/05	13:45	586972	282012
4	04/26/05	13:52	586970	282008
Mean			586969.8	282011.8
SD			1.71	3.86

6) Utwe Harbor

No	Date	Time	UTM58N (m) N	UTM58N (m) E
1	04/05/05	13:25	583156	275702
2	04/14/05	13:25	583155	275708
3	04/20/05	13:26	583156	275702
4	04/26/05	13:37	583157	275705
Mean			583156.0	275704.3
SD			0.82	2.87

Average SD

	UTM58N (m)	
	N	E
SD	1.78	3.14

Maximum SD

	UTM58N (m)	
	N	E
SD	2.68	5.69
Place	3)	4)

Minimum SD

	UTM58N (m)	
	N	E
SD	1.72	0.82
Place	2)	6)

APPENDIX G.
STATISTICAL ANALYSES FOR THE SELECTED VARIABLES

1. Size of parcel (among four municipalities)

Descriptive statistics

	Total	Municipality			
		Lelu	Malem	Utwe	Tafunsak
Original data					
Number of samples	45	11	14	8	12
Total, ha	62.4	14.0	12.7	16.5	19.2
Minimum, ha	0.1	0.2	0.1	0.2	0.2
Maximum, ha	7.1	4.3	6.7	5.1	7.1
Mean, ha	1.39	1.27	0.91	2.06	1.60
Standard Deviation (SD), ha	1.72	1.20	1.68	2.05	1.94
Coefficient of Variation (CV), %	124%	95%	185%	100%	121%
Transformed data (multiplied by 10000 and transformed to log10)					
Detransformed mean, ha	0.76	0.83	0.48	0.98	0.95
Coefficient of Variation (CV), %	12%	11%	11%	16%	11%

Analysis of variance

Source	df	SS	MS	F
Original data				
Total	44	129.7		
Municipalities	3	7.5	2.50	0.84 NS †
Error	41	122.2	2.98	
Transformed data (multiplied by 10000 and transformed to log10)				
Total	44	10.1		
Municipalities	3	0.8	0.26	1.14 NS †
Error	41	9.3	0.23	

† NS, nonsignificant at the 0.05 probability level.

2. Size of parcel (according to vegetation/land cover types)

Descriptive statistics

	Total	Vegetation/land cover type				
		Swamp forest	Upland broadleaf forest	Secondary vegetation	Agroforest	Urban land
Original data						
Number of samples	33	7	7	7	9	3
Minimum, ha	0.2	0.2	0.2	0.2	0.6	0.15
Maximum, ha	7.1	0.8	1.0	4.5	7.1	1.0
Total, ha	44.0	3.3	3.4	9.4	26.5	1.4
Mean, ha §	1.33	0.47a	0.48a	1.34ab	2.94b	0.48a
Standard Deviation (SD), ha	1.79	0.21	0.35	1.57	2.51	0.46
Coefficient of Variation (CV), %	135%	45%	73%	117%	85%	96%
Transformed data (multiplied by 10000 and transformed to log10)						
Detransformed mean, ha §	0.70	0.43a	0.38a	0.69ab	2.09b	0.35a
Coefficient of Variation (CV), %	13%	6%	9%	15%	9%	12%

§ Means followed by the same letter are not significantly different according to LSD (0.05 for the original means and 0.01 for the detransformed means).

Analysis of variance

Source	df	SS	MS	F
Original data				
Total	32	102.6		
Vegetation/land cover types	4	35.7	8.92	3.74 *
Error	28	66.9	2.39	
Transformed data (multiplied by 10000 and transformed to log10)				
Total	32	7.4		
Vegetation/land cover types	4	3.1	0.77	4.94 **
Error	28	4.4	0.16	

*, ** significant at the 0.05 and 0.01 probability levels, respectively.

3. *Terminalia* stand density

Descriptive statistics

	Total	Municipality			
		Lelu	Malem	Utwe	Tafunsak
Original data					
Number of samples	16	3	4	4	5
Minimum, trees ha^{-1}	1	1	13	9	10
Maximum, trees ha^{-1}	283	16	41	198	283
Mean, trees ha^{-1}	54.2	6.6	22.2	68.0	97.3
Standard Deviation (SD), trees ha^{-1}	80.4	8.5	13.2	87.8	114.2
Coefficient of Variation (CV), %	148%	129%	60%	129%	117%
Transformed data (multiplied by 10 and transformed to log10)					
Detransformed mean, trees ha^{-1}	21.4	3.2	19.5	36.3	47.9
Coefficient of Variation (CV), %	28%	46%	10%	22%	23%

Analysis of variance

Source	df	SS	MS	F
Original data				
Total	15	96,903		
Municipalities	3	20,956	6,985	1.10 NS †
Error	12	75,947	6,329	
Transformed data (multiplied by 10 and transformed to log10)				
Total	15	6.50		
Municipalities	3	2.93	0.98	3.28 NS †
Error	12	3.57	0.30	

† NS, nonsignificant at the 0.05 probability level.

4. Average height of *Terminalia*

Descriptive statistics

	Total	Municipality			
		Lelu	Malem	Utwe	Tafunsak
Original data					
Number of samples	16	3	4	4	5
Minimum, m	9	10	12	10	9
Maximum, m	18	14	15	15	18
Mean, m	13.2	11.7	14.3	11.8	14.4
Standard Deviation (SD), m	2.8	2.1	1.5	2.4	3.9
Coefficient of Variation (CV), %	21%	18%	11%	20%	27%
Transformed data (multiplied by 10 and transformed to log10)					
Detransformed mean, m	12.9	11.5	14.1	11.5	13.8
Coefficient of Variation (CV), %	4%	4%	2%	4%	6%

Analysis of variance

Source	df	SS	MS	F
Original data				
Total	15	120.4		
Municipalities	3	27.1	9.0	1.16 NS †
Error	12	93.4	7.8	
Transformed data (transformed to log10)				
Total	15	0.13		
Municipalities	3	0.03	0.009	1.07 NS †
Error	12	0.11	0.009	

† NS, nonsignificant at the 0.05 probability level.

5. Average diameter at breast height (DBH) of *Terminalia*

Descriptive statistics

	Total	Municipality			
		Lelu	Malem	Utwe	Tafunsak
Original data					
Number of samples	16	3	4	4	5
Minimum, cm	30	45	30	30	30
Maximum, cm	84	84	45	50	60
Mean, cm	46.1	58.0	41.3	39.8	48.0
Standard Deviation (SD), cm	13.6	22.5	7.5	9.3	12.5
Coefficient of Variation (CV), %	29%	39%	18%	23%	26%
Transformed data (transformed to log10)					
Detransformed mean, cm	44.5	55.5	40.6	38.9	46.6
Coefficient of Variation (CV), %	7%	9%	5%	6%	7%

Analysis of variance

Source	df	SS	MS	F
Original data				
Total	15	2,772		
Municipalities	3	698	232.8	1.35 NS †
Error	12	2,074	172.8	
Transformed data (transformed to log10)				
Total	15	0.21		
Municipalities	3	0.05	0.02	1.18 NS †
Error	12	0.17	0.01	

† NS, nonsignificant at the 0.05 probability level.

6. Stem volume of *Terminalia*

Descriptive statistics

	Total	Municipality			
		Lelu	Malem	Utwe	Tafunsak
Original data					
Number of samples	16	3	4	4	5
Minimum, m^3 ha^{-1}	1.3	1.3	13.0	20.6	18.5
Maximum, m^3 ha^{-1}	366.4	190.1	76.3	366.4	268.4
Mean, m^3 ha^{-1}	97.8	65.5	37.9	114.8	151.6
Standard Deviation (SD), m^3 ha^{-1}	113.5	108.0	27.7	168.3	111.3
Coefficient of Variation (CV), %	116%	165%	73%	147%	73%
Transformed data (multiplied by 10 and transformed to log10)					
Detransformed mean, m^3 ha^{-1}	42.7	10.7	30.9	53.7	102.3
Coefficient of Variation (CV), %	26%	55%	13%	21%	17%

Analysis of variance

Source	df	SS	MS	F
Original data				
Total	15	193,225		
Municipalities	3	33,098	11,033	0.83 NS †
Error	12	160,127	13,344	
Transformed data (multiplied by 10 and transformed to log10)				
Total	15	6.78		
Municipalities	3	1.92	0.64	1.58 NS †
Error	12	4.86	0.40	

† NS, nonsignificant at the 0.05 probability level.

