CONSERVATION INNOVATION GRANTS
Final Report

Grantee Name: University of Guam	
Project Title: Carbon and Nutrient Pools and Fluxes in Guam and CNMI: Filling the Information Void	
Agreement Number: NRCS Agreement #69-3A75-10-148	
Project Director: Thomas E. Marler	
Contact Information:	Phone Number: 1-671-735-2130 E-Mail: tmarler@uguam.uog.edu
Period Covered by Report: Sept. 23, 2010 – Sept. 23, 2014	
Project End Date: Sept. 23, 2014	

Background

This project addressed a conspicuous void in knowledge for the islands of the Mariana Archipelago, and defined litterfall decomposition and ecosystem flux traits for five farmer cooperator sites. Specifically, we determined leaf litter decomposition characteristics of major tree species in agroforestry and natural settings. This project was ideal for CIG because the field litterbag and controlled microcosm methods that were used to generate the local data are established and proven research methods. The project was timely because the U.S. Department of Defense is poised to convert more of Guam's green areas into hardscapes in the coming 15 years than during any prior era. The pressures imposed on the remaining lands to provide terrestrial ecosystem services (watersheds, habitat, food production, cultural resources, minor forest productions, etc.) will be immense, and it is within these remaining areas that NRCS will be working with farmers, ranchers, and foresters to implement conservation programs.

Small islands in the western Pacific have fragmented ecosystems in which carbon and essential plant element pools and fluxes are not understood. This diminishes the capacity for NRCS and all of its partners to fully understand how to manage these resources responsibly. As the nutrient pools for native and agro forests have been diminished by net losses from anthropogenic activities, an understanding of these natural processes in the region is a prerequisite to reestablishment of forests across the Marianas. Developing sustainable agriculture approaches within Guam and CNMI is limited by a complete lack of local data on litter decomposition dynamics for native forest and traditional agroforest trees.

This snapshot of the current situation on Guam and CNMI clearly reveals our lack of understanding local geochemical processes. Soil organic matter spans the continuum from fresh litter to highly processed, mineral-associated carbon materials, and is the foundation of sustainable terrestrial ecosystems (O'Brien and Iverson, 2009). Land management practices affect carbon cycling at the global scale and carbon/nutrient pools and turnover at the fine scale. Until this project, actual decomposition rates, sequestration potentials, and nutrient release rates for the major tree species in the region have never been determined.

Above-ground litter plays a critical role in nutrient standing pools and rates of release during the transfer of energy between plants and soil. The decomposition of plant litter has major consequences for plant nutrition, and feed back to interactions with herbivores, pathogens, and symbionts both above and below ground. It plays an integrated role in the function of ecosystems because the majority of net primary productivity enters the terrestrial system as litter from canopy tree parts. Litter decomposition also has a profound effect on global carbon cycles. At the global scale, both litter quality and local weather interact to define decomposition processes (Cornwell et al., 2008; Zhang et al., 2008). However, within a defined area like the Mariana Archipelago, litter quality is the controlling factor. Litter nutrient content (primarily N), available carbon, recalcitrant carbon, lignin, and total phenolics are the major quality characteristics that are drivers of decomposition processes (Hobbie et al., 2006).

Determining the decomposition characteristics of leaf litter from dominant individual species is a mandatory first step for understanding carbon and nutrient storage and cycling processes. This can be predicted by direct measurements of the litter quality characteristics listed above. However, many studies have shown that litter derived from combinations of co-existing species usually decomposes in a non-additive manner (Hobbie et al., 2006; Wardle et al., 2009). In other words, the influence of one species in the mixture changes decomposition dynamics for other species. Therefore, combinations of litter in decomposition studies are needed to accurately define how an ecosystem operates in relation to carbon and nutrient storage and cycling. In turn, understanding the role of species in driving ecosystem properties is critical for enhancing our knowledge base of how ecosystems change during perturbations such as conversion to agriculture, large scale disturbances such as typhoons, re-establishment of native forests on previously farmed land, and massive construction projects.

This project generated an enormous amount of data, as conveyed below. The results will become useful for informing a variety of conservation needs.

Funding received

A total of $182,000 was approved for the project in September 2010. We requested a no-cost one-year extension in July 2013 and this was approved in November 2013. Therefore, the duration of the project was from September 23, 2010 until September 23, 2014. In February 2014 we requested some changes in line items within the budget with no alteration of the overall budget, and this was also approved.

Project locations

This project was conducted on the University of Guam campus and on five farms located on the islands of Guam, Rota, Tinian, and Saipan. The controlled research employed the well-tested microcosm approach to standardize cofactors and allow an accurate comparison among the litter treatment effects. A temperature-controlled 106 square meter laboratory at the University was used for this portion of the project. All five farmer cooperators for this CIG project were EQIP eligible and have successfully implemented EQIP projects.

Mr. Bernard Watson holds an agricultural lease agreement with the Chamorro Land Trust Commission. His farm is located above the northern Guam aquifer and the soils are characteristics of all arable land in northern Guam (Guam series, Clayey, gibbsitic, nonacid, isohyperthermic Lithic Ustorthents). He has successfully implemented many EQIP and CSP conservation practices since establishing his mix truck crop and tree crop operation.

Mr. Hisa Hamamoto is farming on privately owned land in an agricultural zone in southern Guam. Research on his land is applicable to the poorly drained volcanic soils that are threatened by erosion. The soils are Pulantat series (Clayey, montmorillonitic, isohyperthermic, shallow Udic Haplustalfs). He has entered into numerous EQIP projects since the establishment of mixed row crops with tropical fruit and timber trees.

Entire project range

Southern Guam

Northern Guam

Mr. Thomas Songsong is farming in the central part of Rota. His farm is ideal as a representative of most arable land. Soils are Luta series (Loamy, oxidic, nonacid, isohyperthermic Lithic Ustorthents).

Mr. Chuck Jordan is a coffee producer and roaster on the island of Saipan. He has successfully implemented EQIP-funded erosion control measures (rock barrier) on his farm, which is on the Takpochao soil series (Clayey-skeletal, kaolinitic, isohyperthermic Lithic Haplustolls). This soil is representative of the shallow moderately sloped limestone soils common on Saipan and Guam.

Mr. Jesus Cruz has been highly active in the EQIP program with implementation of many impressive conservation measures (dry litter system piggery operation). His farm is located in the southern part of Tinian. His soils are a complex of Dandan (Fine, oxidic, isohyperthermic Oxic Haplustalfs) and Chinen (Clayey, oxidic, isohyperthermic Lithic Argiustolls) series.

Rota

Tinian

Saipan

Project activities by objective

Objective A. Define litter quality of common tree species in natural forests and the most common agroforest tree species.

The list of species for inclusion in a study of this nature is crucial for addressing the appropriate questions and ensuring the results are locally applicable. My approach was to balance the most common tree species from recent forest inventories with the most frequently used agroforestry species on the typical farm on Guam and CNMI. Therefore, the individual species were *Artocarpus altilis, Cocos nucifera, Cycas micronesica, Hibiscus tiliaceus, Mangifera indica, Morinda citrifolia, Pandanus tectorius, Persea americana,* and *Premna serratifolia.* In addition to these important native and agroforestry tree species, I also included *Vitex parviflora* and *Leucaena leucocephala* because these two invasive species are among the most common trees in Guam's limestone forests. Inclusion of *Cocos, Cycas, Pandanus, Premna,* and *Hibiscus* was defined by a recent forest survey on Guam (Donnegan et al., 2004). Using these most common species will most accurately inform climate change and soil quality issues in native forests of the Marianas. Inclusion of *Cocos, Artocarpus, Mangifera, Morinda,* and *Persea* ensured the common agroforestry species were represented, and these results will inform sustainable agriculture and forestry, nutrient management, and soil quality issues. Inclusion of *Vitex* and *Leucaena* was crucial because these species have all the signs of inflicting major damage to natural ecosystem processes. Yet to date we have no data other than stand density on how these two invasive species alter decomposition and other ecosystem processes.

Cocos nucifera. Native tree species. Mean of all five farms.

Nitrogen	2.13%
Sulfur	0.09%
Phosphorus	0.08%
Potassium	0.23%
Magnesium	0.45%
Calcium	0.95%
Iron	277.60 ppm
Aluminum	85.27 ppm
Manganese	71.13 ppm
Boron	28.00 ppm
Copper	8.40 ppm
Zinc	88.00 ppm
Carbon/Nitrogen	25
Carbon/Phosphorus	668
Carbon/Potassium	330
Lignin	27.7%
Cellulose	25.4%
Specific leaf area	6.6 mm^2 / mg
Total phenolics	3041 Gallic acid equivalents

Cycas micronesica. Native tree species. Mean of two Guam farms and one Rota farm.

Nitrogen	1.93%
Sulfur	0.33%
Phosphorus	0.19%
Potassium	0.53%
Magnesium	0.56%
Calcium	2.70%
Iron	440.33 ppm
Aluminum	98.6 ppm
Manganese	88.33 ppm
Boron	39.00 ppm
Copper	7.11 ppm
Zinc	28.56 ppm
Carbon/Nitrogen	27.5
Carbon/Phosphorus	422
Carbon/Potassium	138
Lignin	28.6%
Cellulose	22.8%
Specific leaf area	11.5 mm^2 / mg
Total phenolics	693 Gallic acid equivalents

Hibiscus tiliaceus. Native tree species. Mean of all five farms.

Nitrogen	2.39%
Sulfur	0.29%
Phosphorus	0.21%
Potassium	0.75%
Magnesium	1.01%
Calcium	4.95%
Iron	751.53 ppm
Aluminum	88.40 ppm
Manganese	136.00 ppm
Boron	48.53 ppm
Copper	11.27 ppm
Zinc	29.60 ppm
Carbon/Nitrogen	19.6
Carbon/Phosphorus	355
Carbon/Potassium	109
Lignin	15.5%
Cellulose	23.1%
Specific leaf area	10.4 mm^2 / mg
Total phenolics	2,547 Gallic acid equivalents

Morinda citrifolia. Native tree species. Mean of all five farms.

Nitrogen	2.01%
Sulfur	0.38%
Phosphorus	0.12%
Potassium	0.68%
Magnesium	0.75%
Calcium	4.46%
Iron	891.60 ppm
Aluminum	227.67 ppm
Manganese	214.13 ppm
Boron	55.40 ppm
Copper	10.60 ppm
Zinc	46.33 ppm
Carbon/Nitrogen	23.6
Carbon/Phosphorus	434
Carbon/Potassium	90
Lignin	13.3%
Cellulose	17.3%
Specific leaf area	15.9 mm^2 / mg
Total phenolics	459 Gallic acid equivalents

Pandanus tectorius. Native tree species. Mean of all five farms.

Nitrogen	1.77%
Sulfur	0.16%
Phosphorus	0.07%
Potassium	0.32%
Magnesium	0.23%
Calcium	3.25%
Iron	254.60 ppm
Aluminum	75.80 ppm
Manganese	62.87 ppm
Boron	25.07 ppm
Copper	7.20 ppm
Zinc	58.20 ppm
Carbon/Nitrogen	28
Carbon/Phosphorus	1123
Carbon/Potassium	227
Lignin	22.0%
Cellulose	30.5%
Specific leaf area	5.3 mm^2 / mg
Total phenolics	475 Gallic acid equivalents

Premna serratifolia. Native tree species. Mean of five farms.

Nitrogen	2.12%
Sulfur	0.26%
Phosphorus	0.27%
Potassium	1.06%
Magnesium	0.58%
Calcium	3.77%
Iron	396.47 ppm
Aluminum	104.60 ppm
Manganese	128.13 ppm
Boron	55.53 ppm
Copper	14.07 ppm
Zinc	69.07 ppm
Carbon/Nitrogen	22
Carbon/Phosphorus	221
Carbon/Potassium	53
Lignin	12.4%
Cellulose	19.0%
Specific leaf area	10.55 mm^2 / mg
Total phenolics	1,819 Gallic acid equivalents

Artocarpus altilis. Common agroforestry tree species. Mean of all five farms.

Nitrogen	2.28%
Sulfur	0.45%
Phosphorus	0.23%
Potassium	0.48%
Magnesium	0.71%
Calcium	4.99%
Iron	973.93 ppm
Aluminum	46.73 ppm
Manganese	65.60 ppm
Boron	59.53 ppm
Copper	9.40 ppm
Zinc	18.73 ppm
Carbon/Nitrogen	20
Carbon/Phosphorus	250
Carbon/Potassium	166
Lignin	17.9%
Cellulose	24.9%
Specific leaf area	7.7 mm^2 / mg
Total phenolics	785 Gallic acid equivalents

Mangifera indica. Common agroforestry species. Mean of five farms.

Nitrogen	1.75%
Sulfur	0.22%
Phosphorus	0.07%
Potassium	0.32%
Magnesium	0.25%
Calcium	5.87%
Iron	773.67 ppm
Aluminum	42.13 ppm
Manganese	124.73 ppm
Boron	41.53 ppm
Copper	7.60 ppm
Zinc	31.60 ppm
Carbon/Nitrogen	27
Carbon/Phosphorus	1008
Carbon/Potassium	170
Lignin	18.0%
Cellulose	20.0%
Specific leaf area	7.7 mm^2 / mg
Total phenolics	7,349 Gallic acid equivalents

Persea americana. Common agroforestry tree. Mean of all five farms.

