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# A snapshot of agroforestry in *Terminalia carolinensis* wetlands in Kosrae, Federated States of Micronesia

Nobuko K. Conroy[1], Ali Fares

*Department of Natural Resources and Environmental Management, University of Hawaii, Sherman Lab 101, 1910 East West Road, Honolulu HI 96822 USA*

Katherine C. Ewel[2]

*USDA Forest Service, Pacific Southwest Research Station, Institute of Pacific Islands Forestry, 60 Nowelo St., Hilo HI 96720 USA*

Tomoaki Miura

*Department of Natural Resources and Environmental Management, University of Hawaii, Sherman Lab 101, 1910 East West Road, Honolulu HI 96822 USA*

and

Halina M. Zaleski

*Department of Human Nutrition, Food and Animal Sciences, University of Hawaii, Agricultural Sciences 216, 1955 East West Road, Honolulu HI 96822 USA*

**Abstract—**Traditional food and its supporting agricultural and agroforestry systems still play a large part in people's daily lives in Federated Sates of Micronesia (FSM). To date, however, there are few publications on details of these systems in the country. On Kosrae Island, the easternmost island of FSM, one type of agroforestry has been practiced for centuries in coastal freshwater wetlands, with *Terminalia carolinensis* as a dominant overstory species and swamp taro *(Cyrtosperma chamissonis)* as a main agricultural crop. We conducted a survey to obtain baseline information on this wetland-based agroforestry system. Fifty-six households were randomly selected from the four municipalities and interviewed about their agricultural parcels, crop species and varieties, and management practices pertinent to *T. carolinensis*.

Agroforestry parcels with *T. carolinensis* averaged 0.8 ha, with most located outside the wettest areas. A total of 21 agricultural species and 40 varieties were reported by interviewees who owned such parcels, underscoring the importance of traditional agroforestry in conserving various landraces of primary and secondary crops. Over 70% of the species recorded were found in all municipalities and all vegetation types, implying uniform spatial distribution of agricultural plants, ensuring food security. *T. carolinensis* trees in parcels are mostly of natural origin and are allowed to regenerate, but no interviewees seemed to be cognizant of

[1]Author for correspondence (e-mail: nobu-kono@hawaii.rr.com; phone: 1-808-956-7530; fax: 1-808-956-6539).
[2]Present address: School of Forest Resources and Conservation, University of Florida, Gainesville FL 32611 USA.

its regeneration pattern or average life span. Although no consensus was obtained on the trend of *T. carolinensis* population on the island, 70% favored establishment of conservation measures for this tree. Further work on this unique system is highly recommended.

## Introduction

Studies of traditional agroforestry systems often reveal successful adaptations to environments that contribute not only to food security for local people, but to conservation of local plants and animals as well (Raynor & Fownes 1991, Clarke & Thaman 1993, Trinh et al. 2003). Some of these systems have existed for more than 1,000 years, demonstrating their long-term sustainability. Raising awareness of the existence of such systems and the services they provide has been encouraged and promoted worldwide (e.g., FAO 1992, IRETA 2005).

Since the end of World War II, the daily diet of people in the Federated States of Micronesia (FSM) has shifted towards more imported food, as in many other parts of the world. However, people still rely on traditional agroforestry (FSM Government 2002a), with an estimated 80% of the population dependent on subsistence or semi-subsistence activities (Asian Development Bank 2005). A number of large-scale, commercial agricultural projects (e.g., black pepper, livestock) were tried but were unsuccessful during the first phase of the Compact of Free Association with the USA, from 1986 to 2001. Locally grown food continued to be of great importance for subsistence and traditional exchange practices (Connell 1994, Asian Development Bank 2005). Indeed, the proportion of families dependent on subsistence agriculture for their main source of employment increased towards the end of the first Compact period, from 10% to 17% between the 1994 and 2000 censuses (FSM Government 2002b). In spite of their importance, there is still little information on the details of traditional agricultural systems and crops in the country (but see Raynor & Fownes 1991, Falanruw 1994, Englberger et al. 2003a, 2003b, Drew et al. 2005; for a detailed review see Manner 2008). Collection of more baseline information about agroforestry systems is still necessary in order to inventory species and varieties and to document characteristics and practices at a particular time and socioeconomic setting, so as to identify problems and research needs, and ensure well-being and sound continuation of the systems. This is particularly a high priority issue in times when Compact aid money is projected to decrease, and traditional knowledge is being lost rapidly (Lee et al. 2001, Brosi et al. 2007, Manner 2008).

In addition to the role that traditional agroforestry plays in subsistence, there has been growing interest worldwide in the roles it may also play in the conservation of biodiversity, not only of species and crop varieties, but of forest-dependent plants and animals in agroforestry plots as well (e.g., Schroth et al. 2004, Attah-Krah et al. 2004, McNeeley & Schroth 2006, Scales & Marsden 2008, Ouinsavi & Sokpon 2008, Abebe et al. 2009). In this article, we address both interests by reporting baseline information about an agroforestry system based on natural wetlands in Kosrae, FSM.