7. Number of crop species

Descriptive statistics

	Total	Municipality			
		Lelu	Malem	Utwe	Tafunsak
Original data					
Number of samples	42	9	11	7	15
Minimum	1	3	1	4	1
Maximum	17	13	15	17	17
Total	22	17	17	18	18
Mean	9.2	10.3	8.6	9.4	8.8
Standard Deviation (SD)	4.1	3.5	4.7	4.3	4.2
Coefficient of Variation (CV), %	45%	34%	54%	45%	48%
Transformed data (multiplied by 10 and transformed to log10)					
Detransformed mean	7.8	9.5	6.7	8.6	7.4
Coefficient of Variation (CV), %	16%	11%	21%	11%	17%

Analysis of variance

Source	df	SS	MS	F
Original data				
Total	40	678.4		
Municipalities	3	17.8	5.9	0.33 NS †
Error	37	660.6	17.9	
Transformed data (multiplied by 10 and transformed to log10)				
Total	40	3.50		
Municipalities	3	0.14	0.05	0.50 NS †
Error	37	3.37	0.09	

† NS, nonsignificant at the 0.05 probability level.

8. Number of swamp taro (*Cyrtosperma chamissonis*) varieties

Descriptive statistics

	Total	Municipality			
		Lelu	Malem	Utwe	Tafunsak
Original data					
Number of samples	36	6	11	6	13
Minimum	1	1	1	1	1
Maximum	9	4	5	3	9
Total	14	5	6	5	13
Mean	3.1	2.2	3.0	1.8	4.2
Standard Deviation (SD)	1.94	1.17	1.26	0.75	2.49
Coefficient of Variation (CV), %	62%	54%	42%	41%	59%
Transformed data (multiplied by 10 and transformed to log10)					
Detransformed mean	2.6	1.9a	2.7ab	1.7a	3.5b
Coefficient of Variation (CV), %	19%	19%	17%	16%	18%

§ Means followed by the same letter are not significantly different according to LSD (0.05).

Analysis of variance

Source	df	SS	MS	F
Original data				
Total	35	131.6		
Municipalities	3	31.6	10.53	3.37 *
Error	32	100.0	3.12	
Transformed data (multiplied by 10 and transformed to log10)				
Total	35	2.52		
Municipalities	3	0.55	0.18	3.00 *
Error	32	1.97	0.06	

* Significant at the 0.05 probability level.

APPENDIX H.
Z-TEST FOR COMPARING TWO PROPORTIONS

Equation for the Z-test for comparing two proportions

$Z = \{[p(obs)_1 - p(obs)_2] - [p(exp)_1 - p(exp)_2]\} / \sqrt{[p(exp)*q(exp)*(1/n_1 + 1/n_2)]}$

Comparison between the percentages of households who owned *Terminalia* parcels

$p(obs)_1 = 0.89$ (1998 survey), $n_1 = 98$

$p(obs)_2 = 0.79$ (current survey), $n_2 = 56$

$p(exp)_1 = p(exp)_2 = p(exp) = [n_1 * p(obs)_1 + n_2 * p(obs)_2] / (n_1 + n_2) = 0.85$

(assuming $p(exp)_1 = p(exp)_2$)

$q(exp) = 1 - p(exp) = 0.15$

$Z = (0.89 - 0.79) / \sqrt{[0.85 * 0.15 *(1/98 + 1/56)]}$

$= 1.69 < 1.96$ (critical value for $\alpha = 0.05$) -> NOT significant

Reference

Bluman, A.G. 2001. Elementary statistics: a step by step approach. Fourth ed. McGrow-Hill, New York.

APPENDIX I.
MAJOR CROPS AND OTHER PLANTS IN THE PARCELS

No	English name	Scientific name	Variety (in Kosraean)	Household with *Terminalia*		Household without *Terminalia*		Total	
				Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy
	Herbaceous plants								
1	Swamp taro	*Cyrtosperma chamissonis* (Schott) Merr.		40	90.9	11	100	52	92.9
			Ebon	30	68.2	6	54.5	36	64.3
			Kihrngihsi *	24	54.5	7	63.6	31	55.4
			Tepat	19	43.2	7	63.6	26	46.4
			Fikac */ **	12	27.3			12	21.4
			Siminton *	4	9.1	3	27.3	7	12.5
			Wasrwasr	5	11.4	2	18.2	7	12.5
			Mokil	5	11.4	1	9.1	6	10.7
			Nukor	5	11.4	1	9.1	6	10.7
			Hosia **	3	6.8	1	9.1	4	7.1
			Pahsruhk kac	1	2.3	2	18.2	3	5.4
			Palau **	2	4.5			2	3.6
			Erriyot **			1	9.1	1	1.8
			Ikinlahs	1	2.3			1	1.8
			Marvin **	1	2.3			1	1.8
			Pihngpihng **			1	9.1	1	1.8
			Pohnpei **	1	2.3			1	1.8
2	Banana	*Musa* spp.		36	81.8	11	100	48	85.7
	Cooking banana			33	75.0	11	100	45	80.4
			Apact	33	75.0	11	100	45	80.4
			Apact fusus	22	50.0	7	63.6	30	53.6
			Mahlok **	5	11.4	2	18.2	7	12.5
			Inyacir	3	6.8	1	9.1	4	7.1
			Kaclfoni	1	2.3	2	18.2	3	5.4
			Kuhlahsr	1	2.3	1	9.1	2	3.6
			Kuhlontohl	2	4.5			2	3.6
			Sentoki	1	2.3	1	9.1	2	3.6
			Usur wac	1	2.3			1	1.8

No	English name	Scientific name	Variety (in Kosraean)	Household with *Terminalia*		Household without *Terminalia*		Total	
				Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy
	Eating banana			35	79.5	11	100	47	83.9
			Kuhfahfah	35	79.5	11	100	47	83.9
			Fiji	6	13.6	4	36.4	10	17.9
			Taiwang	17	38.6	9	81.8	26	46.4
			Lakuhtan	14	31.8	6	54.5	20	35.7
			Pucnluc	1	2.3			1	1.8
			Kihriac	1	2.3			1	1.8
			Usr ruk	1	2.3			1	1.8
			Atchuo **			1	9.1	1	1.8
			Sacko **			1	9.1	1	1.8
3	Soft taro	*Colocasia esculenta* L.		18	40.9	8	72.7	26	46.4
			Saipan	10	22.7	4	36.4	14	25.0
			Srusra **	3	6.8	2	18.2	5	8.9
			Fahluhl	2	4.5	2	18.2	4	7.1
			Pingelap	2	4.5	2	18.2	4	7.1
			Palau	2	4.5	1	9.1	3	5.4
			Filac	1	2.3	1	9.1	2	3.6
			Ruk	1	2.3	1	9.1	2	3.6
			Hawaii	1	2.3			1	1.8
			Ikinmuhla	1	2.3			1	1.8
			Kohsroh	1	2.3			1	1.8
			Kosrae **			1	9.1	1	1.8
			Kosroh kwekwe	1	2.3			1	1.8
			Nukor	1	2.3			1	1.8
			Pasrdora **	1	2.3			1	1.8