Nitrogen	1.99%
Sulfur	0.52%
Phosphorus	0.09%
Potassium	0.25%
Magnesium	0.48%
Calcium	4.66%
Iron	244.60 ppm
Aluminum	74.40 ppm
Manganese	184.93 ppm
Boron	16.40 ppm
Copper	8.47 ppm
Zinc	30.73 ppm
Carbon/Nitrogen	26
Carbon/Phosphorus	652
Carbon/Potassium	254
Lignin	28.9%
Cellulose	19.0%
Specific leaf area	7.2 mm^2 / mg
Total phenolics	4,585 Gallic acid equivalents

Leucaena leucocephala. Invasive tree species found throughout the Mariana Islands. Mean of all five farms.

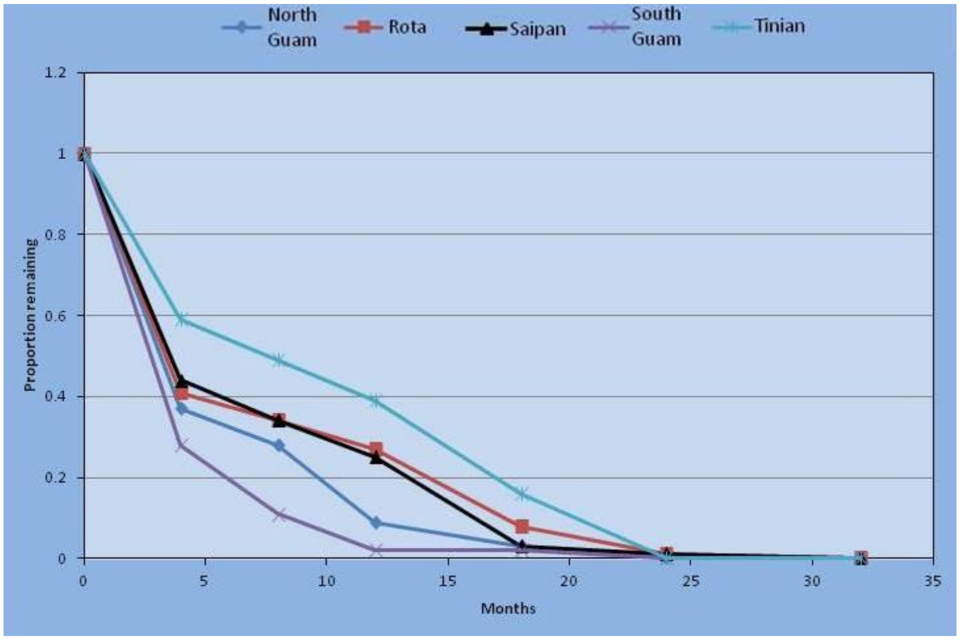
Nitrogen	2.56%
Sulfur	0.20%
Phosphorus	0.08%
Potassium	0.53%
Magnesium	0.60%
Calcium	2.96%
Iron	748.00 ppm
Aluminum	19.40 ppm
Manganese	72.87 ppm
Boron	65.07 ppm
Copper	8.53 ppm
Zinc	20.53 ppm
Carbon/Nitrogen	20.5
Carbon/Phosphorus	689
Carbon/Potassium	135
Lignin	12.4%
Cellulose	15.0%
Specific leaf area	27.6 mm^2 / mg
Total phenolics	7,349 Gallic acid equivalents

Vitex parviflora. Invasive tree species on Guam. Mean of two Guam farms.

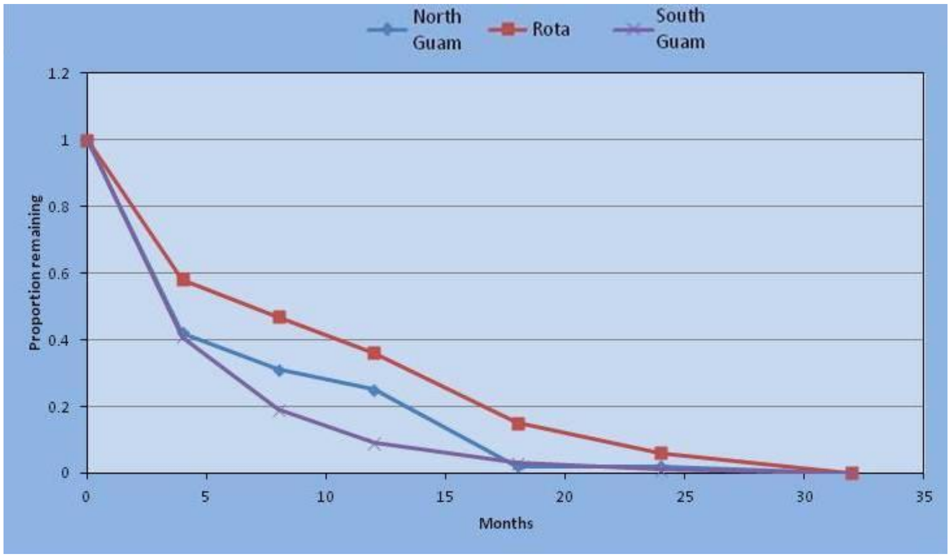
Nitrogen	2.07%
Sulfur	0.36%
Phosphorus	0.22%
Potassium	0.66%
Magnesium	0.58%
Calcium	2.74%
Iron	670.00 ppm
Aluminum	215.50 ppm
Manganese	124.50 ppm
Boron	62.00 ppm
Copper	12.50 ppm
Zinc	128.17 ppm
Carbon/Nitrogen	24
Carbon/Phosphorus	256
Carbon/Potassium	104
Lignin	13.6%
Cellulose	20.4%
Specific leaf area	11.5 mm^2 / mg
Total phenolics	4,228 Gallic acid equivalents

Objective B. Determine decomposition characteristics in field-deployed litterbags of the most common native forest species, the two most troublesome invasive tree species, and three common agroforest tree species.

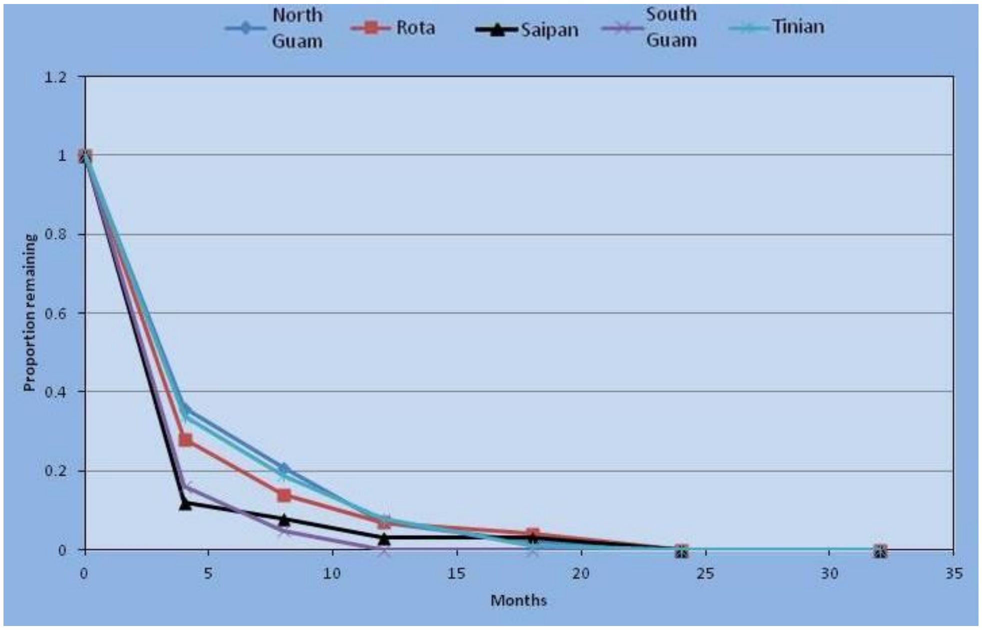
Cocos nucifera. Coconut leaf litter decomposed more slowly than most of the other tree species in this study. About 45% of the litter had decomposed by four months. Most farm sites exhibited complete decomposition by 24 months. The farm site in Tinian exhibited slower coconut leaf litter decomposition than the other farm sites.



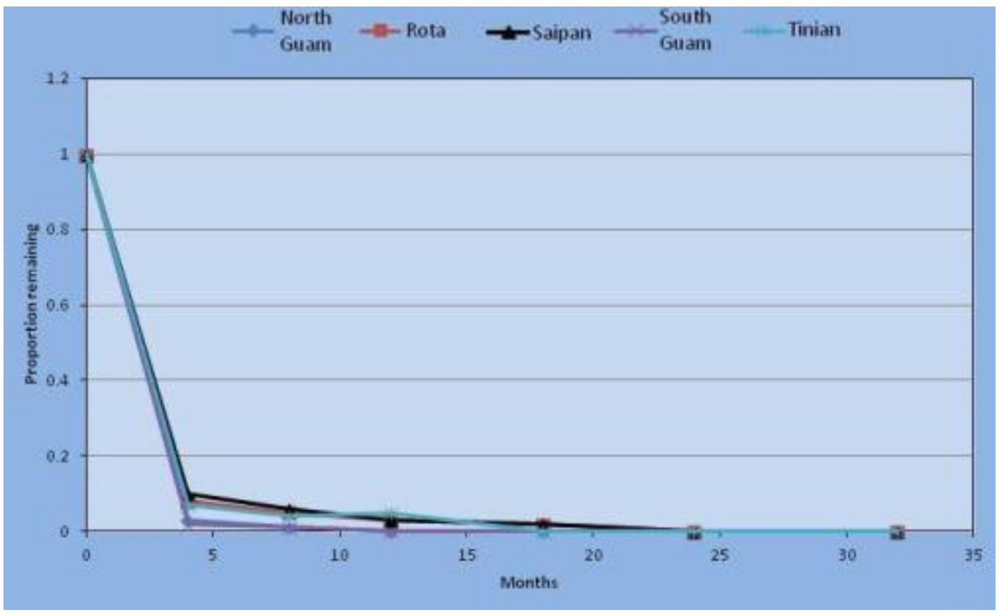
Cycas micronesica – The *Cycas micronesica* leaf litter decomposed more slowly than most of the other tree species in this study. About half of the litter had decomposed by four months. The Rota farm site exhibited slower *Cycas* leaf litter decomposition than the two Guam farm sites.



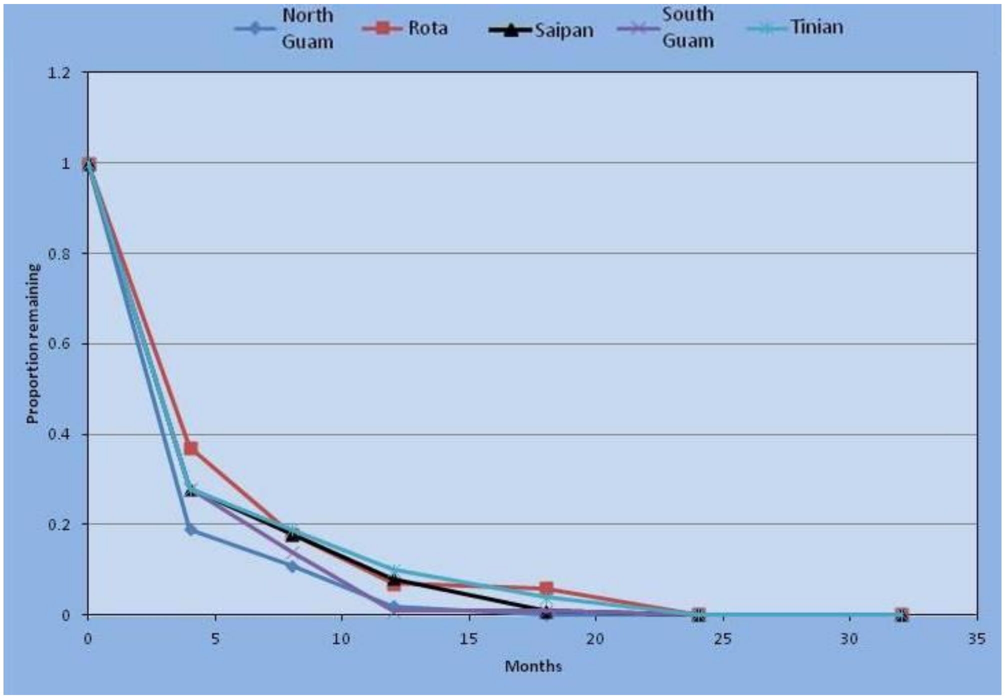
Hibiscus tiliaceus. Sea-hibiscus leaf litter decomposed at a moderate rate compared to the other tree species. About one-fourth of the litter had decomposed by four months. Decomposition was almost complete by 1 year, but then it slowed down such that a full two years was required to complete leaf litter decomposition for this species.