Kosrae's wetland agroforests have been in existence for approximately 1,350 to 1,500 years (Athens et al. 1996). Cultivation of swamp taro *(Cyrtosperma chamissonis),* one of the major crops, does not seem to alter the hydrological condition of the land, so that natural wetland conditions are maintained (Chimner & Ewel 2004, 2005). Such utilization of a natural wetland may be unique (Allen et al. 2005), as many wetlands used in similar ways elsewhere have been irreversibly altered, or set aside as wildlife refuges and completely separated from other land uses (Lemly 1994). Because wetlands continue to be threatened around the globe (Turner et al. 2000), understanding this agroforestry system may be informative not only for Kosraeans but also for people with similar environments who wish to engage in and continue wetland agroforestry/agricultural practices without irreversibly affecting the wetland's basic ecology.

Wetland agroforests in Kosrae are important to the local economy, contributing approximately US$3.7 million of goods and services, mainly from agricultural production (Drew et al. 2005). At an individual household level, this corresponded to 44% of the median annual household income in the late-1990s, when 75% of the households grew swamp taro, soft taro *(Colocasia esculenta)* and bananas (*Musa* spp.) in and around these wetlands. In addition, *Terminalia carolinensis,* an overstory component naturally occurring in lowland wetlands in both Kosrae and the neighboring island of Pohnpei (Merlin et al. 1992, 1993), can attract tourists because of its beauty, endemicity, and the biological significance of the forests it dominates (Dahl 1993, FSM Government 2002b, TNC 2003, UNEP-WCMC 2006). In the late-1990s, most Kosraeans interviewed acknowledged the importance of *T. carolinensis* forests and favored some kind of management plan to govern their use and protection (Drew et al. 2005).

The study by Drew et al. (2005) focused on the market values of major crops and did not include a basic inventory of this agroforestry system. Also, it did not include questions regarding management of *T. carolinensis* trees in its landowner survey. The objectives of this study were therefore to follow up on the previous study by (1) further characterizing *T. carolinensis* agroforestry with regard to parcel sizes, demographic features of owner households, and number of species and crops, (2) documenting more completely the agricultural plant species and varieties that grow in *T. carolinensis* parcels as fundamental information for this agroforestry system, and (3) obtaining more information about the ways in which people manage and value the *T. carolinensis* tree.

## Materials and methods

### Study Area

Kosrae, the smallest and least populated of the four states of FSM, is a densely vegetated, high volcanic island in the Eastern Caroline Islands of Micronesia (5˚19'N and 163˚00'E), with a land area of 109 km$^2$. The climate is humid tropical with high average annual temperature (27 ˚C at sea level) throughout the year, average annual rainfall between 5,000 and 7,000 mm, and relative humidity between 80 and 90% (Merlin et al. 1993). Most of the island is mountainous. The coastal plain, where mangrove forests and freshwater wetlands are abundant, occupies approximately 36% of the total area. The population of the island was 7,686 in 2000 (Kosrae Branch Statistics Office 2002), considered the highest in its history.

Kosrae is divided into four municipalities: Lelu, Malem, Tafunsak, and Utwe (Figure 1). Lelu is the most densely populated of the four, and contains the seat of government. The most isolated village, Walung, is located in the municipality of Tafunsak (the second most densely populated), and boat transport to and from Walung is still common.

### *T. carolinensis* in Kosrae

During the Japanese colonial period between 1914 and 1945, *T. carolinensis* forests were heavily logged. After World War II, they recovered without any further significant exploitation (Dahl 1993). Traditionally, *T. carolinensis* was used for canoe hull material, lumber, and medicine (Merlin et al. 1993). Since World War II, it has nearly disappeared from Pohnpei and is now common only in Kosrae.

Twenty years ago, approximately 10% (1,000 ha) of Kosrae's total land area was classified as existing and former freshwater forested wetlands (Whitesell et