No	English name	Scientific name	Variety (in Kosraean)	Household with *Terminalia*		Household without *Terminalia*		Total	
				Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy
4	Sugarcane	*Saccharum officinarum* L.		16	36.4	7	63.6	23	41.1
			Tuh Pohnpei/ Aiwanik	13	29.5	6	54.5	19	33.9
			Tuh sal/srolsroal	12	27.3	6	54.5	18	32.1
			Tuh fasrfasr	4	9.1			4	7.1
			Tuh tihng	2	4.5	1	9.1	3	5.4
			Tuh Kosrae **			1	9.1	1	1.8
			Tuh srac	1	2.3			1	1.8
5	Tapioca	*Manihot esculenta* Crantz		23	52.3	9	81.8	33	58.9
6	Yam **	*Dioscorea* spp.		10	22.7	7	63.6	17	30.4
7	Pineapple **	*Ananas comosus* (L.) Merr. ***		7	15.9	6	54.5	13	23.2
8	Papaya **	*Carica papaya* L.		2	4.5	1	9.1	3	5.4
9	Ginger **	*Zingiber officiale* Roscoe ***		1	2.3			1	1.8
10	Cucumber **	*Cucumis sativus* L. ***				1	9.1	1	1.8
11	Giant taro (wild)****	*Alocasia macrorrhiza* L.		34	77.3	11	100	46	82.1
	Trees and shrubs								
12	Breadfruit	*Artocarpus altilis* (Parkinson) Fosb.		37	84.1	11	100	49	87.5
	Mos yohlahp (rough-skinned breadfruit varieties)			30	68.2	11	100	42	75.0
			Puhtaktuck	26	59.1	8	72.7	35	62.5
			Foksruhsrack	14	31.8	8	72.7	22	39.3
			Puhtaktuck foksruhsrak	6	13.6	3	27.3	9	16.1
			Fok kwekwe	5	11.4	1	9.1	6	10.7
			Inohl wet	2	4.5	2	18.2	4	7.1
			Barkahs **	1	2.3	1	9.1	2	3.6

No	English name	Scientific name	Variety (in Kosraean)	Household with *Terminalia*		Household without *Terminalia*		Total	
				Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy
			Fok kuhloh	2	4.5			2	3.6
			Ikin pe	2	4.5			2	3.6
			Oahkahs	2	4.5			2	3.6
			Puhtaktuck nurem	2	4.5			2	3.6
			Fok fasr	1	2.3			1	1.8
			Fok kuhracn	1	2.3			1	1.8
			Fucsr	1	2.3			1	1.8
			Iknyacsrihk	1	2.3			1	1.8
			Inohl oa	1	2.3			1	1.8
			Inpuhlah	1	2.3			1	1.8
			Mos Hawaii **	1	2.3			1	1.8
			Mos in Kosra	1	2.3			1	1.8
			Mos Samoa **	1	2.3			1	1.8
			Muhnyepuhng	1	2.3			1	1.8
			Nuuhsr	1	2.3			1	1.8
			Sra waseng	1	2.3			1	1.8
			Sruf	1	2.3			1	1.8
			Yoarkuhn	1	2.3			1	1.8
	Mos fwel (smooth-skinned breadfruit varieties)			31	70.5	10	90.9	42	75.0
			Ikunloal nurem	19	43.2	6	54.5	25	44.6
			Musunwac	22	50.0	9	81.8	32	57.1
			Sra fohn	9	20.5	2	18.2	11	19.6
			Popol	1	2.3			1	1.8
13	Coconut	*Cocos nucifera* L.		34	77.3	11	100	46	82.1
14	Noni	*Morinda citrifolia* L.		34	77.3	10	90.9	44	78.6
15	Tangerine	*Citrus reticulata* Blanco		29	65.9	11	100	41	73.2
16	Lime	*Citrus aurantiifolia* (Christm.) Swingle		28	63.6	11	100	39	69.6

No	English name	Scientific name	Variety (in Kosraean)	Household with *Terminalia*		Household without *Terminalia*		Total	
				Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy
17	Mango **	*Mangifera indica* L.		15	34.1	7	63.6	22	39.3
18	Malay apple **	*Eugenia malaccensis* L.		13	29.5	8	72.7	21	37.5
19	Kava **	*Piper methysticum* Forst.f.		8	18.2	4	36.4	12	21.4
20	Soursap **	*Annona muricata* L. ***		2	4.5	6	54.5	8	14.3
21	Betel palm **	*Areca catechu* L.		2	4.5	2	18.2	4	7.1
22	Pandanus **	*Pandanus* spp.		1	2.3	1	9.1	2	3.6
23	Guava **	*Psidium guajava* L.		1	2.3			1	1.8
	Total number of crops and trees in the parcels			22	95.7	21	91.3	23	100
	Varieties	Swamp taro		14	87.5	11	68.8	16	100
		Banana (cooking banana)		9	100	7	77.8	9	100
		Banana (eating banana)		7	77.8	6	66.7	9	100
		Soft taro		13	92.9	8	57.1	14	100
		Sugarcane		5	83.3	4	66.7	6	100
		Breadfruit (mos yohlahp)		24	100	6	25.0	24	100
		Breadfruit (mos fwel)		4	100	3	75.0	4	100
		Subtotal		76 (45)*****	92.7 (54.9)*****	45	54.9	82	100

* Swamp taro varieties that have been reported to contain high level of α- and β- carotene (Engelberger *et al*., 2003a; Engelberger *et al*., 2003b).

** Crops, trees, and varieties not listed in Merlin *et al*. (1993), but reported by the interviewees.

*** Scientific names were not shown in Merlin *et al*. (1993).
Most common and likely scientific names (corresponding to the English names) were applied.

**** Giant taro is considered as famine food and people in Kosrae usually do not cultivate it (Merlin *et al*., 1993).

***** Numbers in parentheses are subtotal and percentage calculated without one interviewee's answers who owned almost all varieties.

APPENDIX J.
OTHER PLANTS RECOGNIZED IN THE PARCELS (REPORTED BY THE INTERVIEWEES)

English name (*Kosraean name*)	Scientific name	Household with *Terminalia*		Household without *Terminalia*		Total		Use*
		Occurrence	% Frequency	Occurrence	% Frequency	Occurrence	% Frequency	
Horsfieldia (*Nunu*)	*Horsfieldia nunu* Kaneh.	40	90.9	8	72.7	48	85.7	Lumber, canoe hull (wood); fruit eaten by Micronesian pigeon (Ducula oceanica)
False sandalwood (*Metkwem*)	*Adenanthera pavonina* L.	8	18.2			8	14.3	Fuelwood (wood); neck garlands (fruit)
Barringtonia (*Kwenguhl*)	*Barringtonia racemosa* (L.) Sprengel	7	15.9	2	18.2	9	16.1	Medicine (fruit)
Tree hibiscus (*Lo*)	*Hibiscus tiliaceus* L.	7	15.9	1	9.1	8	14.3	Fishing float, pole, canoe material, fuelwood (wood); woody fibers used as cord
Neubergia (*Tohoh*)	*Neubergia celebica* (Koord.) Leenhouts	3	6.8			3	5.4	Fruit eaten by Miconesian pigeon
Banyan tree (*Kohnya*)	*Ficus prolixa* Forst.	2	4.5			2	3.6	Medicine (leaves, fruit, bark, root)

English name (*Kosraean name*)	Scientific name	Household with *Terminalia*		Household without *Terminalia*		Total		Use*
		Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy	Occur-rence	% Frequen-cy	
Campnosperma (*Elahk*)	*Campnosperma brevipetiolata* Volk.	1	2.3			1	1.8	Canoe hull (wood); medicine (fruit)
Eugenia (*Nes*)	*Eugenia stelechantha* (Diels) Kanchira	1	2.3			1	1.8	Spear handles, poles (wood); fruit eaten by forest birds
Parinari (*Ahset*)	*Parinari laurina* A. Gray	1	2.3			1	1.8	Oil from fruit used as varnish over the traditional red clay paint
Ivory nut palm	*Metroxylon amicarum* (H.Wendel.) Hook.f	1	2.3			1	1.8	Fruit used for carving ornaments
- (*Ahlko*)	*Commersonia bartramia* (L.) Merr.	1	2.3			1	1.8	Fruit eaten by birds, medicine (fruit, terminal buds)

* Source: Merlin *et al*. (1993)

APPENDIX K.
SHORT REPORT ON THE CLASSIFICATION OF A QUICKBIRD IMAGE

Introduction

A preliminary work was conducted on the digital image classification of a Quickbird satellite image for the detection of the spatial distribution of *Terminalia carolinensis* (hereafter referred to as "*Terminalia*") in Kosrae Island, Federated States of Micronesia. The result is briefly summarized in this appendix.