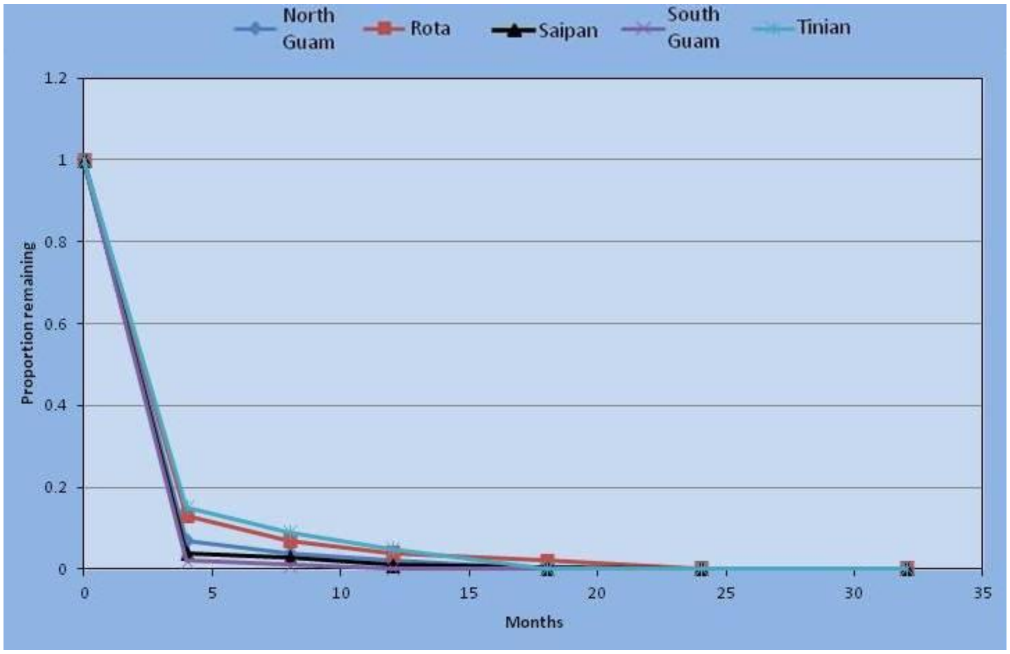
Morinda citrifolia. *Morinda* leaf litter was one of the most rapid to decompose. More than 90% of the litter had decomposed by four months. The litter of this species also exhibited minimal variation in decomposition speed among the farm sites.



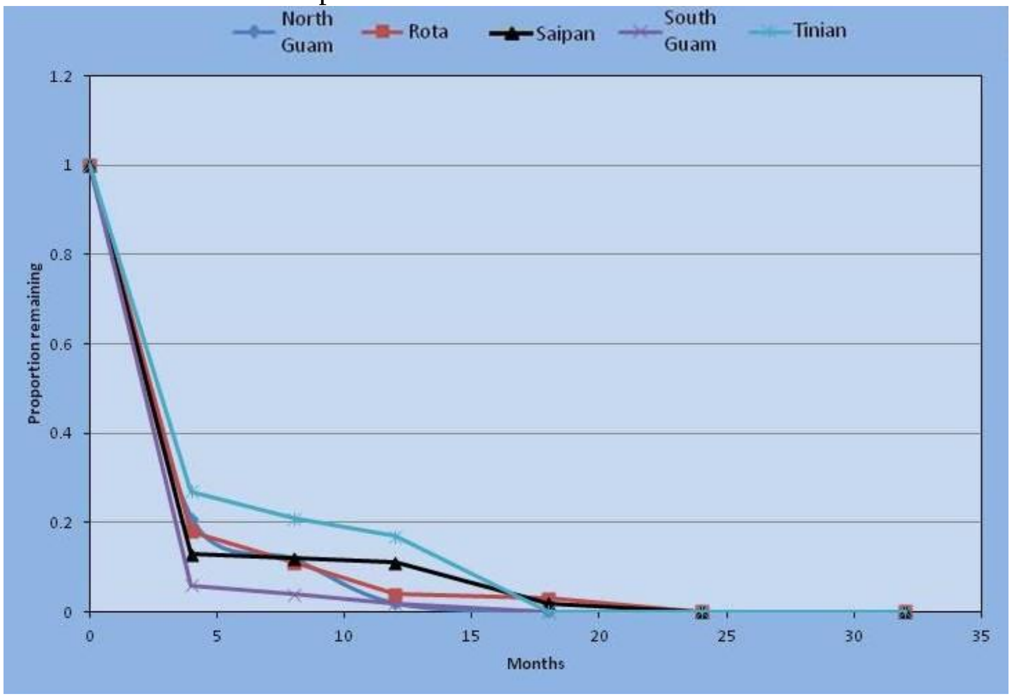
Pandanus tectorius. *Pandanus* leaf litter decomposed more rapidly than expected, considering the leaves of this genus are used for making many utilitarian products and the leaves are built to withstand the mechanical forces imposed by typhoons. About 70% of the litter had decomposed by four months. All of the farm sites exhibited complete decomposition by 24 months.



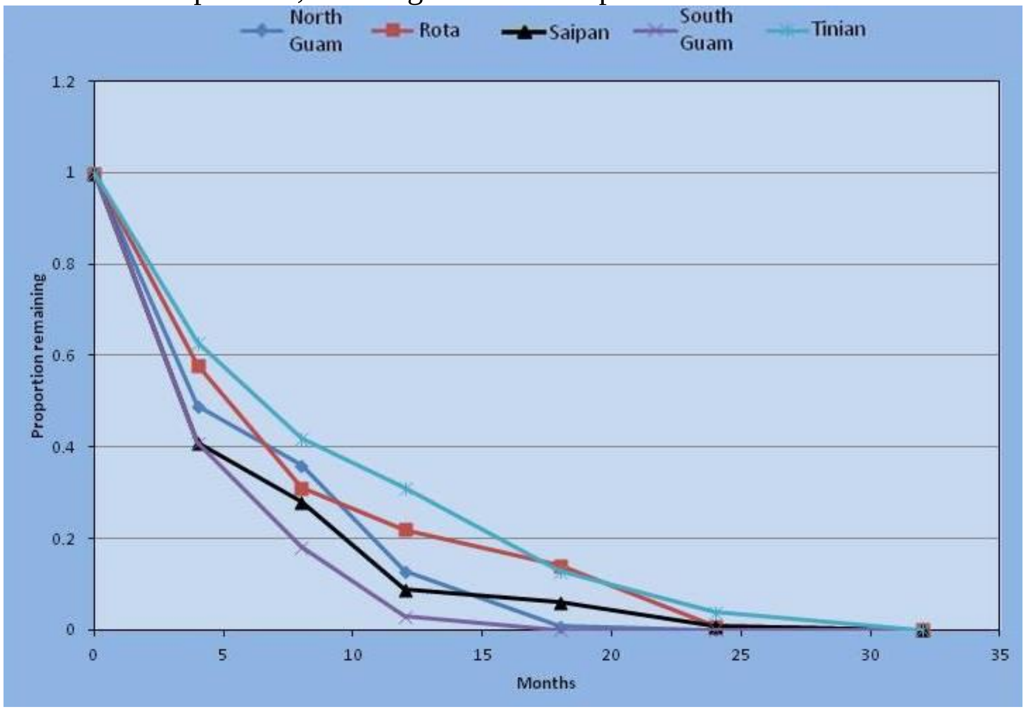
Premna serratifolia. *Premna* leaf litter decomposed rapidly in comparison to all of the species in this study. More than 90% of the litter had decomposed by four months. Most of the farm sites exhibited complete decomposition by 18 months.



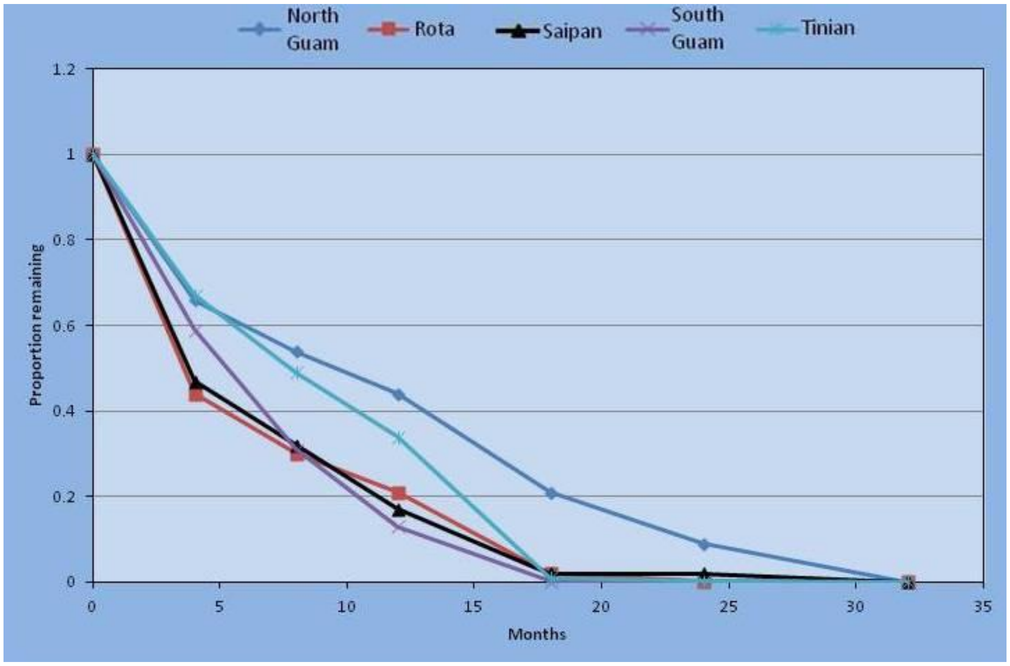
Artocarpus altilis. Breadfruit leaf litter decomposed at moderately rapid rate compared to the other tree species. About 80% of the litter had decomposed by four months. Most of the farm sites exhibited complete decomposition by 18 months. The farm site in Tinian exhibited slower breadfruit leaf litter decomposition than the other farm sites.



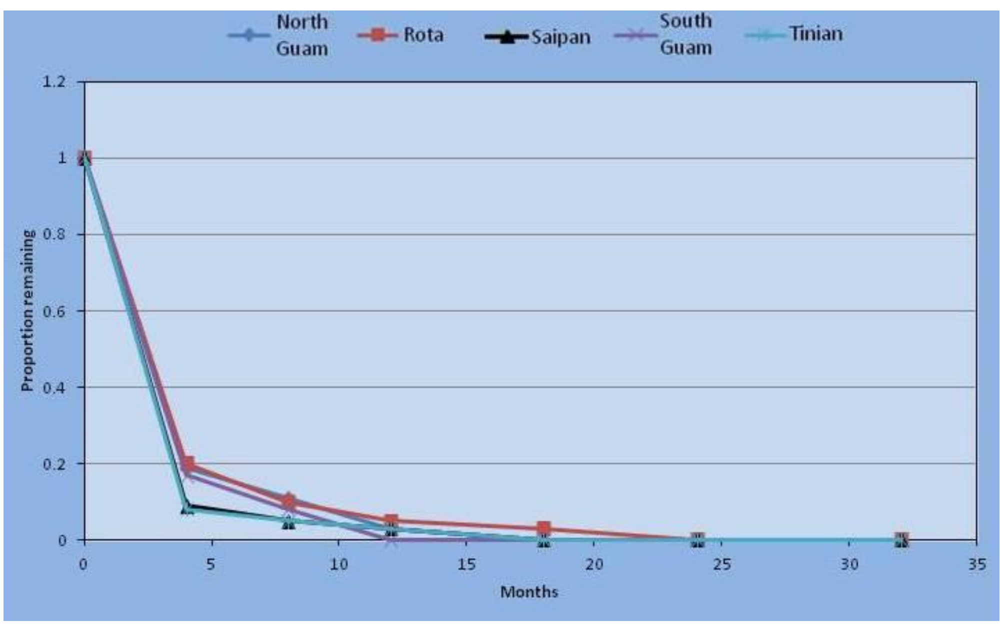
Mangifera indica. Mango leaf litter decomposed at a relatively slow rate compared to the other tree species. About half of the litter had decomposed by four months. Most of the farm sites exhibited complete decomposition by 24 months. The farm site in Tinian exhibited slower mango leaf litter decomposition, reaching 100% decomposition at 32 months.



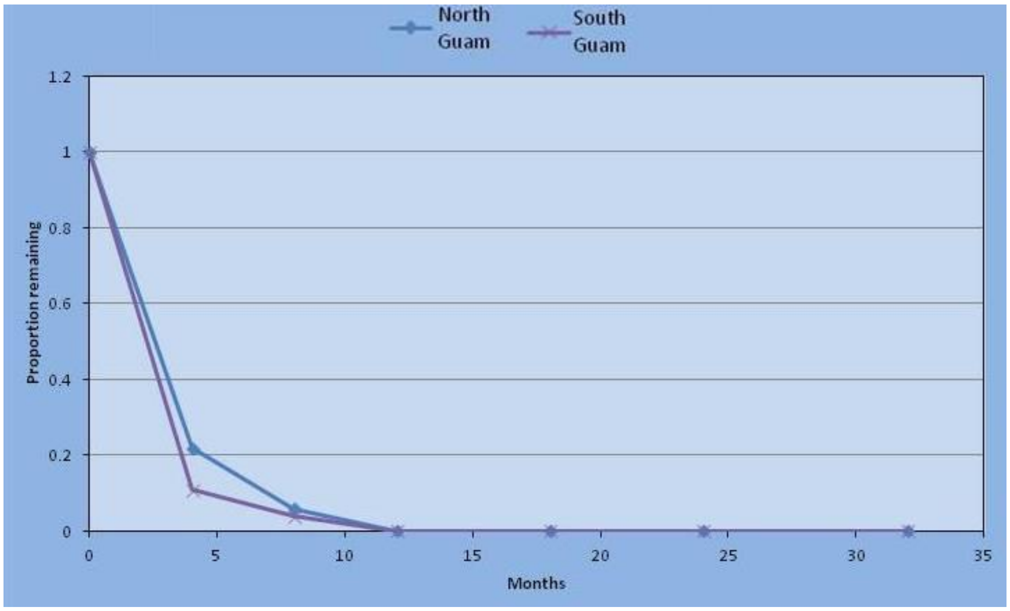
Persea americana. Avocado leaf litter decomposed at a relatively slow rate compared to the other tree species. About half of the litter had decomposed by four months. Most of the farm sites exhibited complete decomposition by 18 months. The farm site in northern Guam exhibited slower avocado leaf litter decomposition, reaching 100% decomposition at 32 months.