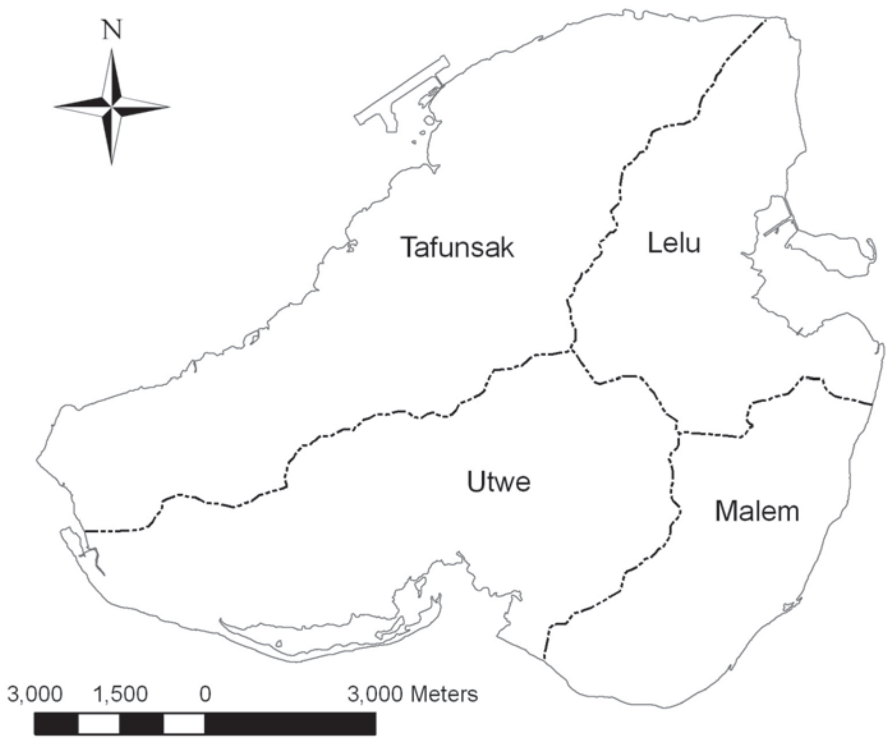


Figure 1. Four municipalities in Kosrae.

al. 1986). Three percent of the total land area (345 ha) was categorized as existing freshwater forested wetlands, 2% (175 ha) as a mixture of freshwater forested wetlands and secondary vegetation, and 5% as agroforest within freshwater forested wetlands (Laird 1983). A later estimate of the total *T. carolinensis* land that was in cultivation, based on interviews, came within 20% of Whitesell's figure (1,264 ha: Drew et al. 2005). An approximate breakdown of the areas combining freshwater wetlands and mixture of freshwater forested wetlands and secondary vegetation among municipalities are 281 ha for Tafunsak, 126 ha for Utwe, 77 ha for Malem, and 34 ha for Lelu, respectively. Tafunsak contained 77 ha of dense *T. carolinensis* forest that was not under cultivation. Most *T. carolinensis* land has been privately owned and divided into small parcels.

*T. carolinensis* on Kosrae occurs on three major soil types; Inkosr, Nansepsep, and Sonahnpil, all of which belong to soil order Inceptisol (Laird 1983). In a transect study conducted in 2000 using 5 sites with different soil types, *T. carolinensis* regeneration was observed only on Inkosr soil, which features high water tables (Allen et al. 2005). *T. carolinensis* on all but the wettest sites may require periodic disturbances such as typhoons or large-scale clear-cutting to maintain dominance (Allen et al. 2005).

## Interviews and Site Visits

Fifty-six households were selected for interviews in stratified random sampling from the four municipalities (with the number of interviews based on the percentage of population in each municipality from FSM Government 2002b) between March and April 2005. The total corresponded to approximately 5% of all households on the island; numbers of households interviewed were 22 from Lelu, 14 from Tafunsak, 14 from Malem, and 7 from Utwe. The interviewers asked to speak with a person who was either the head of the household or engaged in farming, regardless of gender.

Personal information obtained included the interviewee's age and occupation, and number of household members. The interviewees were asked whether they owned parcels of land, and, if so, where the parcels were, presence or absence of *T. carolinensis,* and names of agricultural plants grown, as well as information pertaining to *T. carolinensis:* number and age of trees, whether they were planted or had regenerated naturally, and harvesting practices. For collecting information about agricultural plants, a list of 13 plant species including 65 variety names of swamp taro, soft taro, banana, sugar cane, and breadfruit (from Merlin et al. 1993) was given to the interviewees. Questions were also asked about changes in the incidence of *T. carolinensis* over the entire island, and whether conservation measures were necessary for this tree. 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, six key informants knowledgeable about *T. carolinensis* were interviewed to obtain more technical views on its spatial distribution and possible population changes. The survey in 1995 by Drew et al. (2005) will be referred to as "previous survey" unless otherwise noted.

After the interviews, 20 site visits were conducted: three in Lelu, five in Malem, eight in Tafunsak, and four in Utwe. During these visits, the Kosrae Assistant State Forester recorded the approximate number of *T. carolinensis* trees at each site. The locations of these visited parcels were recorded using an eTrex Legend Global Positioning System unit (Garmin International Inc., Olathe, KS, USA), enabling us to generate a Geographic Information System (GIS) layer in ArcGIS ver 9.1 (ESRI, Redlands, CA, USA) that could be superimposed on existing layers to categorize the land cover and soil types associated with these parcels. Approximate center coordinates of these parcels were obtained from the Division of Surveying and Mapping, Department of Agriculture, Land and Fisheries, Kosrae State, to cross-check the locations of parcels visited. Digitized land-cover- and soil maps of Kosrae were provided by The Nature Conservancy's Micronesia Program Office and U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), respectively. Official sizes of the *T. carolinensis* parcels were obtained from the Land Court, Kosrae State, and the Division of Surveying and Mapping, Kosrae State.