One of the interests as part of the follow-up study of Drew *et al.* (2005) was to capture the spatial distribution of *Terminalia* over the entire island, because the vegetation map of Kosrae (Whitesell *et al.*, 1986) was published approximately 20 years ago. Conventionally, vegetation maps have been created through the interpretation of aerial photography and extensive field validation work. Recently, satellite imagery has been incorporated into such work, some virtually replacing aerial photography, because of the wide range of choices among various types of sensors and platforms differing in spatial and temporal resolutions, and furthermore, availability of multispectral information that can be used for the quantitative analyses (Carleer and Wolff, 2004).

Numerous researchers have worked on the mapping of vegetation and land cover/land use using satellite imagery. Results varied depending on the type of target group (e.g., forests, wetlands) and the media used for the analyses. For the vast majority of land cover mapping, image processing has been conducted through supervised- or unsupervised classification algorithms (or hybrid of both methods) that use clustering techniques to identify spectrally distinct groups of data (Richards, 1993). More complex techniques, such as expert systems and neural networks, have been used by some researchers as newer methods (Wharton, 1989; Benediktsson *et al.*, 1990). All of them are computer-based processes with different levels of automation.

Detection and mapping of genus and/or species level is more difficult than those of land cover, which requires a finer level of imagery in space and/or spectra. Successes have been reported however, with the use of multitemporal remote sensing data (Wolter *et al.*, 1995); in combination with relevant environmental data in a Geographic Information System (GIS) (Bolstad and Lillesand, 1992; Gress *et al.*, 1993; White *et al.*, 1995; Sader *et al.*, 1995; Hong *et al.*, 1998); with the use of decision tree or knowledge-based classification (Friedl and Brodley, 1997; Gao *et al.*, 2004); with the use of high spatial resolution data (Carleer and Wolff, 2004); and most recently, with the use of hyperspectral data (Underwood *et al.*, 2003; Schmidt and Skidmore, 2003).

Materials and methods

A Quickbird satellite image of Kosrae Island was obtained for the digital image classification (image acquired on September 18, 2003; Figure 1). Quickbird image has the finest spatial resolution that is commercially available thus far; 2.8 m for the multispectral image (blue, green, red, and near-infra red bands) and 0.6 m for the panchromatic image, respectively (Digital Globe Inc., 2004). These two images are taken simultaneously and sold as a set, and may be combined so as to create a finer colored image (data not shown); however, digital image classification uses multispectral image only.

Since *Terminalia* is known to establish itself on the specific soil types (Inkosr, Nansepsep, Ngerungor, and Sonahnpil; Laird, 1983) and below the elevations of 80 m (Merlin *et al.*, 1993), a digitized soil map (Laird, 1983) and a digital elevation model (DEM) were obtained, as well as a digitized vegetation map (Whitesell *et al.*, 1986) that showed freshwater wetland areas. Digital form of soil map was obtained from the U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), and DEM and digital form of vegetation map from The Nature Conservancy Micronesia Program Office, respectively. These files and the Quickbird image were incorporated in ENVI v4.1 (Research Systems Inc., Boulder, CO, USA) for the image classification.

One of the necessary processes before the image classification was 1) to try to remove unnecessary areas, e.g., excluding ocean areas, or 2) to try to extract the areas of interest only (or combination of both) from the original image, so as to save time and also to reduce the known sources of error in the classification. For this purpose, two types of "mask files" were created. Mask files are intermediate files that extract only the desired areas (pixels) from the original images.

The first mask file was created based on the criteria of elevation and that of an index called Normalized Differential Vegetation Index (NDVI) (Rouse, 1974). NDVI is obtained using the values for the red- and the near infrared band in the multispectral image, which equation is expressed as follows:

$$NDVI = (\rho_{NIR} - \rho_{red}) / (\rho_{NIR} + \rho_{red}), \quad (1)$$

where ρ_{NIR} is the reflectance in the near infra red band and ρ_{red} is the reflectance in the red band (Schowengerdt, 1997). Calculation of this vegetation index for a given pixel results in a number between -1 and 1, and allows us to separate the areas with dense vegetation and those without (areas with NDVI > 0.3 has dense vegetation) (Research Systems Inc., 2003). Decision tree classifier in ENVI was used to create this mask file using the criteria as below:

1) Extract the area below 80 m (using DEM file), and
2) Extract the area with NDVI > 0.3 (using Quickbird multispectral image).

The extracted pixels were saved as the first mask file.

The second mask file was created to extract only the combined areas of swamp forests and suitable soil types (Inkosr, Nansepsep, Ngerungor, and Sonahnpil). These areas were extracted from the vegetation map and soil map, respectively, and combined using ArcGIS v9.1 (ESRI, Redlands, CA, USA). The purpose of creating this second mask file was to test whether known *Terminalia* forested area would help facilitate obtaining a unique spectral signature of *Terminalia*, as some of the dense *Terminalia* forests were visually recognizable (Figure 2).

The multispectral Quickbird image was filtered through these mask files separately, and unsupervised classification was conducted on each filtered file. Unsupervised classification is a process whereby numerical operations are performed that search for natural groupings of the spectral properties of pixels. After this classification by the computer, analysts will attempt to assign known vegetation or land use classes ("information classes") to each cluster (Jensen, 1996). Because the image of Kosrae island was stored in four separate electronic files, only one file that contained known *Terminalia* forest (Yela area) was used to apply the classification. For both classification, number of prefixed class was set as 15, and iteration of calculation was set as 20 times.

After the classification, user's accuracy was calculated for each class. Normally, three different types of accuracy are calculated for the accuracy assessment of a classified image: producer's, user's, and overall accuracy. Only the user's accuracy was calculated for this time (for the detail of complete accuracy assessment, see Congalton, 1991). User's accuracy is derived by dividing the total number of correctly classified samples (pixels) by the total number of reference samples (Story and Congalton, 1986). A local GIS expert in Kosrae Island Resources Management Authority (KIRMA) identified several *Terminalia* clusters on an IKONOS image of Kosrae acquired in March 2001, and these areas were used as reference sample areas. IKONOS is another commercially available satellite imagery which spatial resolution is 4 m for the multispectral image.

Results

Neither classification results were able to capture the unique spectral signature of *Terminalia* (Figure 2). Mangroves and *Terminalia*, both of dark color vegetation, were not completely separable using this method (Figure 3). Some other visually distinctive trees, such as coconut trees, were not separable either (Figure 4). This is mostly attributed to the similar chemical composition of the plants, resulting in similar reflectance spectral curves from many plants (Zwiggelaar, 1998).

References suggested that a genus/species is most likely to be classified separately if a specific season or distinctive characteristic of the target is known, e.g., has season for dropping leaves, or has a bright colored flower (e.g. Wolter *et al.*, 1995; Edmonds, 2002). *Terminalia* trees in Pohnpei were once observed to change its leaf color and drop leaves in the mid September (Imanishi, 1944), making the trees visually distinctive from a distance. However, this was not observed on the satellite image although the shot was taken in September 2003. Imanishi's observation was made during one single trip, thus it might have been an unusual event.

The highest user's accuracy for a class was 17% in both of the classified results. Considering the results from the literature (minimum percentage was 40% in Schmidt and Skidmore (2003) using a hyperspectral image), these percentages are considered quite low, and the classified images still need to be refined more.

Conclusion and further work

Quickbird imagery has proven to be useful in visually obtaining information, such as locations of dense *Terminalia* clusters. *Terminalia* clusters, however, did not exhibit a spectral signature unique enough to be discriminable throughout a scene with the unsupervised classification algorithm used in this study.

There are several possibilities to perform classification throughout a scene. One possibility is the use of hyperspectral remote sensing. As mentioned earlier, some studies have proved its superior capabilities of detecting individual species (Schmidt and Skidmore, 2003; Underwood *et al.*, 2003). Although its data availability over the pacific islands is still very limited, it is of great importance to investigate their potential uses in the island settings using field or airborne-based radiometry. Another possibility is to include textures into classification. Texture information can be readily derived from fine resolution data such as Quickbird used in this study and have been shown to result in detailed classification maps (e.g., Wang *et al.*, 2004).

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References (for Appendix K only)

Benediktsson, J., P. Swain, and O.K. Ersoy. 1990. Neural network approaches versus statistical methods in classification of multisource remote sensing data. IEEE Trans. Geosci. Remote Sens. 28:540-552.