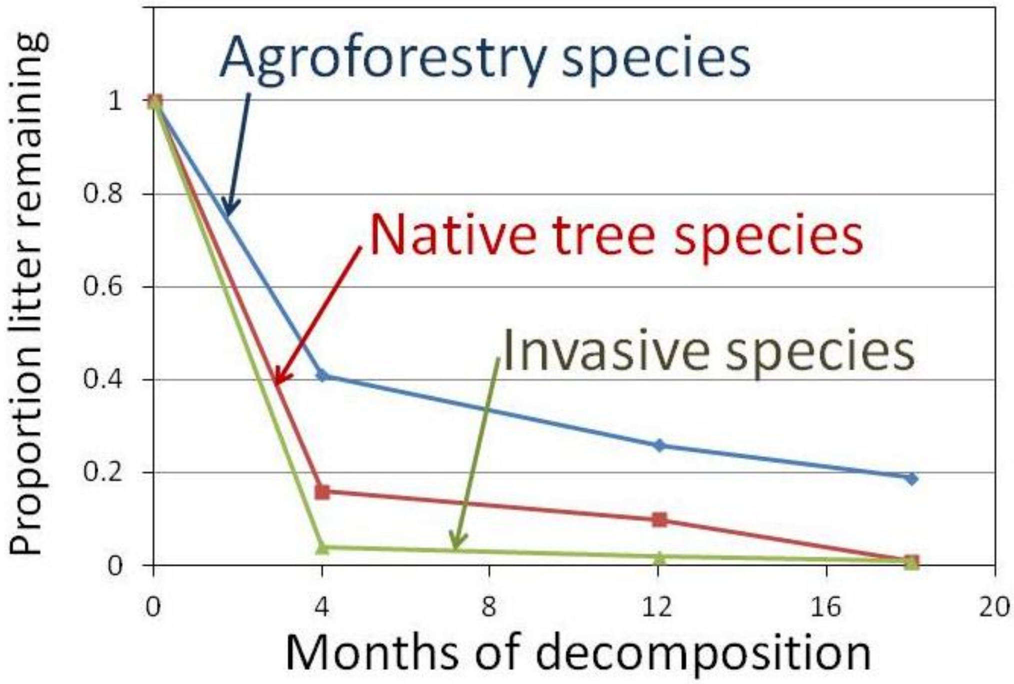
Leucaena leucocephala. *Leucaena* leaf litter decomposed at a rapid rate compared to the other tree species in this study. About 85% of the litter had decomposed by four months. One of the concerns with invasive alien species that can so aggressively displace native tree species is what the changes in species composition do to nutrient and carbon cycling in the habitats.



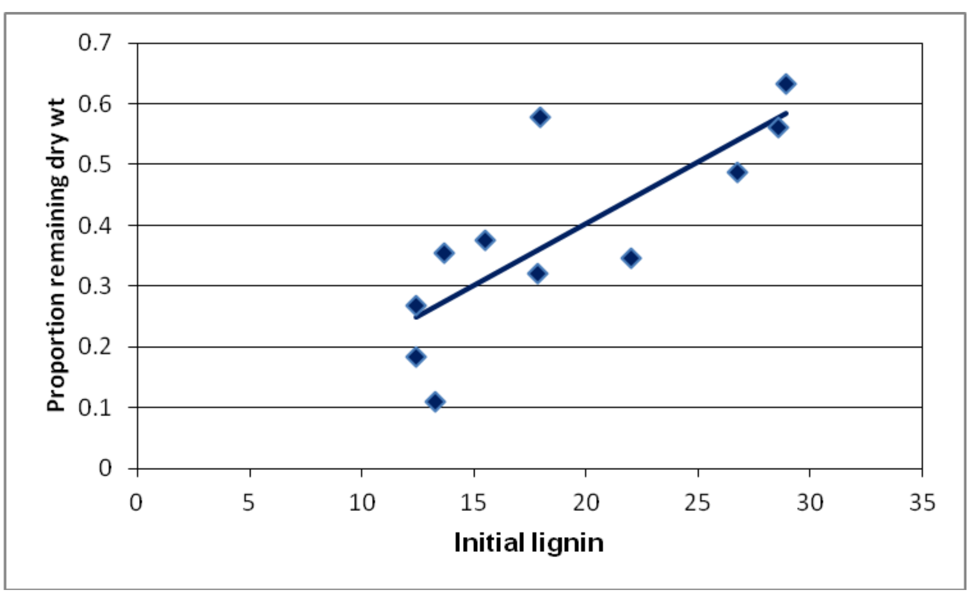
Vitex parviflora. Vitex leaf litter decomposed rapidly compared to the other tree species. About 85% of the litter had decomposed by four months. Both Guam farm sites exhibited complete decomposition by 12 months.



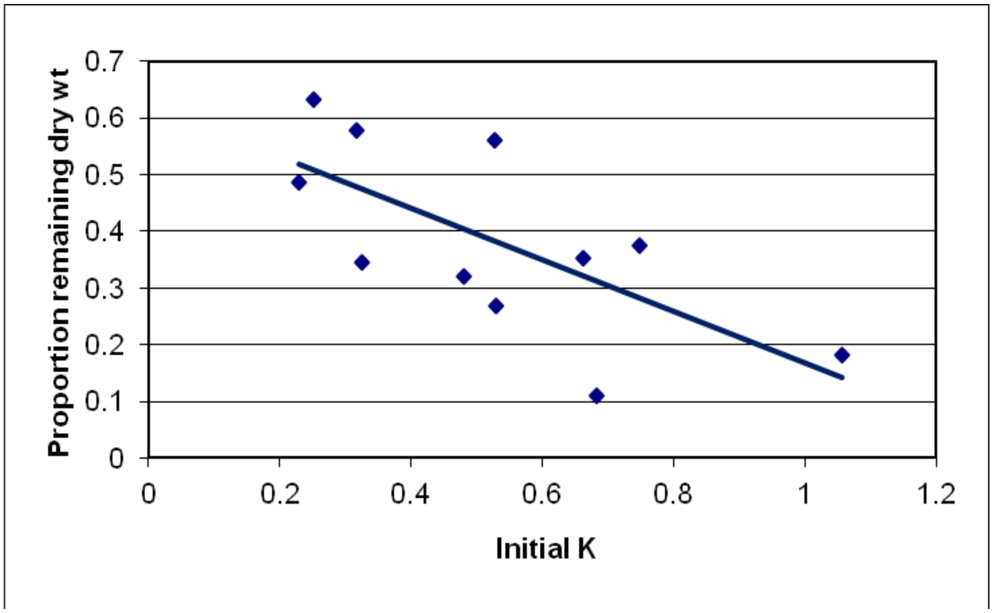
Decomposition by tree classification. The native species that exhibited the most sluggish leaf decomposition were *Cocos nucifera* and *Cycas micronesica*. The native species that exhibited the most rapid leaf decomposition were *Hibiscus tiliaceus*, *Morinda citrifolia*, and *Premna serratifolia*. *Pandanus tectorius* leaf litter decomposed at moderate speed in relation to the other species. The agroforestry species as a group exhibited leaf litter decomposition that was slower than the native species as a group. Litter decomposition for *Artocarpus altilis* was more rapid than for *Mangifera indica* and *Persea americana*. The invasive species exhibited accelerated leaf litter decomposition compared to the other species in this study. This raises concerns about how *Leucaena leucocephala*, *Vitex parviflora*, and other alien trees are changing carbon and nutrient cycling processes in the Mariana Islands.



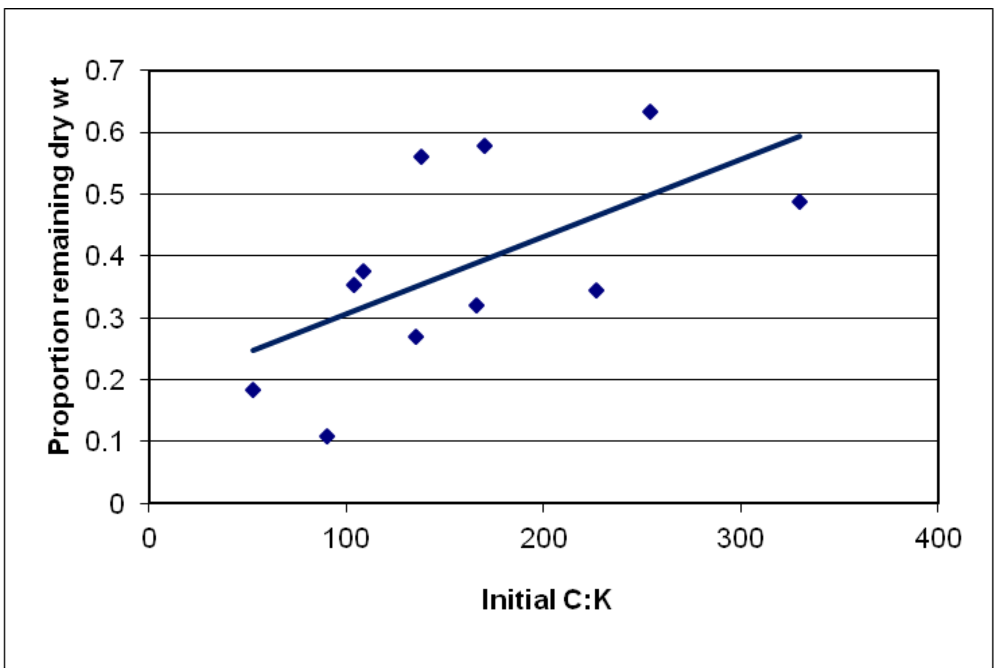
Decomposition as influenced by leaf chemical and physical traits.



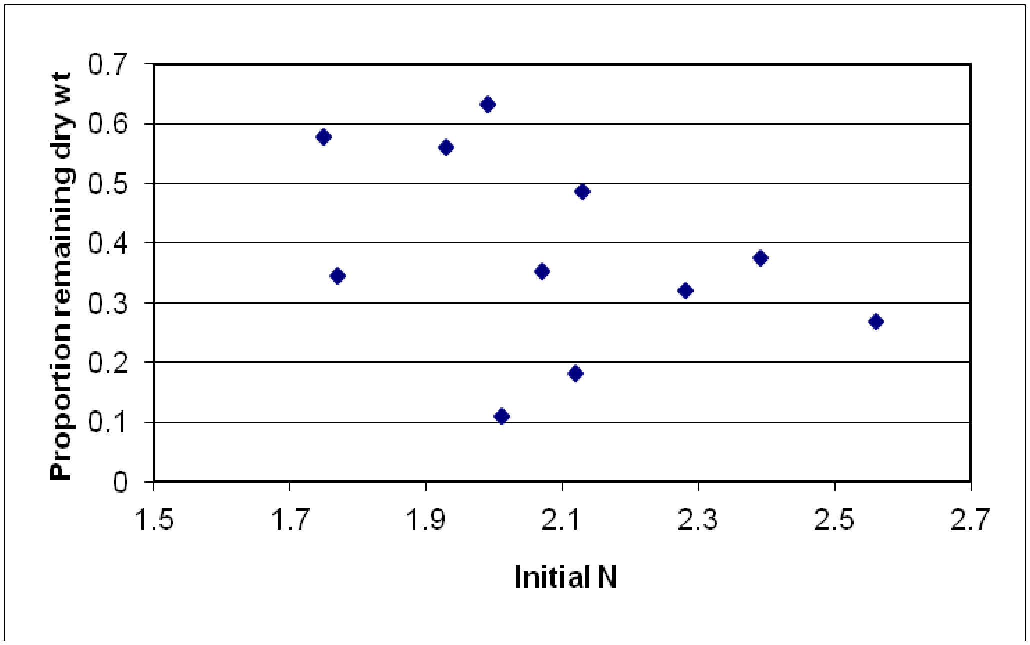
The best predictor of decomposition speed was leaf lignin content, with a significant increase in amount of litter remaining (slower decomposition) with increased lignin.