## Statistical Analyses

### Z-test for comparing two proportions

A Z test was used to compare the percentages of previous and current surveys, 1) percentage of households that owned (or leased) *T. carolinensis,* and 2) percentage of parcels that were 2 ha or smaller. Equations are as follows:

$$z = \frac{(\hat{p}_1 - \hat{p}_2) - (p_1 - p_2)}{\overline{p}\overline{q}\sqrt{\dfrac{1}{n_1} + \dfrac{1}{n_2}}}$$

where

$\hat{p}_1 = \dfrac{X_1}{n_1}$ (observed value in 1998)

$\hat{p}_2 = \dfrac{X_2}{n_2}$ (observed value in 2005)

$\overline{p} = \dfrac{X_1 + X_2}{n_1 + n_2}$

$\overline{q} = 1 - \overline{p}$

and p1 = p2 (expected values, $H_0$).

### Agricultural species and varieties of selected crops

First, a chi-square independence test was used to test the ratio between the numbers of households with vs. without *T. carolinensis* trees in their agricultural parcels among different municipalities. After confirming there was no significant difference among municipalities ($\chi^2 = 2.056$; df = 1 [a table of 2 municipality groups (Lelu vs. Others) x 2 Terminalia groups (With or Without *T. carolinensis*)]; P > 0.05), all data (N = 52) were combined in one data set for each subject, i.e., species numbers, varieties of swamp taro, banana, and breadfruit. Descriptive statistics were obtained for each data set using Microsoft Excel 2000 (Redmond, WA, USA) to verify normal distribution of data. This led to square root transformation of [original values plus 0.5] for the variety numbers of three major crops, as well as exclusion of outlier values (total sample numbers were N = 51 for breadfruit, and N = 52 for the rest). The significance of differences among municipalities and parcel groups (with or without *T. carolinensis*) was analyzed using factorial (factors Municipality, Terminalia, and Municipality x Terminalia interaction) Analysis of Variance (ANOVA) in SAS General Linear Models in SAS ver 9.1 (SAS Institute, Cary, NC, USA). Differences in means were analyzed by the Waller-Duncan k-ratio t-test for mean comparisons. Means for the variety numbers of the three major crops were transformed back to the original scale at the end of analyses. The level of statistical significance was set as $\alpha = 0.05$. Additionally, a simple linear regression was applied to see whether there was a relationship between number of agricultural species and the family size, number of people engaged in farming in a household, or parcel size.

Parcel size among municipalities and vegetation types

The significance of difference in parcel size among municipalities and different vegetation types were conducted using the data from the households with *T. carolinensis* in their parcels. In the same manner as above, data were transformed to log 10, then factorial ANOVA (Municipality, Vegetation Type, and Municipality x Vegetation Type interaction) and the Waller-Duncan k-ratio t-test were conducted. Finally, means were transformed back to the original scale. The level of statistical significance was set as $\alpha = 0.05$.

Interviewee responses among municipalities

Chi-square independence tests were conducted to test the numbers of interviewee responses to selected questions (e.g., Yes/No type of questions) among municipalities regarding their management practices with *T. carolinensis* and its distribution over the island. As a rule of thumb for the chi-square test, a class should contain at least five responses; a group with fewer than five responses was grouped together with similar categories (e.g., “No”, “Don’t Know” and “No Answer” were grouped together). Accordingly, responses from Utwe were grouped together with those from Tafunsak, the neighbor municipality in the north-west side of the island, because Utwe had the least numbers of interviewees.

## Results

### Demographic Features of the Interviewees and Households

Mean 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. In 16% of the households, no family member was formally employed. This percentage was less than in previous studies (19% in 1996, Naylor & Drew 1998; 23% in 1998, Drew et al. 2005). Mean size of household and number of adults has increased slightly over the past 8 years, while mean number of children has decreased slightly (Table 1).

Table 1. Mean number of household members per household in comparison with different studies in Kosrae.

| Year | Mean number | Adults (over 18 yrs) | Children (0-17 yrs) | Percentage of Households surveyed | Source |
|---|---|---|---|---|---|
| 1996 | 8 | 4 | 4 | 5 | Naylor & Drew (1998) |
| 1998 | 8.2 | 4.4 | 3.9 | 10 | Drew et al. (2005) |
| 2005 | 8.4 | 4.7 | 3.7 | 5 | Current study |

The mean number of people engaged in farming in a household was three. Assuming a minimum of 4 hours of labor input per person per day, mean labor input on a *T. carolinensis* parcel was estimated as 4.8 hours per person per week (n = 39; each household had different number of people as well as different number of days working on their parcels), categorizing this as a low input system (cf. Roces et al. 1989, Méndez et al. 2001, Kabir & Webb 2008).