Bolstad, P.V., and T.M. Lillesand. 1992. Rule-based classification models: flexible integration of satellite imagery and thematic spatial data. Photogramm. Eng. Remote Sens. 58:965-971.

Carleer, A., and E. Wolff. 2004. Exploitation of very high resolution satellite data for tree species identification. Photogramm. Eng. Remote Sens. 70:135-140.

Congalton, R.C. 1991. A review of assessing the accuracy of classification of remotely sensed data. Remote Sens. Environ. 37:35-46.

Drew, W.M., K.C. Ewel, R.L. Naylor, and A. Sigrah. A tropical freshwater wetland: III. Direct use values and other goods and services. Wetlands Ecol. Manage. 13:685-693.

Digital Globe Inc. 2004. Quickbird specifications [Online]. Available at http://www.digitalglobe.com/about/quickbird.html (verified 26 Nov. 2004).

Edmonds, T. 2002. Mapping Pond Apple (Annona glabra) in Northeast Queensland using a habitat suitability index and Landsat ETM data. M.S. thesis. Univ. of Queensland, St. Lucia, Australia.

Friedl, M.A., and C.E. Brodley. 1997. Decision tree classification of land cover mapping from remotely sensed data. Remote Sens. Environ. 61:399-409.

Gao, J., H. Chen, Y. Zhang, and Y. Zha. 2004. Knowledge-based approaches to accurate mapping of mangroves from satellite data. Photogramm. Eng. Remote Sens. 70:1241-1248.

Gress, T.A., D. Kettler, C. Mao, L. Wright, and S. Berta. 1993. Wetland recertification and sampling using satellite remote sensing. Adv. Space Res. 13(11):83-90.

Hong, S.H., D.J. Mladenoff, V.C. Radeloff, and T.R. Crow. 1998. Integration of GIS data and classified satellite imagery for regional forest assessment. Ecol. Applic. 8:1072-1083.

Imanishi, K. 1994. Ponape Island – an ecological study. (In Japanese). Kodansha Ltd., Tokyo.

Jensen, J.R. 1996. Introductory digital image processing - A remote sensing perspective. 2nd ed. Prentice Hall, Upper Saddle River, NJ.

Laird, W.E. 1983. Soil survey of Island of Kosrae, Federated States of Micronesia. USDA Soil Conservation Service, Honolulu, HI.

Research Systems Research Systems Inc. 2003. ENVI tutorial 4: decision tree classification. ENVI tutorials. Research Systems Inc., Boulder, CO.

Richards, JA. 1993. Remote sensing digital image analysis: an introduction. 3rd ed. Springer-Verlag, New York.

Rouse, J.W., R.W. Harrs, J.A. Schell, D.W. Deering, and J.C. Harlan. 1974. Monitoring the vernal advancement and retrogradation (green wave effect) of natural vegetation. NASA/GSFC Type III Report. NASA/GSF.

Sader, S.A., D. Ahl, and W.S. Liou. 1995. Accuracy of Landsat-TM and GIS rule-based methods for forest wetland classification in Maine. Remote Sens. Environ. 53:133-144.

Schmidt, K.S., and A.K. Skidmore. 2003. Spectral discrimination of vegetation types in a coastal wetland. Remote Sens. Environ. 85:92-108.

Schowengerdt, R.A. 1997. Remote sensing: models and methods for image processing. 2nd ed. Academic Press, New York.

Story, M., and R. Congalton. 1986. Accuracy assessment: a user's perspective. Photogramm. Eng. Remote Sens. 52(3):397-399.

Underwood, E., S. Ustin, and D. DiPietro. 2003. Mapping nonnative plants using hyperspectral imagery. Remote Sens. Environ. 86:150-161.

Wang, L., W. P. Sousa, P. Gong, and G. S. Biging. 2004. Comparison of IKONOS and QuickBird images for mapping mangrove species on the Caribbean coast of Panama. Remote Sens. Environ. 91:432-440.

Wharton, S.W. 1989. Knowledge-based spectral classification of remotely sensed image data. In G. Asrar (ed.) Theory and applications of optical remote sensing. Wiley, New York.

White, J.D., G.C. Kroh, and J.E. Pinder III. 1995. Forest mapping at Lassen Volcanic National Park, California, using Landsat TM data and a geographical information system. Photogramm. Eng. Remote Sens. 61:299-305.

Whitesell, C., C. MacLean, M. Falanruw, T. Cole, and A. Ambacher. 1986. Vegetation survey of Kosrae, Federated States of Micronesia. Resour. Bull. PSW-17. P Pacific Forest and Range Experiment Station, U.S. Department of Agriculture, Berkeley, California.

Wolter, P.T., D.J. Mladenoff, G.E. Host, and T.R. Crow. 1995. Improved forest classification in the Northern lake states using multi-temporal Landsat imagery. Photogramm. Eng. Remote Sens. 61:1129-1143.

Zwiggelaar, R. 1998. A review of spectral properties of plants and their potential use for crop/weed discrimination in row-crops. Crop Prot. 17(3):189-206.

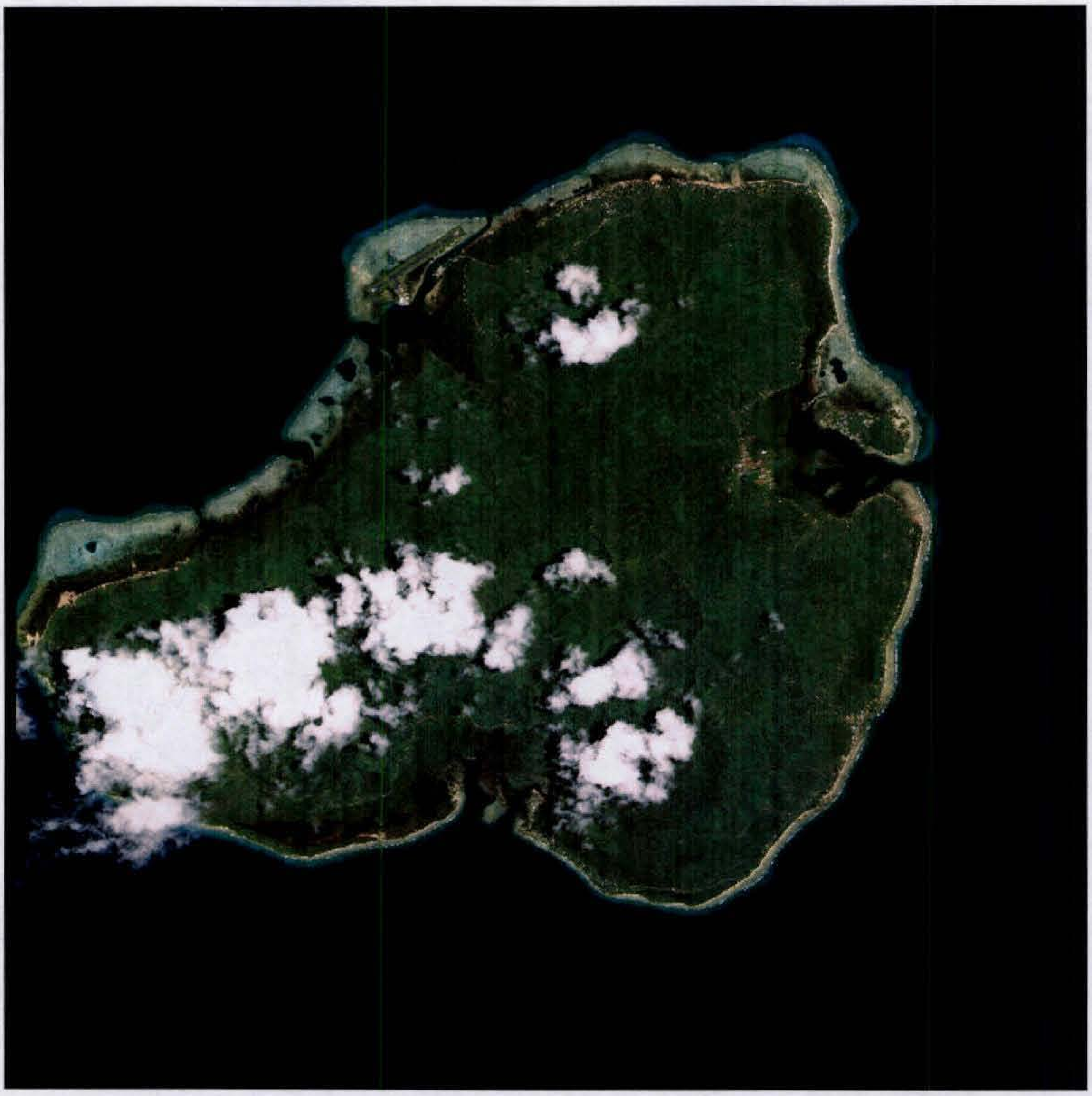


Figure 1. Quickbird image of Kosrae Island (aquired on September 13, 2003).