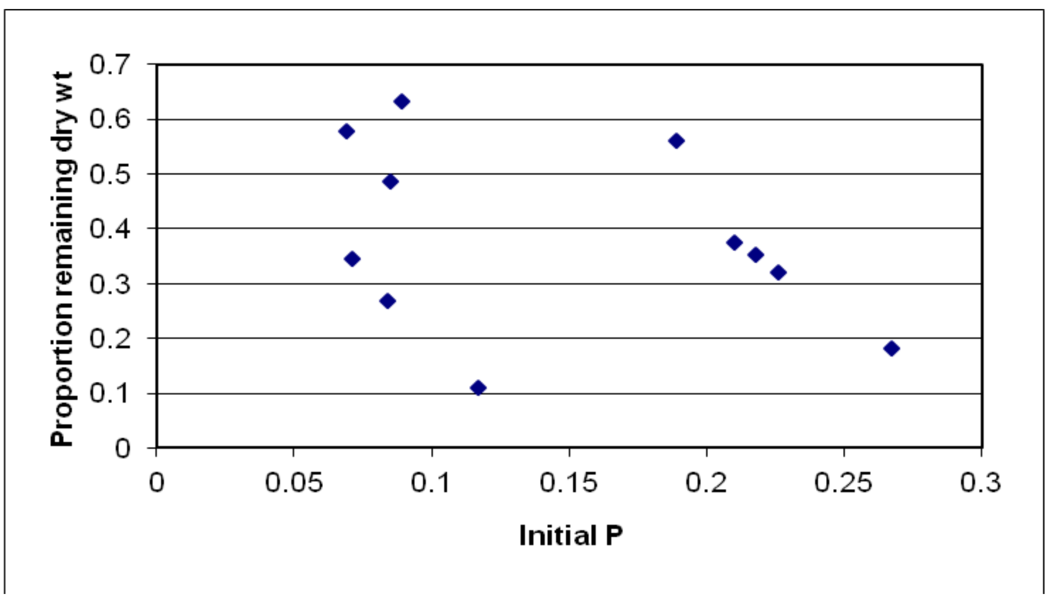
Initial leaf potassium content was also a good predictor of decomposition speed. Greater potassium significantly increased decomposition speed.



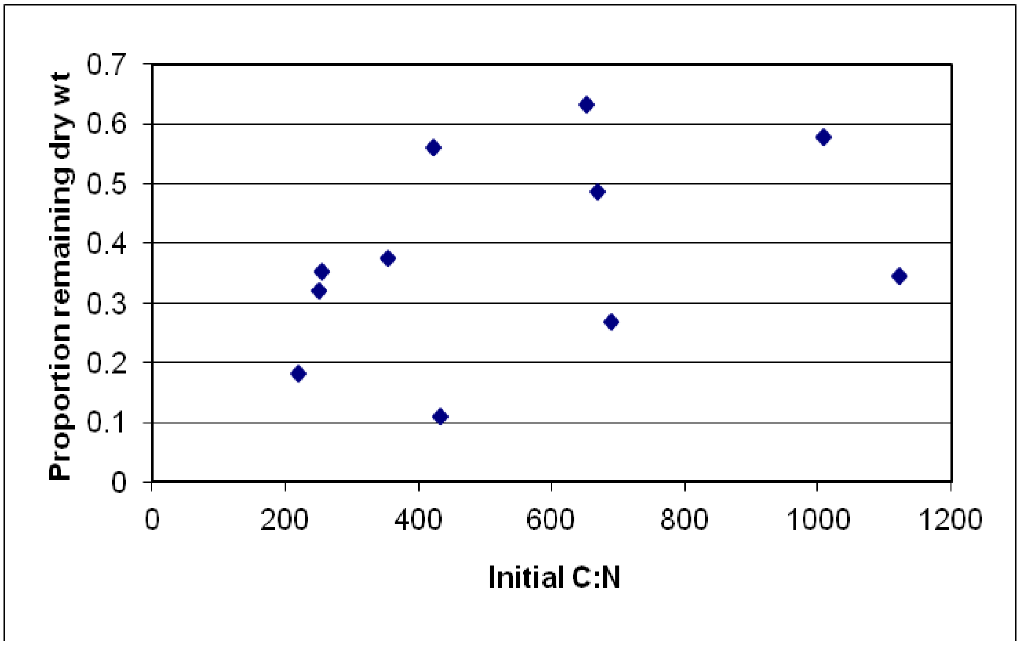
The relationship of carbon to potassium also significantly influenced decomposition speed. A significant increase in amount of litter remaining (slower decomposition) occurred with increased C:K.



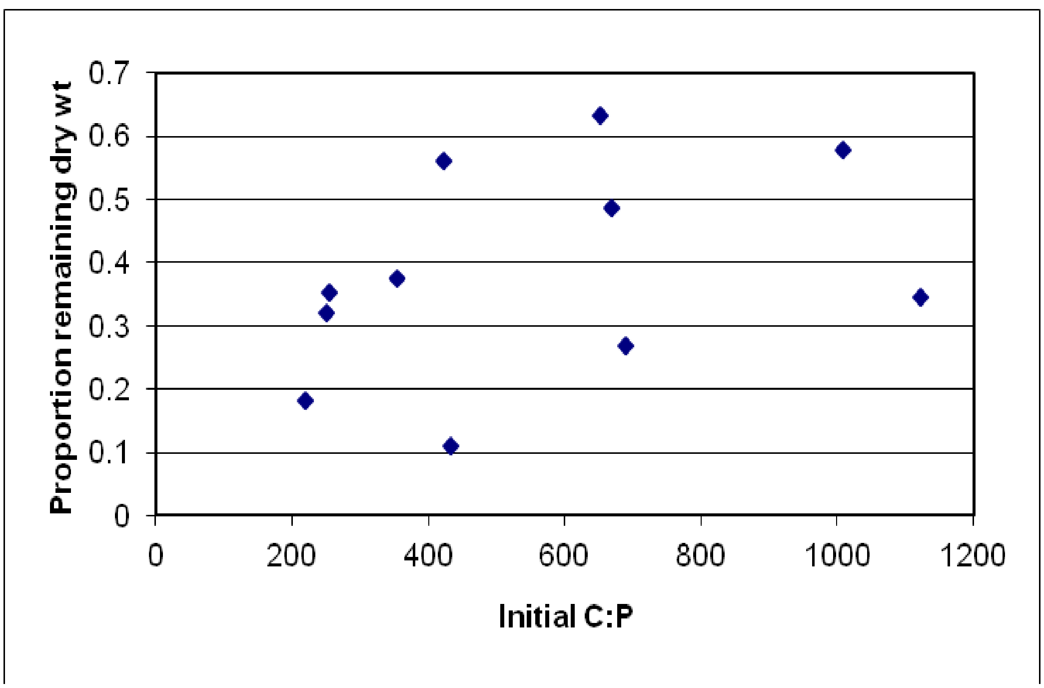
The leaf nitrogen content did not significantly influence initial decomposition speed.



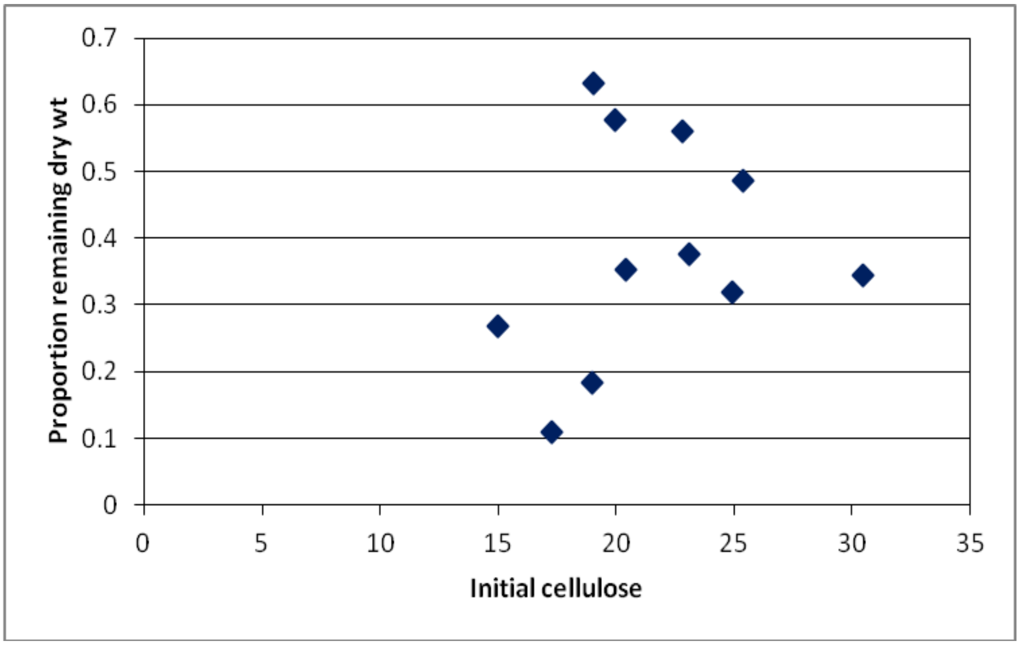
The leaf phosphorus content did not significantly influence initial decomposition speed.



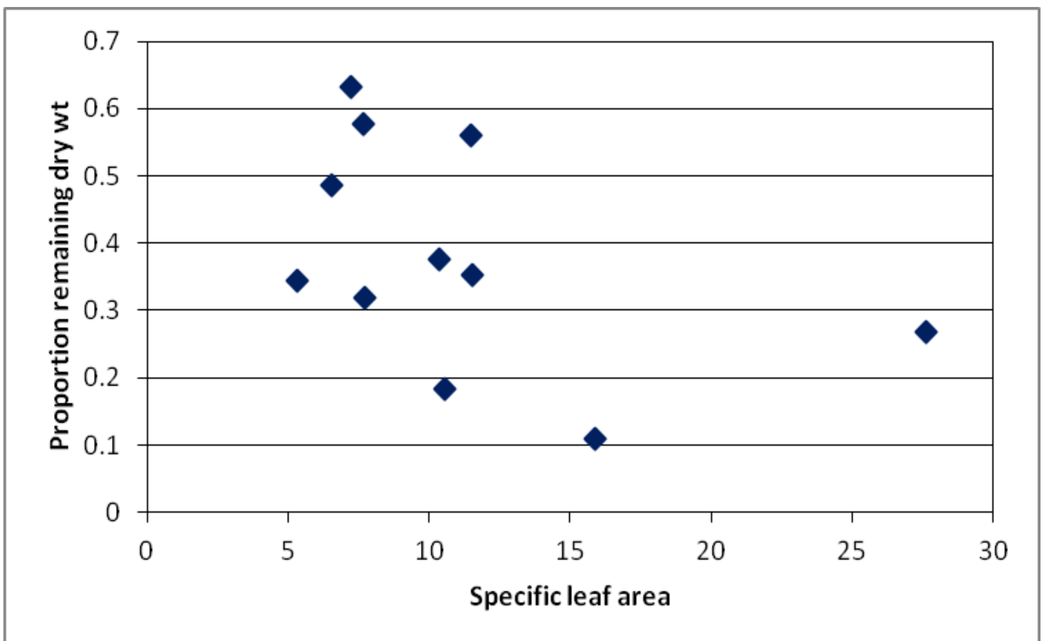
The relationship of carbon to nitrogen did not significantly influence initial decomposition speed.



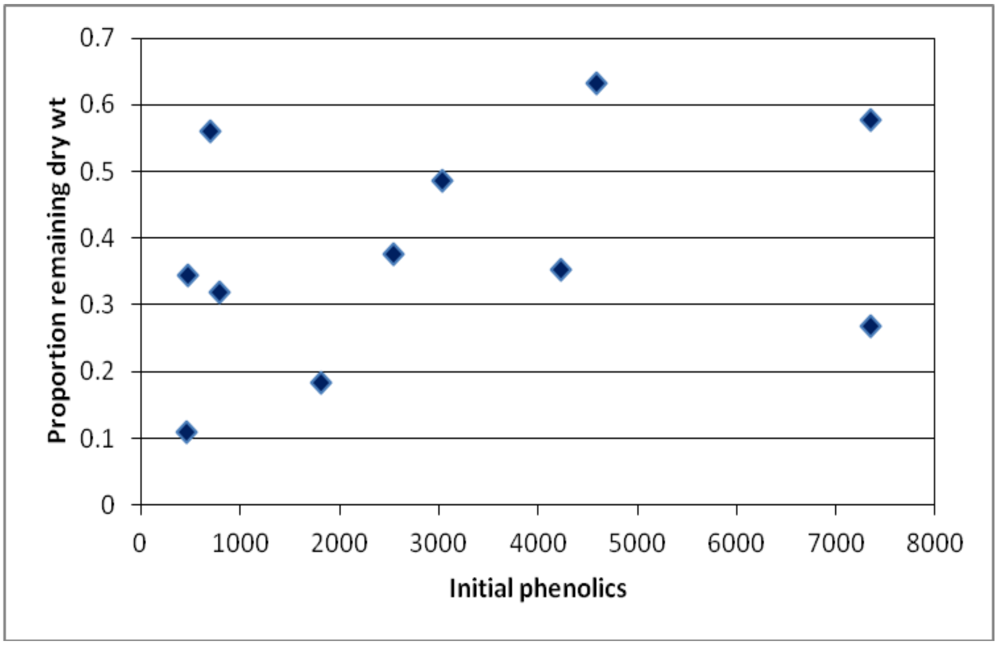
The relationship of carbon to phosphorus did not significantly influence initial decomposition speed.



The leaf cellulose content did not significantly influence initial decomposition speed.