## Characteristics of Parcels

Most households surveyed owned or leased two parcels, and 79% of these households had at least one parcel with *T. carolinensis* on it. This was not significantly different from the previous survey (89%) ($z = 1.69$, df = 1). Among the 34 parcels with *T. carolinensis,* 79% were smaller than 2 ha, the same as in the previous survey (80%) ($z = 0.07$, df = 1). Mean *T. carolinensis* parcel size was 0.8 ha. Eighty-two percent of *T. carolinensis* parcels were actively used for agriculture, and 57% of the households cultivated at least half the parcels, suggesting that approximately half of the *T. carolinensis* area may be in actual use.

Most households (84%) had their *T. carolinensis* parcels in the same municipality as their residence. As noted earlier, the ratio of households with *T. carolinensis* parcels did not differ significantly among the four municipalities, ranging from 0.62 (or 62%) in Lelu to 0.93 in Malem.

Among the 33 parcels of households with *T. carolinensis* for which vegetation types and their locations were identified, *T. carolinensis* parcels in agroforest (2.1 ha) were significantly larger than those in swamp forest, upland broadleaf forest, and urban land (0.4 ha) ($F_{\text{Parcel - Vegetation Type}} = 3.89$; df = 4; $P = 0.02$); those in secondary vegetation (0.7 ha) were not significantly different from either of the two groups (Table 2). No statistical difference was found among municipalities, and there was no interactive effect between municipalities and vegetation types (FParcel - Municipality = 0.34, df = 3, $P > 0.05$; $F_{\text{Parcel -Municipality x Vegetation Type}} = 1.00$, df

= 7, P > 0.05). All parcels in swamp forest, upland broadleaf forest, and urban land were equal to or less than 1 ha. Parcels in swamp forest accounted for 21% of the total number of parcels, and those on the wettest soil type (Inkosr and Ngerungor [mucky peat]) accounted for 21% of the total number of parcels. Combining these two characteristics, parcels that were both in swamp forest and on the wettest soil types accounted for 15% of the total number of parcels, but only 6% (2.6 ha) of the total area for the 33 parcels. For vegetation types, 60% of the parcels were in agroforests (total 26.5 ha), 21% in secondary vegetation (9.4 ha), and the rest in swamp forest, upland broadleaf forest, and urban land (3.3 ha, 3.4 ha, and 1.4 ha, respectively).

Table 2. Mean parcel size in different vegetation types.

| Vegetation type | n | Parcel size (ha)† |
|---|---|---|
| Agroforest | 9 | 2.1 a |
| Secondary Vegetation | 7 | 0.7 ab |
| Swamp Forest | 7 | 0.4 b |
| Upland Broadleaf Forest | 7 | 0.4 b |
| Urban Land | 3 | 0.4 b |
| Total / Average | 33 | 0.8 |

†Numbers followed by the same lower case letter are not significantly different ($\alpha = 0.05$).

## Agricultural Plants Grown in the Parcels

A total of 22 agricultural plant species were recorded in the whole survey, including 11 species that were added to the list by the interviewees; all may be categorized as traditional or common plants on the island. Swamp taro was grown by almost all of the interviewees (91%), followed by breadfruit (84%), bananas (82%), coconut (*Cocos nucifera* L., 77%), and noni (*Morinda citrifolia* L., 77%). Although swamp taro is sometimes referred to as "famine food" on some Pacific Islands (Merlin et al. 1993), it is a staple on Kosrae and is appreciated as much as soft taro (L. Livaie [KIRMA], pers. comm. 2006).

As in the previous survey, numbers of plant species between two parcel groups were almost the same; 22 and 21, respectively. However, households with *T. carolinensis* had significantly fewer species per household (10.5 species) than those without (15.7 species) ($F_{Spp\ -\ Terminalia} = 5.08$; df = 1; P = 0.03) (Table 3). No statistical difference was found among municipalities, and there was no interactive effect between municipality and parcel group [with vs. without *T. carolinensis*] ($F_{Spp\ -\ Municipality} = 0.34$, df = 3, P > 0.05; $F_{Spp\ -\ Municipality\ x\ Terminalia} = 0.21$, df = 3, P > 0.05). In fact, percentages of species shared between any two municipalities as well as between any two vegetation types were all over 70%. No relationships were observed between species number in the *T. carolinensis* parcel and family size, number of people engaged in farming in a household, or parcel size, when single-order linear regression was applied for each pair.

Table 3. Mean numbers of species and varieties of selected agricultural crops in parcels with or without *T. carolinensis*.

| | Parcels with *T. carolinensis* | Parcels without *T. carolinensis* |
|---|---|---|
| Mean number of agricultural crop species † | 10.5 b | 15.7 a |
| Mean number of varieties of selected crops ¶ | | |
| Swamp Taro *(Cyrtosperma chammissonis)* | 2.2 | 2.1 |
| Banana (*Musa* spp.) | 3.4 | 6.2 |
| Breadfruit *(Artocarpus altilis)* | 2.2 | 3.4 |

† Numbers followed by a different lower case letter is significantly different ($\alpha = 0.05$). Data were transformed to $\log_{10}$; detransformed numbers are shown.
¶ No statistical difference was observed for the number of same crop varieties between two groups ($\alpha = 0.05$). Square root transformation (adding 0.5 to original data before transformation) was applied to original dataset; detransformed values are shown.