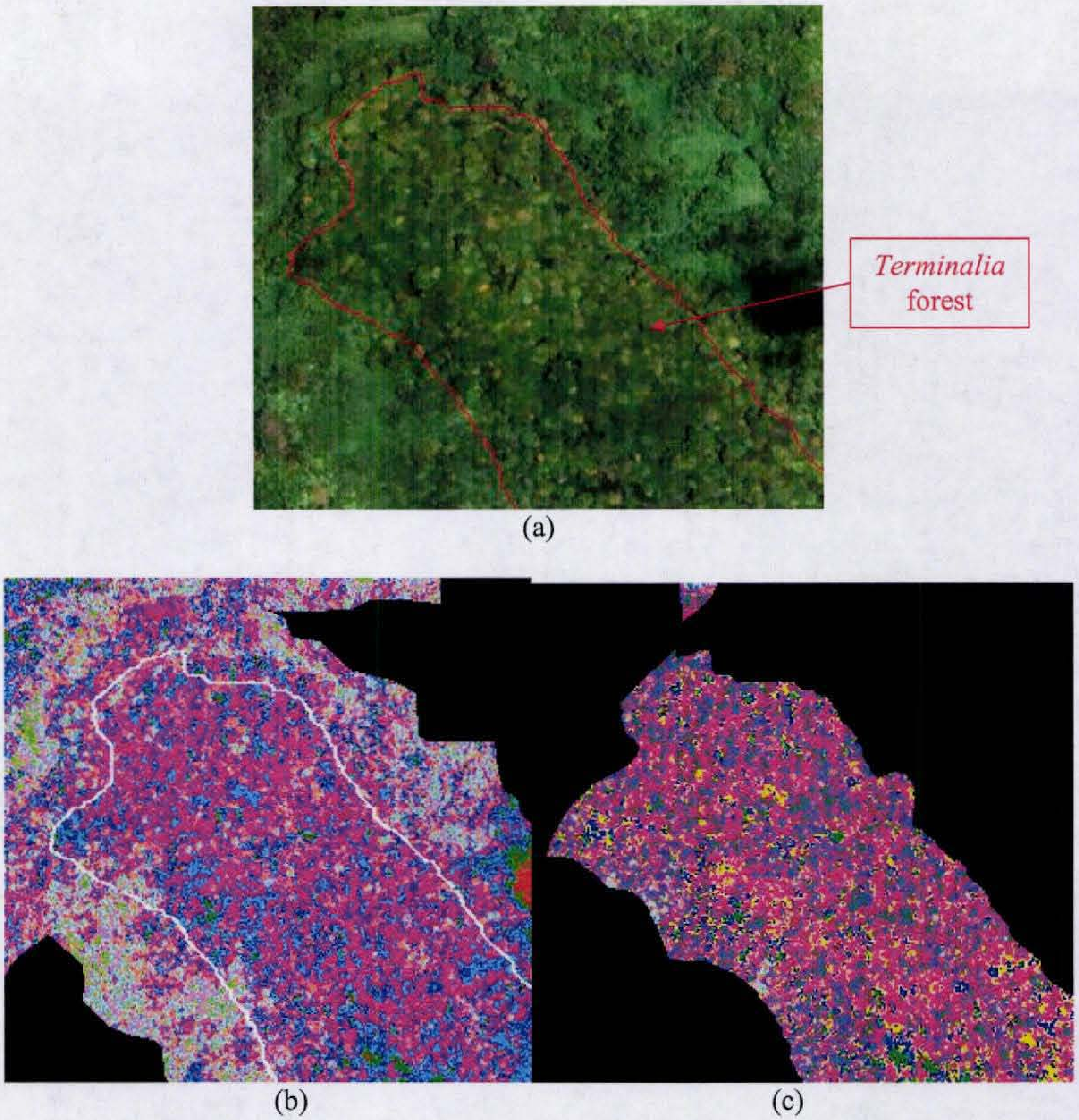
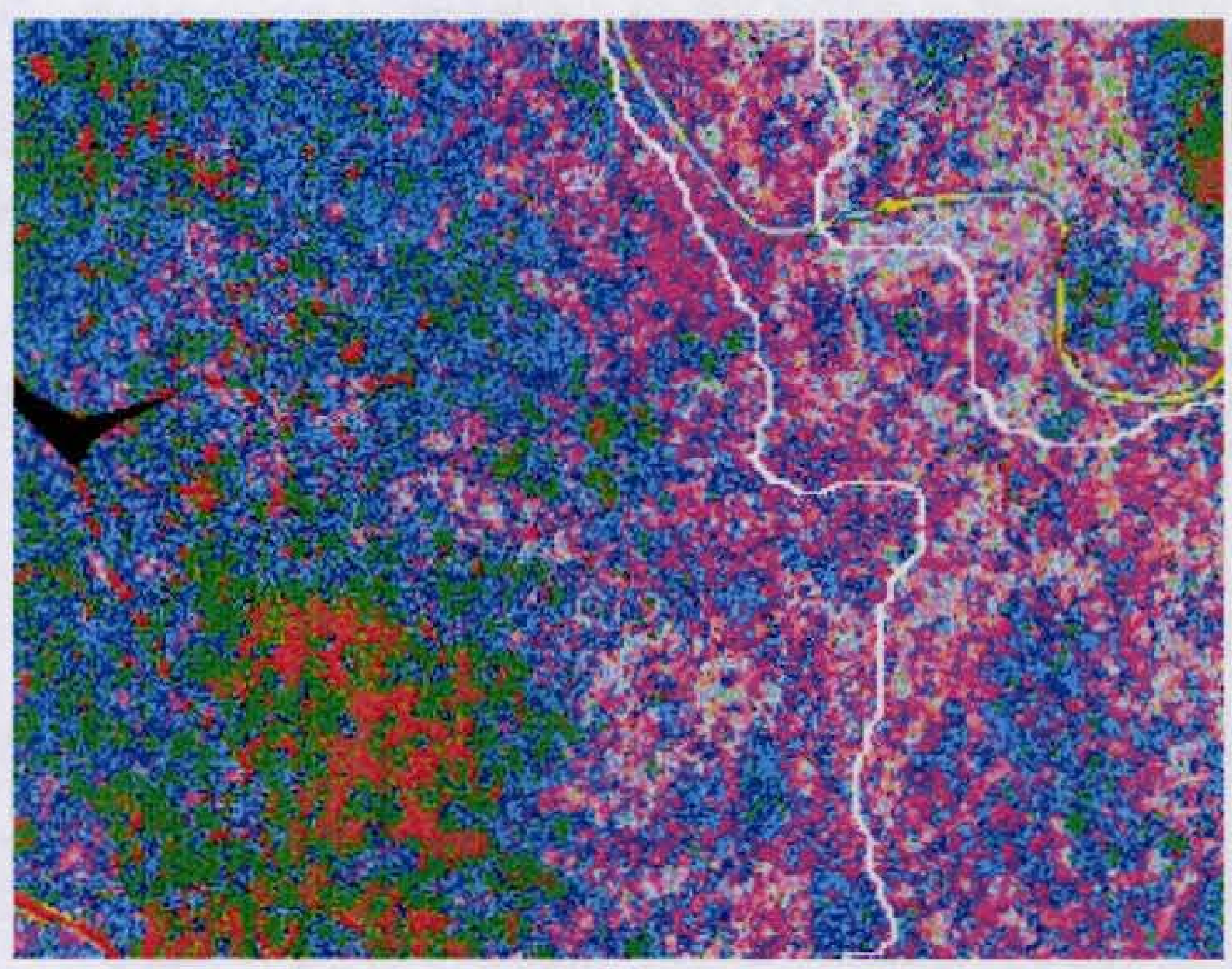


Figure 2. Original multispectral image and results of the unsupervised classification, (a) original image, inside the red line is dense *Terminalia* forest (Yela area), (b) unsupervised classification result with mask file 1 as a filter (eliminated areas of water and higher elevation, and extracted areas with dense vegetation), and (c) unsupervised classification result with mask file 2 as a filter (extracted areas of swamp forests and suitable soil types only). Both classifications were assigned to have 15 classes, and 20 iteration for clustering. Different colors represent different classes in an image, and colors in two results are not related.