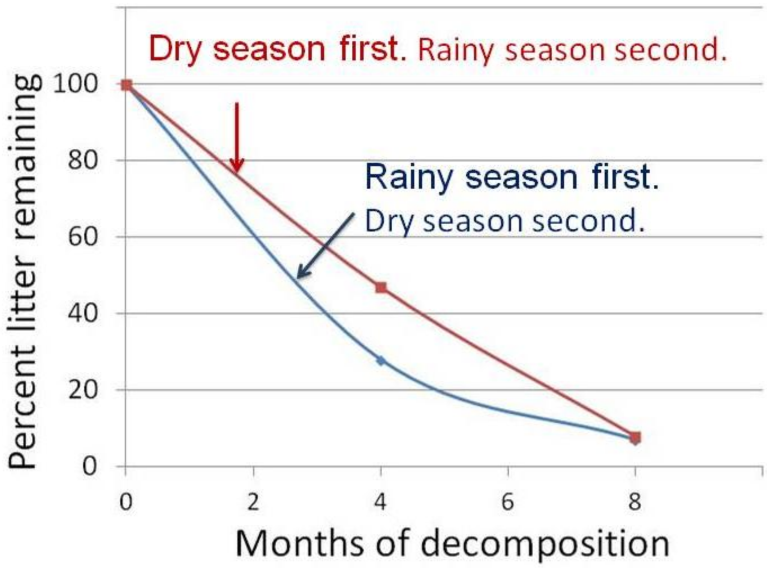


The specific leaf area (mm^2 / mg) did not significantly influence initial decomposition speed.



The total phenolics content of leaves did not significantly influence initial decomposition speed.

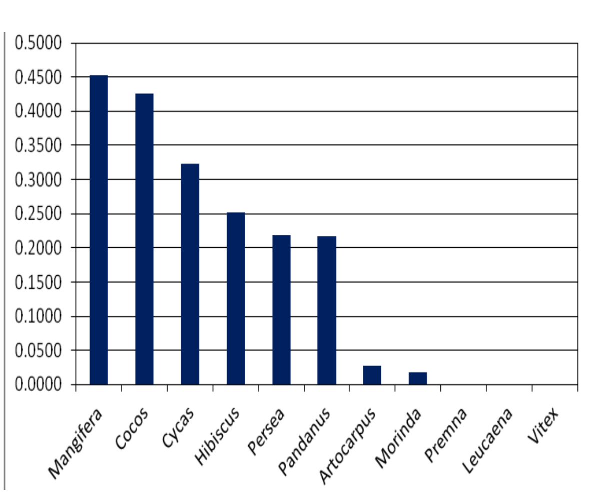
Decomposition as influenced by season. Considering the influence of rainfall on litter decomposition and the distinct rainy versus dry seasons of the Mariana Islands, we conducted paired experiments to determine litter decomposition during the first 8 months of deployment. The first experiment was initiated at the beginning of the rainy season, and the second experiment was initiated at the beginning of the dry season. The two Guam sites were included and we used all 11 tree species for this study.

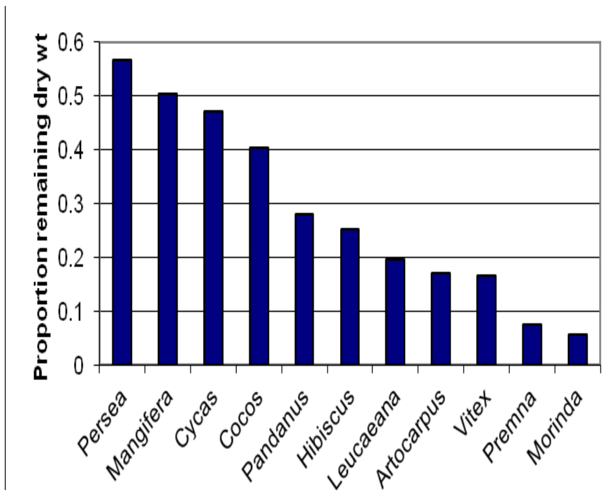


Litter decomposition during the initial 4 months was more rapid during the rainy season as predicted. However, the season in which leaf litterfall occurs will influence initial speed of litter decomposition, which is under the control of rainfall abundance. However, this divergence of decomposition speed as influenced by season disappears during the 4 to 8 month period when rainfall is limited for the litter that began decomposing in the rainy season but rainfall is abundant for litter that began decomposing in the dry season.

Objective C. Determine decomposition characteristics in a controlled microcosm approach of the species studied in objective B.

A microcosm approach to litter decomposition research provides a uniform environment for incubating litter. This approach is ideal for implementing manipulations then measuring the response to those manipulations. The microcosm that we used for this study was constructed on the University of Guam campus. The results following four months of decomposition in this microcosm are shown in the left graph below. The results following four months of decomposition in the field sites are shown in the right graph.





In general, decomposition occurred at more rapid rate in the microcosm. Moreover, the ranking of species was not the same for the two styles of incubation. One influential factor that differs between the two incubation styles is rainfall and resultant leaching. Soluble chemicals in the litter may have been heavily leached from the litter by the rainfall imposed on the field sites. These same chemicals would not be heavily leached from the litter that was being incubated in the microcosm.

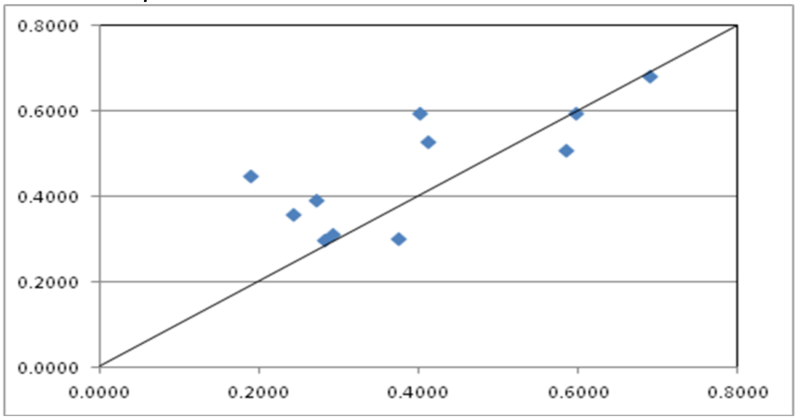
Objective D. Determine the influence of combinations of the litter from these species to define which species exert a strong effect on carbon and nutrient cycling of general litterfall.

In all of the region's native forestry and agroforestry situations, leaf litter of different species occurs together in the litterfall. Therefore, their decomposition does not occur in isolation. Inclusion of species mixtures defined the facilitative and competitive manner in which litter mixtures decomposed. The interactive effects can be strongly positive to strongly negative

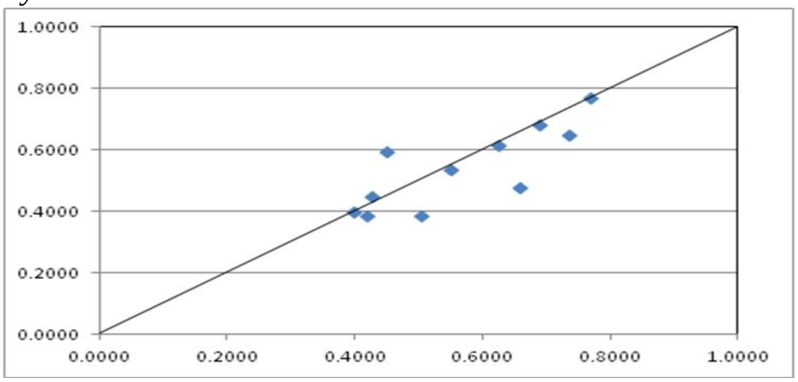
(Wardle et al., 2009). We used every possible two-way mixture of litters. Inclusion of the two major invasive tree species in these mixture approaches developed an understanding of how these alien species alter carbon and nutrient cycling within litterfall of native species. Their influence cannot be predicted without actual data because invasive plants can either speed up or slow down decomposition via direct influence on litter chemistry and indirect influences on detritovore communities and soil moisture relations (e.g. Godoy et al., 2010; Hartemink & O'Sullivan, 2001; Standish et al., 2004). In fact, changes in the litter layer may be causal for the invasive nature of some plant species (Farrer & Goldberg, 2009). This information will aid NRCS to support information conservation planning to address protection of water resources, improve sustainable agriculture practices to reduce current reliance on imported foods, and manage fragmented native forests to conserve biological diversity and maximize ecosystem services.

The following ten graphs show how each of the species influences the decomposition speed of all other species. In each graph, the line depicts where each of the markers would occur if there were no deviations from additive effects. A blue marker to the left indicates a species pair that decomposed more rapidly than predicted. A blue marker to the right indicates a species pair that decomposed more slowly than predicted.

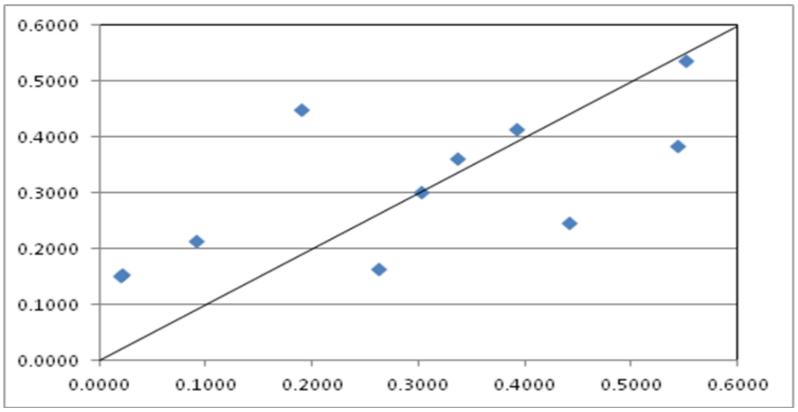
Cocos nucifera.



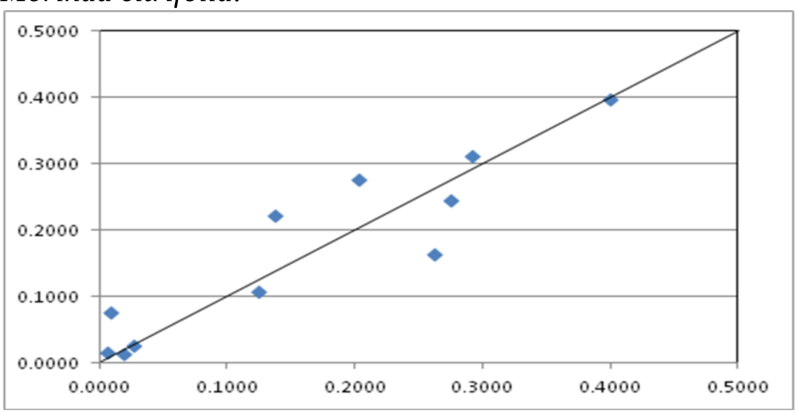
Cycas micronesica.



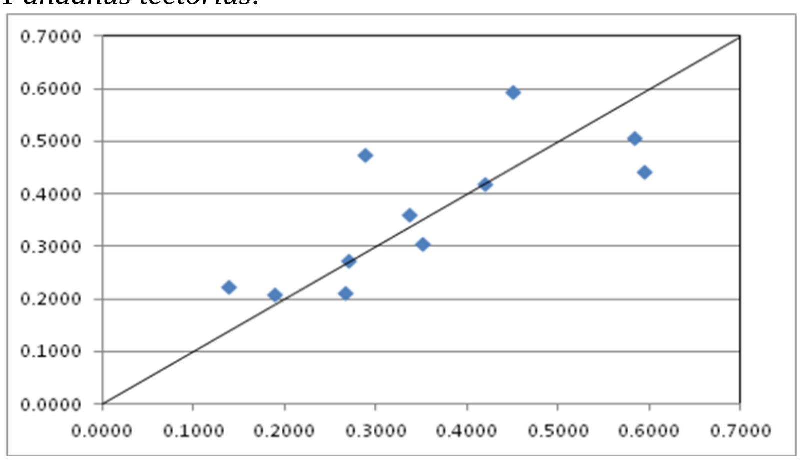
Hibiscus tiliaceus.



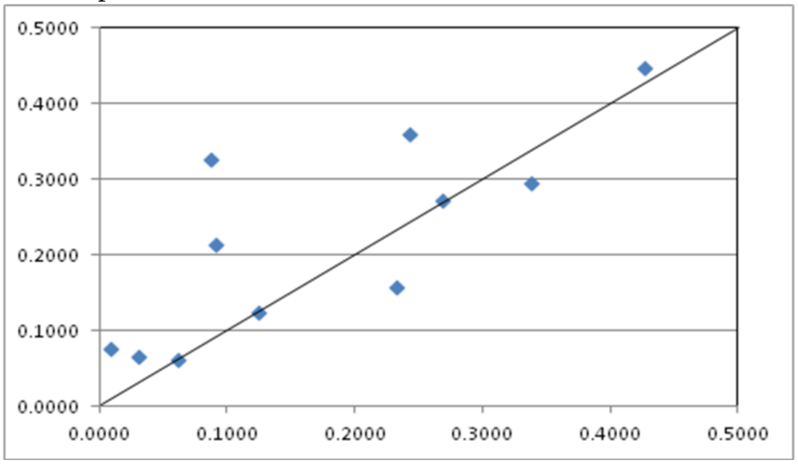
Morinda citrifolia.