The interviewees added 17 varieties to the original list of 65 possible varieties of swamp taro, banana, soft taro, sugarcane, and breadfruit. Households with and without *T. carolinensis* parcels reported a total of 40 and 28 varieties, respectively, excluding varieties that occurred only once (76 and 45, including all the varieties recorded: Table 4). Numbers of banana and breadfruit varieties in the two groups did not differ significantly from each other among municipalities, and there was no interactive effect between municipality and parcel group ($F_{Banana} = 1.16$, df = 7, $P > 0.05$; $F_{Breadfruit} = 1.25$, df = 7, $P > 0.05$). For numbers of swamp taro varieties, the interactive effect between municipality and parcel group was significant but main effects were not ($F_{Swamp\ Taro} = 2.26$, df = 7, $P = 0.05$; $F_{Swamp\ Taro\ -\ Municipality\ x\ Terminalia} = 4.21$, df = 3, $P = 0.01$, $F_{Swamp\ Taro\ -\ Municipality} = 0.98$, df = 3, $P > 0.05$; $F_{Swamp\ Taro\ -\ Terminalia} = 0.00$, df = 1, $P > 0.05$).

Table 4. Total numbers of varieties of major crops recorded (excluding varieties reported only once).

| Common name | Scientific name | Parcel with *T. carolinensis* | Parcel without *T. carolinensis* | Total |
|---|---|---|---|---|
| Swamp taro | *Cyrtosperma chamissonis* | 10 | 6 | 11 |
| Soft taro | *Colocasia esculenta* | 5 | 4 | 5 |
| Banana | *Musa* spp. | 9 | 8 | 11 |
| Sugar cane | *Saccharum officinarum* | 4 | 3 | 4 |
| Breadfruit | *Artocarpus altilis* | 12 | 7 | 12 |
| Total | | 40 | 28 | 43 |
| (Total number of varieties recorded, including those reported only once) | | 76 | 45 | 82 |

## *T. Carolinensis* in the Parcels

Among the interviewees with *T. carolinensis* in their parcels, 46% considered *T. carolinensis* as part of the agroforestry system. Within this group, 68% agreed it served as shade for other crops, and 25% thought it might be important for erosion control. These statements were consistent with the previous survey.

Ninety-six percent reported the presence of this tree from as long as they could remember, and only one interviewee reported planting it. The most frequent combination of answers (18%) regarding the number and age of the tree was "the number of *T. carolinensis* trees is between 10 and 50," and "the age is between 10 and 30 years on average." Among the data from 22 interviewees who owned only one *T. carolinensis* parcel, no relationship was observed between the number and age of *T. carolinensis* and species number (ranging from 0 to 13 species per parcel).

Regeneration of *T. carolinensis* in parcels was observed by 52% of the interviewees, and 84% reported making no overt attempt to conserve the tree; only 4% tried transplanting the tree from other places. The likelihood that *T. carolinensis* seedlings might be light-demanding and require a large gap for survival (Allen et al. 2005) was not mentioned by any of the interviewees, including the key informants. No one seemed to be cognizant of an average life span of this species, either.

Fifty-five percent of the interviewees reported never having harvested *T. carolinensis*. Among those who had harvested it, frequency was once in 3 years or within the past 3 years (18%), or once in 4 to 10 years (7%). The use of fire primarily for clearing land was reported by 9% of the interviewees, regardless of whether they had harvested *T. carolinensis*.

Because almost half of the interviewees had never harvested *T. carolinensis*, and because canoes were traditionally made from *T. carolinensis* (some from breadfruit trees more recently), we added one more question in two municipalities (Tafunsak and Malem) about means of transportation. Only 2% reported owning a canoe, while 88% of the interviewed households owned cars, and 12% owned motorboats. The percentage of households who owned canoes was much fewer than in the previous survey (47%, which may have been unusually high because of a local traditional celebration at that time).

Attitudes of people towards the *T. carolinensis* tree differed among municipalities. Some interviewees from Lelu mistook *T. carolinensis* for *Campnosperma brevipetiolata,* another common tree in the lowland and upland forests in Kosrae (Merlin et al. 1993). Lelu also had only 3 to 5 *T. carolinensis* trees per parcel, and densities in other municipalities were higher: 5 to 30 in Malem, 7 to 50 in Utwe, and 10 to 100 in Tafunsak, respectively.