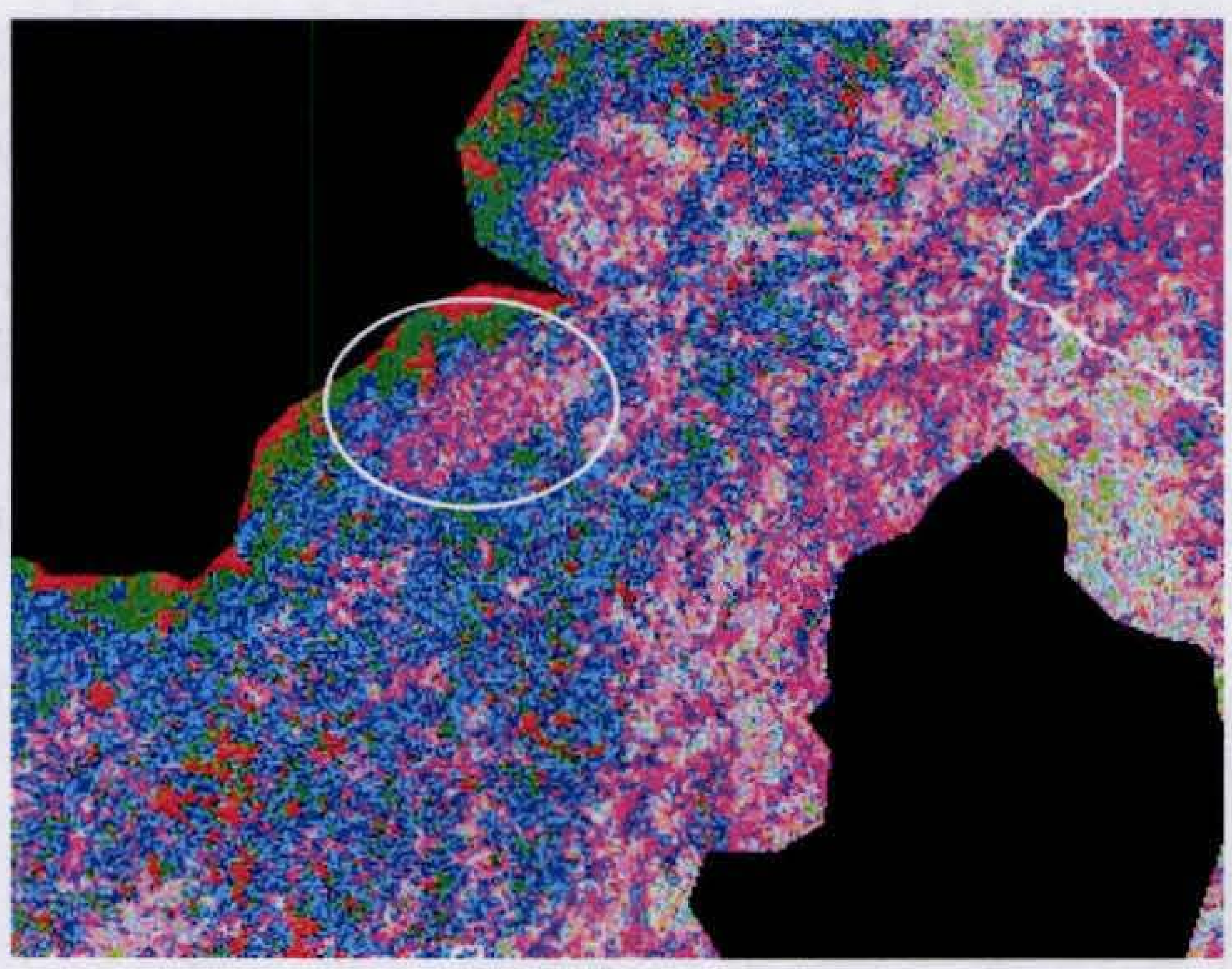
(a)



(b)

Figure 3. Result of the unsupervised classification (with mask file 1 as a filter), (a) original image showing mangroves and swamp forest (with *Terminalia*) areas, and (b) classified image. The same color (e.g., light blue) is classified as one class. Two to three classes (dark blue, red, and light green color) seem to have captured large mangrove area; however, these classes also appear in other areas with other dark colored vegetation or shadows.

(a)



(b)

Figure 4. Result of the unsupervised classification (with mask file 1 as a filter), (a) original image showing a coconut tree cluster, and (b) classified image. The area of coconut tree is classified in the same class as some of the *Terminalia* forest (dark pink color).

APPENDIX L.
AN EXAMPLE OF *TERMINALIA* AGROFORESTRY

REFERENCES

Allen, J.A., K. Krauss, K.C. Ewel, B. Keeland, and E.E. Waguk. 2005. A tropical freshwater wetland: I. Structure, growth, and regeneration. Wetlands Ecol. and Manage. 13:657-669.

Athens, J.S., Ward, J.V., and G.M. Murakami. 1996. Development of an agroforest on a Micronesian high island: prehistoric Kosraean agriculture. Antiquity 70:834-46.

Bank of Hawaii. 2000. Federated States of Micronesia economic report.

Barrau, J. 1961. Subsistence agriculture in Polynesia and Micronesia. Bernice P. Bishop Museum Bulletin, 223. Bernice P. Bishop Museum, Honolulu.

Chimner, R.A. and K.C. Ewel. 2005. A tropical freshwater wetland: II. Production, decomposition, and peat formation. Wetlands Ecol. and Manage. 13:671-684.

Chimner, R.A. and K.C. Ewel. 2004. Differences in carbon fluxes between forested and cultivated Micronesian tropical peatlands. Wetlands Ecol. and Manage. 12:419-427.

Clarke, W.C., and R.R. Thaman. 1993. Agroforestry in the Pacific Islands: systems for sustainability. United Nations Univ. Press, Tokyo.

Dahl, C.R. 1993. The Federated States of Micronesia. In D.A. Scott (ed.), A directory of wetlands in Oceania. IWRB, Slimbridge, and AWB, Kuala Lumpur.

Department of Botany, National Museum of Natural History, Smithonian Institution. 2004. Flora of the Marquesas Islands [Online]. Available at http://ravenel.si.edu/botany/pacificislandbiodiversity/marquesasflora/allthelist2.htm (verified 26 June 2004).

Des Rochers, K. 1990. Women's fishing on Kosrae Island, Federated States of Micronesia: the effects of cultural, social, and technological change on women's use of the nearshore zone. M.A. thesis. Univ. of Hawai'I, Honolulu.

Drew, W.M., K.C. Ewel, R.L. Naylor, and A. Sigrah. 2005. A tropical freshwater wetland: III. Direct use values and other goods and services. Wetlands Ecol. Manage. 13:685-693.

Drexler, J.Z., and E.W. de Carlo. 2002. Source wacter partitioning as a means of characterizing hydrologic function in mangroves. Wetlands Ecol. and Manage. 10: 103-113.

Drexler, J.Z., and K.C. Ewel. 2001. Effect of the 1997-1998 ENSO-related drought on hydrology and salinity in a Micronesian wetland complex. Estuaries 24(3): 347-356.

Englberger, L., J. Schierle, G.C. Marks, and M.H. Fitzgerald. 2003a. Micronesian banana, taro, and other foods: newly recognized sources of provitamin A and other carotenoids. J. Food Comp. Anal. 16:3-19.