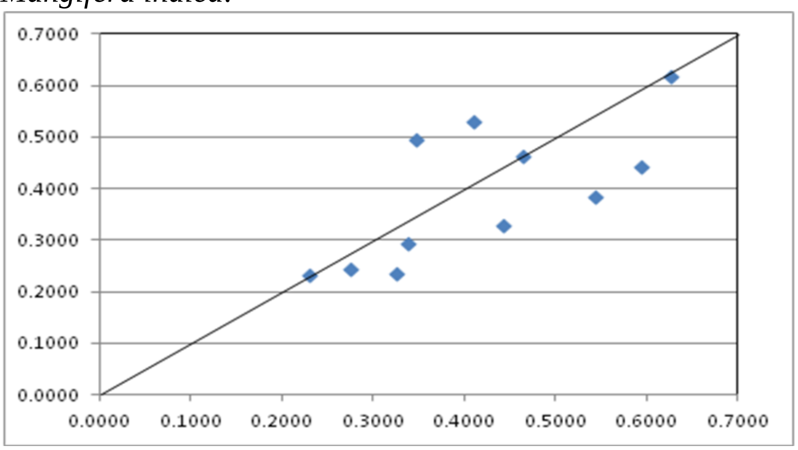
Pandanus tectorius.



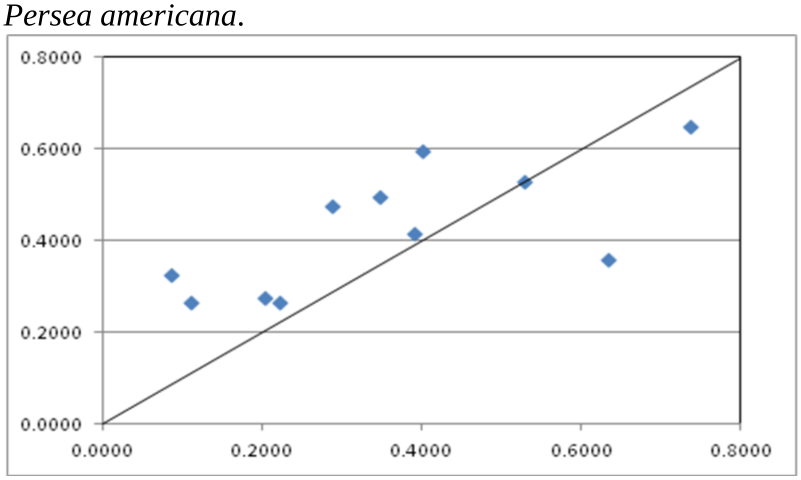
Artocarpus altilis.



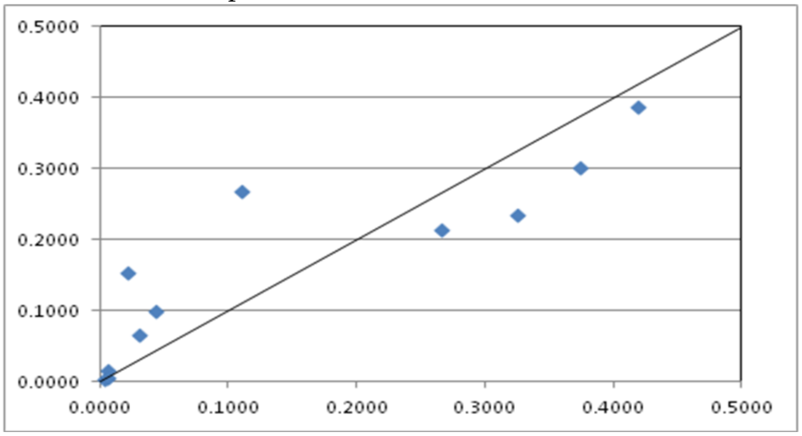
Mangifera indica.



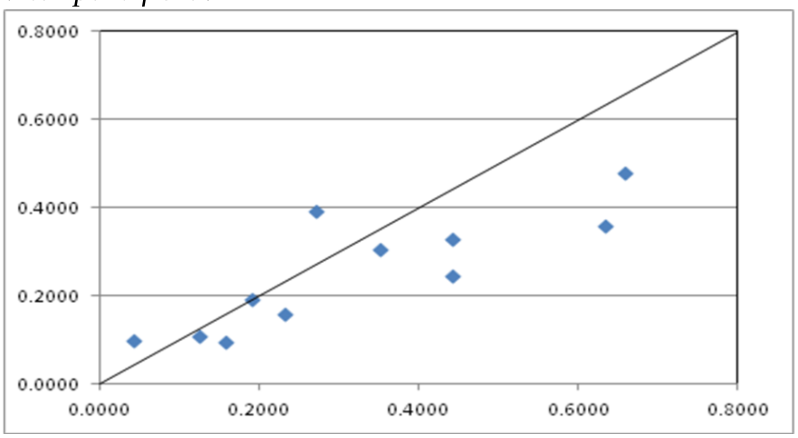
Persea americana.



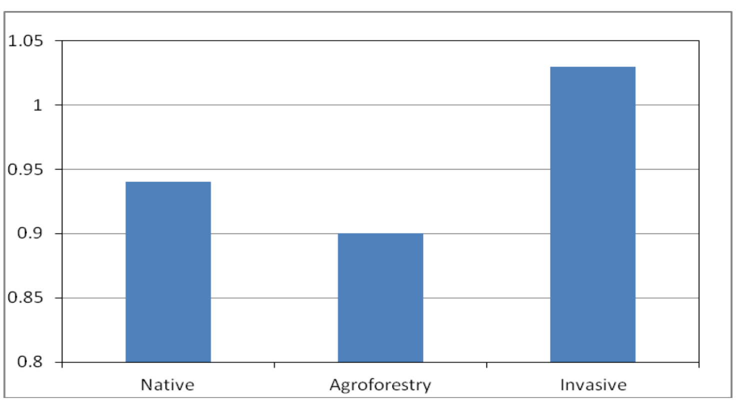
Leucaena leucocephala.



Vitex parviflora.



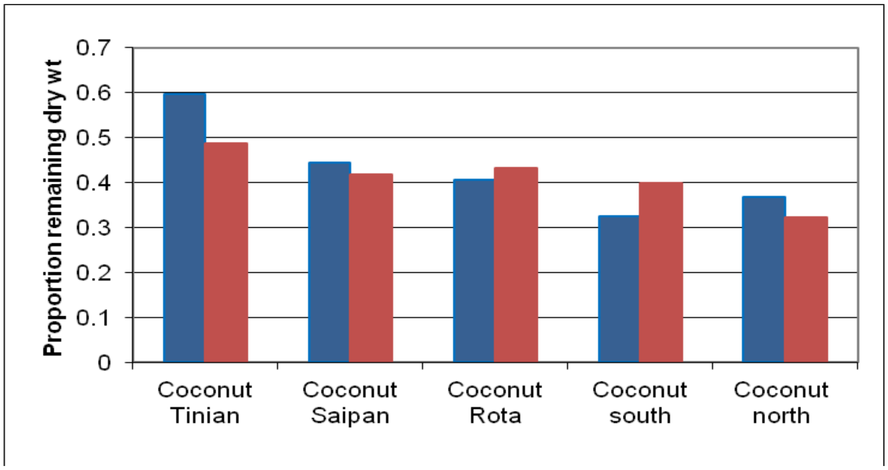
A quotient defined by actual decomposition / predicted decomposition may be used to assign a single number to each species pair, with a number of 1 indicating actual decomposition matched predicted decomposition, above 1 indicating slower decomposition than predicted, and a number below 1 indicating a more rapid decomposition than predicted. The following figure reveals the mean of the native tree species indicated actual decomposition was slightly faster than predicted, adding agroforestry species sped up decomposition, and adding invasive species slowed down decomposition.



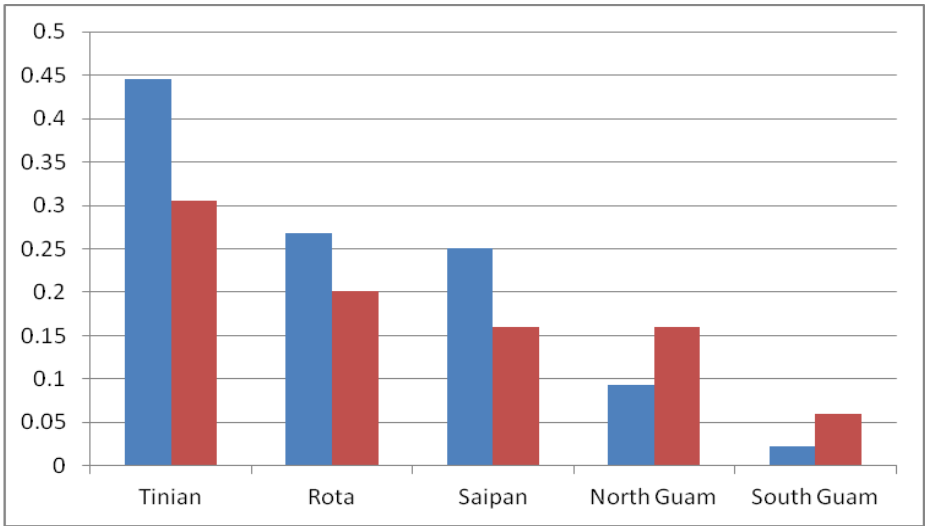
Objective E. Determine the role of habitat on decomposition processes of Cocos nucifera litter to disentangle the role of site-specific ecosystem processes.

A phenomenon called "home field advantage" often exerts strong control over litter decomposition traits. The concept is founded in the fact that the decomposer community that is highly efficient at decomposing litter from a particular species tends to increase in population nearby trees of that species. Therefore, if litter from that species falls in these microsites where the species-specific decomposers have increased in population, the decomposition speed is increased.

Our methods were on an ecosystem level, not on a micro-site level. In general, the differences in decomposition between coconut litter from local trees versus coconut litter from the four "away" farm sites were idiosyncratic and minimal.



Four months decompositon. Blue is home, maroon is away.



Twelve months decomposition.

The influence of “home field advantage” at the micro-site level on litter decomposition dynamics within the Mariana Islands remains to be determined. At the ecosystem level there appears to be no consistent pattern of decomposition between home and away coconut litter.

F. Determine net nitrification, net N mineralization, and gas exchange characteristics within litter deployment sites of the five EQIP farm habitats.

Nutrient status of the soil directly influences decomposition. Therefore, site-to-site variability in litter decomposition may be substantial. If leaf litter is deficient in nitrogen or other nutrients, a soil with high relative levels of nutrients may make up for the deficiency in the litter and speed up the decomposition process.

Sites that are nutrient deficient also indirectly influence decomposition by increasing the nutrient resorption efficiency of the trees. As leaves begin to age and die, the plant can retrieve the nutrients prior to ultimate leaf death. This occurs to a greater extent in poor soils, and the result is slower decomposition of the resulting leaf litter.

The results from this project indicated that site-to-site variation of leaf litter decomposition speed was not substantial in the southern portion of the Mariana Islands from Guam to Saipan. The variations in weather patterns throughout this geographic range are minimal, as most rainfall and cloud cover is controlled by weather patterns that are brought in from the open ocean by trade winds. The small size and relatively limited elevation of the Mariana Islands also exert minimal orographic influence on rainfall patterns.

Variation in leaf litter traits exerted much more control over nutrient and carbon turnover than did variation in site traits in the Mariana Islands. However, to our knowledge these are the first-ever data collected in the Mariana Islands of nitrification and mineralization, and the first time that soil respiration has been measured on a range of soils types.

Site characteristics for <u>Southern Guam</u> farm site.

Net nitrification	2.20 µg/g/day
Net mineralization	1.99 µg/g/day
Nitrogen total	1.04 %
Nitrogen available	81.6 µg/g
Nitrogen nitrate	10.8 µg/g
Nitrogen ammonium	70.8 µg/g
Carbon	13.30 %
pH	7.40
Calcium	1.38 %
Phosphorus	57.00 µg/g
Potassium	206.00 mg/g
Magnesium	405.00 mg/g
Manganese	121.00 mg/g
Iron	53.00 mg/g
Copper	86.72 mg/g
Nickel	56.25 mg/g
Selenium	1.15 mg/g
Zinc	49.28 mg/g

Site characteristics for Northern Guam farm site.

Net nitrification	4.53 µg/g/day
Net mineralization	2.58 µg/g/day
Nitrogen total	1.02 %
Nitrogen available	163.3 µg/g
Nitrogen nitrate	6.2 µg/g
Nitrogen ammonium	157.1 µg/g
Carbon	12.00 %
pH	7.40
Calcium	1.20 %
Phosphorus	54.00 µg/g
Potassium	92.00 mg/g
Magnesium	441.00 mg/g
Manganese	143.00 mg/g
Iron	16.00 mg/g
Copper	23.12 mg/g
Nickel	76.95 mg/g
Selenium	1.72 mg/g
Zinc	83.42 mg/g

Site characteristics for Rota farm site.