### *T. Carolinensis* Population Over the Entire Island

The opinions of the interviewees regarding the status of the *T. carolinensis* population on Kosrae were divided: 39% thought that it was increasing, 29% thought it was decreasing, and 11% viewed it as stable; these answers were not significantly different among municipalities ($\chi^2 = 2.828$; df = 2 [a table of 2 municipality groups (Lelu vs. Others) x 3 selective response groups (Increasing, Decreasing/ Stable, Don't Know)]; $P > 0.05$). Explanations for the increase in population size included reliance on imported goods such as cars; those for the decrease included overexploitation of the tree for canoes and lumber, or land clearing for agriculture or houses. Most of the key informants thought the incidence of *T. carolinensis* trees was increasing, except for the Kosrae State Forester, who viewed it as fluctuating over time (E. Waguk, pers. comm. 2006). Although there was no consensus on the population status, 70% of the household interviewees agreed that conservation measures directed towards this tree were necessary.

## Discussion

### Parcel Size and Location of Parcels

An average homegarden size is approximately 0.1 to 1.0 ha worldwide, with most of them under 1 ha, reflecting the subsistence nature of their function as well as the effect of population pressure in countries where densities may be equal to or more than 300 persons/km$^2$ (Fernandes & Nair 1986, Trinh et al. 2003). The small size of the *T. carolinensis* parcels on Kosrae, where population densities are fewer than 100 persons/km$^2$, still fits within the range of the global homegarden unit, suggesting that the size unit from which subsistence can be obtained may be universal. The sizes of the larger parcels were closer to that of agroforest in Pohnpei (4.9 ha) (Raynor & Fownes 1991), suggesting that these Pacific islands are not under as severe population pressure as other, densely-populated developing countries.

The smaller *T. carolinensis* parcels in Kosrae are mainly located on the flat coastal plain, where access is easier and the peaty soils may be more fertile (Chimner & Ewel 2004). These parcels may have been dissected into smaller units over time to accommodate more people as families grew. On the other hand, most parcels located in agroforest were around wetlands and secondary vegetation, presumably on slopes; these were much larger, but may be more difficult to access due to steepness or distance from roads.

Our overlay analysis suggested that up to approximately 20% of the parcel counts might be identified as either in swamp forest or on wet soil types, but the wettest sites (combination of swamp forest and Inkosr or Ngerungor soil type) might account for less than 10% of the total area covered by *T. carolinensis*. These data suggest that difficulty in regeneration and re-establishment of *T. carolinensis* stands in Kosrae may be encountered on approximately 90% of the total *T. carolinensis* land, if people were willing to conserve this tree in their parcels. On the other hand, this result also implies that most agricultural use of *T. carolinensis* parcels is on marginal or buffer lands around core wetlands, perhaps encouraging conservation of unique *T. carolinensis* forests. In consideration of the low population density, partial use of agricultural parcels followed by sufficient fallow period (Chimner & Ewel 2004, 2005), and the lack of development projects ongoing on the island, co-existence of dense *T. carolinensis* forests on core wetlands and *T. carolinensis* agroforests on marginal lands is likely to continue. The situation should be closely monitored however, when large changes loom, such as road improvement, or damage by natural disasters such as typhoons.

## Number of Species and Varieties of Agricultural Plants

Studies in other parts of the world have shown that species number may be positively correlated to the quantity (and quality) of labor input (Kabir & Webb 2008, Méndez et al. 2001). Correlation of species number with parcel size is still being debated (Kabir & Webb 2008, Rico-Gray et al. 1990, Kumar & Nair 2004, Abdoellah et al. 2006), but seems case specific. In our case, there was no relationship between species number and either of these factors. Using a natural freshwater wetland for agriculture should certainly limit adaptable species and varieties, as can be seen from the difference in number between the households with and without *T. carolinensis* parcels.

We recorded a total of 21 species, 14 more agricultural plant species than the previous survey, along with a maximum of 76 varieties of swamp taro, soft taro, banana, sugarcane, and breadfruit (full list is provided in Conroy 2006). Our survey had fewer species than the number identified in Pohnpeian agroforests (102 species including weeds: Raynor & Fownes 1991), but close to that identified in intermittent mixed gardens in Yap (35 common crop species: Falanruw 1994). Both Kosrae's *T. carolinensis* agroforests and Yap's intermittent tree gardens may be categorized as "shifting cultivation systems" (Watters 1971, cited by Finegan & Nasi 2004). An important feature of these systems is that they serve as a possible reservoir of genetic resources by including many varieties or landraces of main crops, along with a large number of secondary crops (Finegan & Nasi 2004). This feature certainly applies to *T. carolinensis* agroforest, although adaptable species may be limited by the natural conditions of the site; all municipalities and all vegetation types accommodated three major crops, i.e., swamp taro, banana, and breadfruit. This even distribution of major crops can be considered as beneficial for food security. Such characteristics are common in other traditional agricultural systems in the Pacific in general (Raynor & Fownes 1991, Manner 2008). Another characteristic of the *T. carolinensis* agroforests is uniform distribution of species, as shown by the percentages of species shared (all over 70%) between any two different geographic and ecological locations.