Englberger, L., W. Aalbersberg, P. Ravi, E. Bonnin, G.C. Marks, M.H. Fitzgerald, and J. Elymore. 2003b. Further analyses on Micronesian banana, taro, breadfruit and other foods for provitamin A and carotenoids and minerals. J. Food Comp. Anal. 16:219-236.

Eyzaguirre, P., G.J. Martin, and S. Barrow (ed.). 2001. Growing diversity, conserving plant genetic resources. People and plants handbook 7. UNESCO, Paris, WWF, Gland, Switzerland and IPGRI, Rome.

Fernandes, E.C.M, and P.K.R. Nair. 1986. An evaluation of the structure and function of tropical homegardens. Agric. Sys. 21:279-310.

Falanruw, M.V.C. 1993. Micronesian agroforestry: evidence from the past, implications for the future. *In* B. Raynor and R. Roger (ed.) Proceedings of the workshop on research methodologies and applications for Pacific Island agroforestry, Kolonia, Pohnpei, FSM. July 16-20, 1990. General technical report PSW-GTR-140. USDA Forest Service Pacific Southwest Research Station.

Falanruw, M.V.C. 1990. The food production system of the Yap islands. *In* K. Landauer and M. Brazil (ed.) Tropical home gardens. United Nations University Press, Tokyo.

Keating, B.H., D.P. Mattey, C.E. Heisley, J.J. Naughton, and D. Epp. 1984. Evidence for a hot spot origin of the Caroline Islands. J. Geoph. Res. 89:9937-9948.

Kosrae Branch Statistics Office. 2002. Kosrae State census report: 2000 FSM census of population and housing. Department of Economic Affairs, National Government of FSM, Kosrae, FSM.

Kumar, B.M., S.J. George, and S. Chinnamani. 1994. Diversity, structure, and standing stock of wood in the homegardens of Kerala in peninsular India. Agrofor. Sys. 25:243-262.

Laird, W.E. 1983. Soil survey of Island of Kosrae, Federated States of Micronesia. USDA Soil Conservation Service, Honolulu, HI.

Lamb, H.P.A., and O.O. Ntima. 1971. Terminalia ivorensis. Commonwealth Forestry Institute, Oxford University.

Lee, R.A., M.J. Balick, D.L. Ling, F. Sohl, B.J. Brosi, and W. Raynor. 2001. Cultural dynamism and change in Micronesia. Econ. Bot. 55:9-13.

Little, T.M., and F.J. Hills. 1978. Agricultural experimentation. John Wiley and Sons, New York.

MacLean, C., T. Cole, C. Whitesell, and K. McDuffie. 1988. Timber resources of Kosrae, Pohnpei, Truk and Yap, Federated States of Micronesia. Resour. Bull. PSW-24. Pacific Forest and Range Experiment Station, U.S. Department of Agriculture, Berkeley, California.

Matsuoka, J.K., J.P. McGregor, and L. Minerbi. 1998. Molokai: a study of Hawaiian subsistence and community sustainability. In M.D. Hoff (ed), Sustainable community development: studies in economic, environmental, and cultural revitalization. Lewis Pub., Boca Raton.

Merlin, M., R. Taulung, and J. Juvik. 1993. Sahk Kap ac Kain in Acn Kosrae: Plants and Environments of Kosrae. East-West Center, Honolulu, Hawaii.

Merlin, M.R., D. Jano, W. Raynor, T. Keene, J. Juvik, and B. Sebastian. 1992. Tuhke en Pohnpei: Plants of Pohnpei. East-West Center, Honolulu, Hawaii.

Micronesian Seminar. 1997. Sustainable human development in the FSM [Online]. Available at http://www.microsem.org/pubs/articles/economic/shd/shd.htm (posted 1997; verified 3 August 2004).

Naylor, R., and M. Drew. 1998. Valuing mangrove resources in Kosrae, Micronesia. Environ. and Dev. Econ. 3:471-490.

Nanyo Boeki Co., 1942. Nanyo Boeki gojunenshi (50 years history of Nanyo Boeki Co.). Tsukada Insatsusho, Tokyo (in Japanese).

Pacific Islands Development Program/East-West Center. 2003. U.S. Federated States sign 20-year Compact. Pacific Islands Report [Online]. Available at http://166.122.164.43/archive/2003/May/05-14-01.htm (posted 14 May 2003; verified 02 Jan. 2006).

Pouli, T., T. Alatimu, and L. Thomson. 2002. Conserving the Pacific Island's unique trees: Terminalia richii and Manikara samoensis in Samoa. Int. For. Rev. 4(4): 286-290.

Randall, R.P. 2001. A global compendium of weeds [Online]. Available at http://www.hear.org/gcw/html/autogend/species/19034.htm (verified 26 June 2004).

Raynor, W.C. 1989. Structure, production, and seasonality in an indigenous Pacific Island agroforestry system: a case example of Pohnpei Island, F.S.M. M.S. thesis. Univ. of Hawaii, Hawaii.

Raynor, W.C., and J.H. Fownes. 1991. Indigenous agroforestry of Pohnpei 1. Plant species and cultivars. Agrofor. Sys. 16:139-157.

Scott, D.A. (ed.) 1993. A directory of wetlands in Oceania. IWRB, Slimbridge, and AWB, Kuala Lumpur.

Seniloli, M., L. Taylor, and S. Fulivai. 2002. Gender issues in environmental sustainability and poverty reduction in the community: social and community issues. Defelopment Bulletin 58:96-98. (Available on-line at http://devnet.anu.edu.au/online%20versions%20pdfs/58/2458Seniloli.pdf) (verifed 16 March 2006).

Small Island Developing States Network. 2003. Who are SIDS? [Online]. Available at http://www.sidsnet.org/2.html (verified 13 March 2006).

Srivastav, P.K., P. Ranjan, and S.S. Sinha. 1996. Conservation of *Terminalia* genetic resources: the principal source of non-food forest products in India. For. Genet. Res. 24. (Available on-line at http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/008/w3354e/w3354e00.htm (verified 16 March 2006).

Thaman, R.R. 1976. The Tongan agricultural system: with special emphasis on plant assemblages. Ph.D. diss. Univ. of California, Los Angeles.

The Nature Conservancy. 2003. A blueprint for conserving the biodiversity of the Federated States of Micronesia. Micronesia Program Office, The Nature Conservancy.

The New York Botanical Garden, 2004. The New York Botanical Garden Specimens Detailed Results: Terminalia carolinensis Kaneh. [Online]. Available at http://scisun.nybg.org:8890/searchdb/owa/wwwcatalog.detail_list?this_id=4432583, http://scisun.nybg.org:8890/searchdb/owa/wwwcatalog.detail_list?this_id=4432415, http://scisun.nybg.org:8890/searchdb/owa/wwwcatalog.detail_list?this_id=4434490 (verified 26 June 2004).

Trinh. L.N., J.W. Watson, N.N. Hue, N.N. De, N.V. Minh, P. Chu, B.R. Sthapit, and P.B. Eyzaguirre. 2003. Agrobiodiversity conservation and development in Vietnamese home gardens. Agric. Ecosys. Environ. 97:317-344.

United Nations Environmental Programme World Conservation Monitoring Centre (UNEP-WCMC) Protected Areas Programme. 2001. Yela River *Terminalia* Swamp Forest [Online]. Available at http://www.unep-wcmc.org/index.html?http://sea.unep-wcmc.org/sites/wetlands/yela_swp.htm~main (revised 1 Dec. 2004; verified 16 March 2006).

UNIFEM. 1998. Gender considerations in sectoral planning for Pacific Island planners in agriculture, fisheries and forestry. UNIFEM Pacific Regional Office, Suva.

Vergara, N.T., and Nair, P.K.R. 1985. Agroforestry in the South Pacific region - an overview. Agrofor. Syst. 3:363-379.

Whitemore, P.C. 1972. Tree flora of Malaya I (FRI, Keopong). Longman, London.

Whitesell, C., C. MacLean, M. Falanruw, T. Cole, and A. Ambacher. 1986. Vegetation survey of Kosrae, Federated States of Micronesia. Resour. Bull. PSW-17. P Pacific Forest and Range Experiment Station, U.S. Department of Agriculture, Berkeley, California.