Net nitrification	2.24 µg/g/day
Net mineralization	2.44 µg/g/day
Nitrogen total	1.22 %
Nitrogen available	81.9 µg/g
Nitrogen nitrate	5.6 µg/g
Nitrogen ammonium	76.3 µg/g
Carbon	12.00 %
pH	7.10
Calcium	0.75 %
Phosphorus	57.00 µg/g
Potassium	51.00 mg/g
Magnesium	766.00 mg/g
Manganese	234.00 mg/g
Iron	41.00 mg/g
Copper	11.74 mg/g
Nickel	23.84 mg/g
Selenium	0.56 mg/g
Zinc	73.89 mg/g

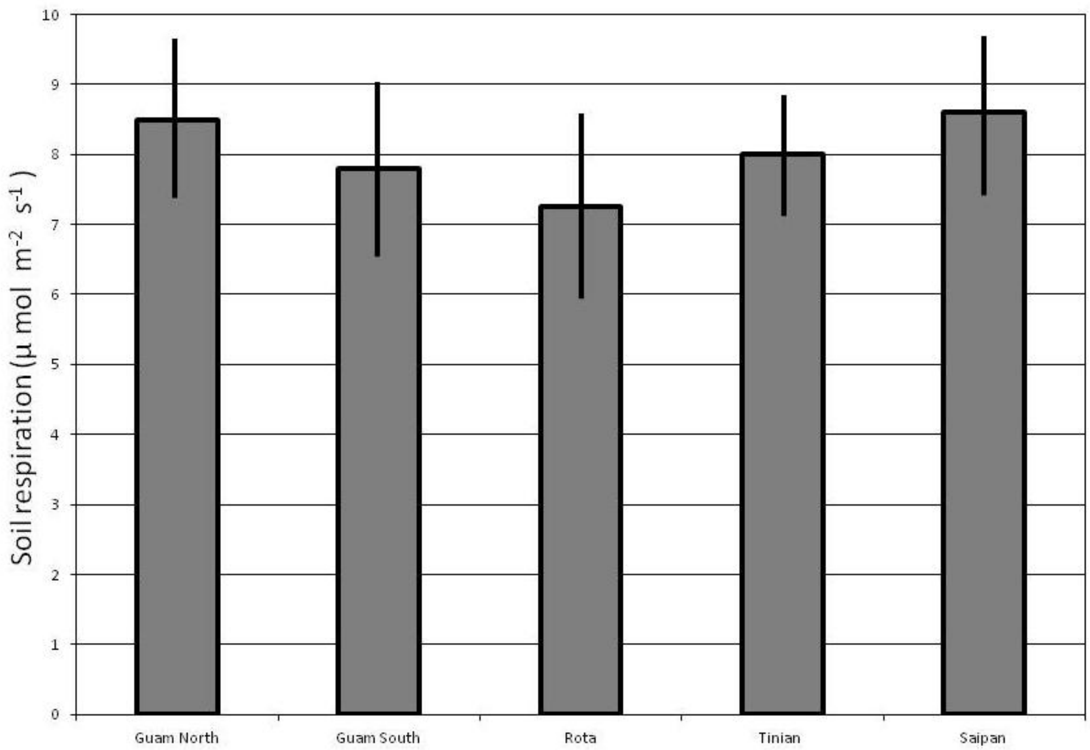
Site characteristics for <u>Saipan</u> farm site.

Net nitrification	2.77 µg/g/day
Net mineralization	3.02 µg/g/day
Nitrogen total	2.01 %
Nitrogen available	129.2 µg/g
Nitrogen nitrate	18.6 µg/g
Nitrogen ammonium	110.6 µg/g
Carbon	21.40 %
pH	7.40
Calcium	1.63 %
Phosphorus	28.00 µg/g
Potassium	64.00 mg/g
Magnesium	832.00 mg/g
Manganese	37.00 mg/g
Iron	121.00 mg/g
Copper	46.02 mg/g
Nickel	3.72 mg/g
Selenium	0.49 mg/g
Zinc	39.49 mg/g

Site characteristics for <u>Tinian</u> farm site.

Net nitrification	6.61 µg/g/day
Net mineralization	2.61 µg/g/day
Nitrogen total	2.45 %
Nitrogen available	317.1 µg/g
Nitrogen nitrate	43.4 µg/g
Nitrogen ammonium	273.7 µg/g
Carbon	26.80 %
pH	7.20
Calcium	1.98 %
Phosphorus	278.00 µg/g
Potassium	406.00 mg/g
Magnesium	3004.00 mg/g
Manganese	137.00 mg/g
Iron	85.00 mg/g
Copper	49.17 mg/g
Nickel	3.06 mg/g
Selenium	1.49 mg/g
Zinc	96.61 mg/g

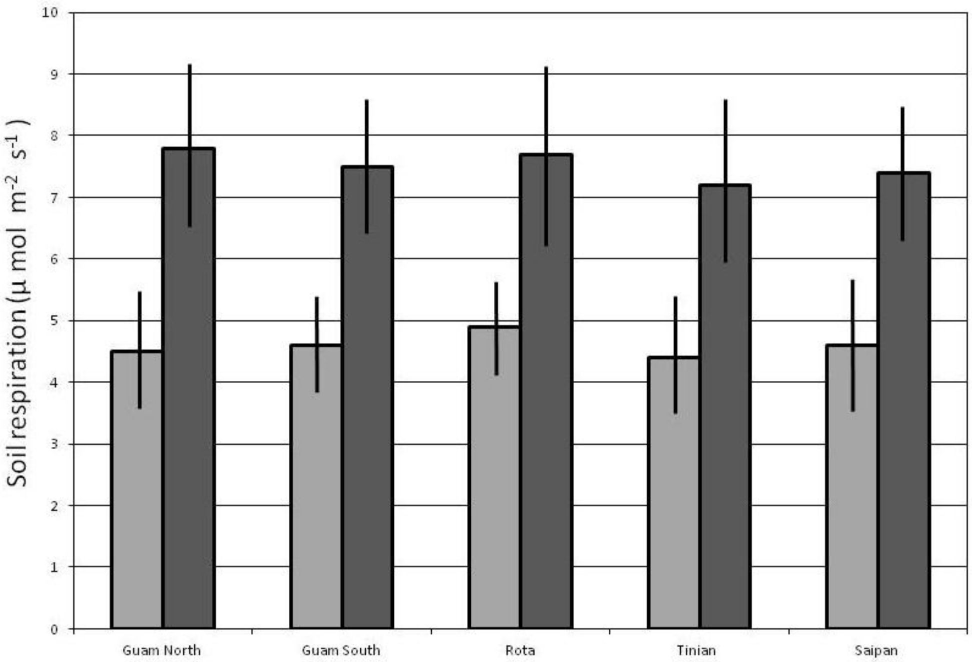
Our soil respiration measurements were conducted during the two major seasons of the Mariana Islands. For the rainy season, we limited the days of measurement to one day following a rainfall event of 2.5 – 3.5 cm. This approach revealed remarkable similarity in soil respiration among the five cooperator farms. The overall mean for the rainy season was 8.0 µmol · m^{-2} · s^{-1}.



For the dry season, using natural rainfall events to time our soil respiration measurements proved to be impossible to achieve due to the geographic distance among the five farm sites, difficulty in transportation logistics, and the infrequent rainfall events. Therefore, we used irrigation of our farm sites with 3.5 cm of irrigation water to standardize the water status of the soil during gas exchange measurements. This approach allowed us to compare the dry soil respiration measured prior to the irrigation event, with the soil respiration of the sites one day following application of the 3.5 cm of water.

Dry season soil respiration was also homogeneous among the five cooperator farm sites. Prior to irrigation, the soils in these farms exhibited mean respiration flux of 4.6 µmol · m^{-2} · s^{-1}. On the day following application of 3.5-cm of irrigation, these same soils exhibited mean respiration flux of 7.5 µmol · m^{-2} · s^{-1}. This sort of response to rainfall or water application is commonplace, and the great influence of soil water on soil respiration is one reason homogeneous soil water content is required to accurately compare various soils or various sites.

When the soil water content was adequate, the soil respiration did not differ between rainy and dry season. Heterogeneity among the sampling sites in each farm was greater in the dry season (Fig. below) than in the rainy season (Fig. above), as indicated by the greater standard errors.



Dry season soil respiration flux among five cooperator farms in the Mariana Islands. Light shaded bars indicate natural water content, dark shaded bars represent one day following a 3.5-cm irrigation event. Mean ± SE, n = 10.

Conclusions.

This project generated unprecedented knowledge that may be used to inform various conservation issues. The details of soil chemistry are comprehensive for the soil series represented at each of our farm sites, and NRCS may now add those data to their database. The concentrations of metals and the various fractions of nitrogen that we reported are of particular import. The project has confirmed predictions that litter decomposition on farm sites in the Mariana Islands is rapid in comparison to global data. The benign, wet, warm conditions of local soils create ideal conditions for detritovores. The decomposition variations among the farm sites from Guam as the southern limits and Saipan as the northern limits were revealed to be minimal. All of these sites were on neutral to alkaline soils, so the highly acidic soils found in Guam and Rota have not been studied to date, and these acidic soils may behave differently in regards to litter decomposition, soil respiration, and nitrogen flux traits. The variation among the tree species was substantial both in leaf litter chemistry and decomposition speed. Lignin, K, and C:K were the only leaf litter traits that significantly influenced decomposition within the framework of this study. That the enormous variation in specific leaf area did not influence decomposition was not expected. As a group, the agroforestry species that are commonly planted on local farms sped up decomposition of co-mingled native tree litter. As a group, the invasive species that immigrate into local farm sites slowed down decomposition of co-mingled native tree litter. These data can be used to better understand how farmers can manage the natural areas of their farm sites and how those forests can contribute to overall health of natural resources on the farm sites. They also provide more evidence of the benefits of culling invasive trees from farm sites. Finally, when farmers use non-native tree species for windbreaks, these data may help them understand how the windbreak species contribute to the production areas in ways that augment actual wind protection.

The information was packaged in lay terms as a Powerpoint presentation and presented to various farmer workshops. NRCS staff now have this Powerpoint presentation on file and it can be used in any of their future farmer training session (Appendix A).

The information was also uploaded to a dedicated web page that is housed on the Western Pacific Tropical Research Center's web site. Users can find the site using a navigation link on the home page of the main site. A dedicated link to the web site: http://www.wptrc.org/trees.asp

References

Cornwell, W.K. et al. 2008. Plant species traits are the predominant control on litter decomposition rates within biomes worldwide. Ecology Letters 11:1065-1071.

Donnegan, J.A., et al. 2004. Guam's forest resources, 2002. Res. Bull. PNW-RB-243. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Farrer, E.C. and D.E. Goldberg. 2009. Litter drives ecosystem and plant community changes in cattail invasion. Ecological Applications 19: 398-412.

Hanson, P.J. and C.A. Gunderson. 2009. Root carbon flux: measurements versus mechanisms. New Phytologist 184:4-6.

Hartemink, A.E. and J.N. O'Sullivan. 2001. Leaf litter decomposition of *Piper aduncum, Gliricidia sepium* and *Imperata cylindrica* in the humid lowlands of Papua New Guinea. Plant Soil 230:115-124.

Hobbie, S.E., et al. 2006. Tree species effects on decomposition and forest floor dynamics in a common garden. Ecology 87:2288-2297.

Godoy, O. et al. 2010. Leaf litter traits of invasive species slow down decomposition compared to Spanish natives: a broad phylogenetic comparison. Oecologia 162:781-790.

Kotilainen, T. et al. 2009. Solar ultraviolet radiation alters alder and birch litter chemistry that in turn affects decomposers and soil respiration. Oecologia 161:719-728.

Lorenz, K., et al. 2004. Decomposition of needle/leaf litter from Scots pine, black cherry, common oak and European beech at a conurbation forest site. Eur. J. Forest Research 123:177-188.

Motavalli, P.P., et al. 2000. The impact of land clearing and agricultural practices on soil organic C fractions and CO2 efflux in the Northern Guam aquifer. Agriculture Ecosystems & Environment 79:17-27.

O'Brien, S.L. and C. M. Iversen. 2009. Missing links in the root-soil organic matter continuum. New Phytologist 184:513-516.

Reynolds, B.C. and M.D. Hunter. 2001. Response of soil respiration, soil nutrients, and litter decomposition to inputs from canopy herbivores. Soil Biology & Biochem. 33:1641-1652.

Rice, S.K. et al. 2004. Impacts of the exotic, nitrogen-fixing black locust on nitrogen-cycling in a pine-oak ecosystem. Plant Ecology 174:97-107.

Seavy, N.E. and C.A. Howell. 2010. How can we improve information delivery to support conservation and restoration decisions? Biodiversity and Conservation 19:1261-1267.

Standish, R.J. et al. 2004. Invasion by a perennial herb increases decomposition rate and alters nutrient availability in warm temperature lowland forest remnants. Biol. Invasions 6:71-81.

Wardle, D.A. et al., 2009. Among- and within-species variation in plant litter decomposition in contrasting long-term chronosequences. Functional Ecology 23:442-453.

Wright, I.J. and M. Westoby. 2003. Nutrient concentration, resorption and lifespan: leaf traits of Australian sclerophyll species. Functional Ecology 17:10-19.

Zhang, D. et al. 2008. Rates of litter decomposition in terrestrial ecosystems: global patterns and controlling factors. J. Plant Ecology 1:85-93.

Appendix A. Lay farmer Powerpoint presentation.