Our survey focused specifically on agricultural plants. Although food security is an important topic, in analyzing biodiversity of agroforestry systems, diversity of functional groups is also important. Huang et al (2002) divided plant species into ecological, conservational, and livelihood functional groups, based on the primary role of the species within a parcel: the ecological functional group contributes to protection of natural reserves (e.g., against soil erosion and land degradation); the conservational functional group contributes to minimizing pressure on natural resources (e.g., over-harvesting from natural forests); and the livelihood functional group contributes food and nutrient security of the people. Some species may belong to more than one functional group. In our study, only the livelihood functional group and one conservation species (*T. carolinensis*) were considered. Although total species numbers in *T. carolinensis* agroforests were not high, these forests are likely to contain components that apply to all three groups. Further studies should consider other functions of plants as well.

Our finding of no significant difference among municipalities in swamp taro varieties may be due to the unbalanced sample numbers for each class. Since swamp taro is one of the key species associated with freshwater wetlands in Kosrae, further study of this relationship may lead to better understanding of this agroforestry system.

### *T. Carolinensis* in the Parcels

Almost all *T. carolinensis* trees in agricultural plots on Kosrae germinated in place, and many of the owners of *T. carolinensis* parcels apparently rely on natural regeneration. Observation of *T. carolinensis* regeneration by approximately half of the interviewees suggests that advance regeneration may be sufficient for the species when large gaps are created (Allen et al. 2005). Incorporating approximately 10 crop species into a plot does not seem to affect natural stand establishment of *T. carolinensis*, particularly when cultivated areas lie fallow periodically (Chimner & Ewel 2004, 2005).

The number of canoes owned by the interviewees differed remarkably between the current and previous surveys. One of the reasons could be the exclusion of Utwe for this particular question in the current survey. Utwe still has channels where people often use canoes, and also has more forests with large trees, so the chance that an interviewee would own a canoe might have been higher. Tafunsak has a similar environment to Utwe, but the interviewees did not own as many canoes as might be expected. Improvement of roads and increased reliance on automobiles may account for this difference.

The number of canoes in each village could serve as an indicator of the importance of the local people's resource use and traditional culture. Evidence indicates loss of traditional canoe making skills in Pohnpei (Brosi et al. 2007), and a tendency toward cultural erosion has been perceived in other states as well (Lee et al. 2001). Canoe making appears to be an important traditional skill that may be revitalized later, especially with increases in the price of gasoline (Brosi et al. 2007).

*T. carolinensis* forests differed among municipalities. Lelu had the smallest percentage of households with *T. carolinensis* parcels and the fewest number of *T. carolinensis* trees per parcel, along with a tendency toward misidentification of the tree. Lelu does not have a large area of freshwater wetlands, perhaps because it is the most densely populated municipality among the four. Previous stands may have been harvested when the land was being developed. Misclassification of the tree by Lelu's residents might be due to the scarcity of the tree around their area. This situation may be similar to Pohnpei's residents, where fewer lowland wetlands with *T. carolinensis* exist (Merlin et al. 1992).

In Benin, most of the remnant iroko trees *(Milicia excelsa),* an important timber species in sub-Saharan Africa but under threat due to overexploitation, are reported to be conserved on farms (Ouinsavi et al. 2005). Although the density of this species is low (1 – 4 stems/ha), traditional agroforestry systems are considered as a positive conservation tool for genetic resources (Ouinsavi et al. 2005, Ouinsavi & Sokpon 2008). Likewise, in Kosrae, any future conservation planning regarding *T. carolinensis* should address spatial variability of the species within the island, and parcels with fewer *T. carolinensis* trees should also be included as a part of such a plan.

### Need for Further Work With *T. Carolinensis* and its Habitat

Developing a management or conservation plan for this tree and its forests is not an urgent need, considering that natural regeneration of *T. carolinensis* is likely given that nearly half the interviewees and most key informants viewed the total *T. carolinensis* population as increasing. As noted earlier, continuation of *T. carolinensis* agroforestry without substantial change appears likely (e.g., Chimner & Ewel, 2004; Allen et al. 2005). Nevertheless, this species and its habitat could still be threatened by increasing human population, and increased reliance on subsistence agriculture as Compact payments from the USA decrease.

The scarcity of education in traditional agriculture and the lack of involvement of the younger generation (Connell 1994, Asian Development Bank 2005) suggest that Kosrae's use of the accumulating body of information on *T. carolinensis* agroforestry may be helpful in raising the interest of young people in conserving their endemic species and traditional practices. Possible educational topics include the long history of *T. carolinensis*'s use in agroforestry in Kosrae, ecosystem services derived from the forests, the high potential of *T. carolinensis* forests to attract global attention as a showcase of local biodiversity, the uniqueness of *T. carolinensis* agroforestry in a global sense for both conserving and using natural wetlands, and traditional canoe making skills. Educational and outreach activities should extend not only to schools but also to the general public, along with the formulation of best management practices for families who continue to manage the lands. For instance, harvest pressure on mangrove crabs *(Scylla serrata)* in Kosrae may be decreasing because of heightened awareness of the species' vulnerability (Ewel 2008). Kosrae's small population may allow information to be disseminated effectively.

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