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Agroforestry is a traditional farming practice in American Samoa that has helped to sustain the livelihood of the native population for centuries. These once self-sufficient islands have become economically dependent on U.S monies and other external resources during the past century. Dependency has caused a shift in the carrying capacity of the islands and has changed cultural attitudes regarding land use. This attitude is expressed on the landscape of changing agricultural and communal lands. Preserving traditional agroforestry practices and improving these systems may be important factors contributing to the future ecological, economic, and cultural sustainability of the territory.

The goal of this study was to document and describe agroforestry farming in American Samoa in order to provide base-line information regarding the utilization of agroforestry species, agroforestry farming incentives and constraints, and current practices and systems.

Thirty-eight farmers were randomly selected and farmer interviews and field surveys were conducted between the months of May-August 2003. Formal survey questions for the interview were divided into five major sections: woody species usage, livestock, inputs and soil, land tenure, and farmer demographics. Site selection corresponded with the participant farmers. Basic topographical information was collected for each site. Agroforestry practices mentioned during the interview process that were observed on site were documented. Each agroforestry site was placed into an initial classification type based on a visual assessment of plot size, species diversity, and vertical vegetative structure.

Subplot data regarding species composition and vertical canopy structure was measured for each site. Data collection was divided into five vertical layers primarily by height: 1) low crop (<1.5m), 2) shrub/sapling (1.5-4m), 3) small tree (4-10m), 4) large tree (10+m) and 5) climbing vines. For each subplot all ethnobotanically useful plant species were identified. Percent cover of useful species in each stratum layer was estimated and assigned one of seven percent cover classes. Subplot cover classes were averaged to obtain a single site estimate for each species in each stratum.

Results from the farmer interviews suggest that agroforestry systems continue to be an important cultural and product resource in American Samoa. Although there is no longer the same level of dependency on these systems for meeting basic needs, agroforestry products continue to supplement household diets and are utilized for a variety of non-timber forest products and ecological services. Several agroforestry practices were observed among the farms in the study. However, the effectiveness of some of the practices including windbreaks, fallow, and erosion control was not optimal. This indicated that farmers could greatly benefit from institutionalized agroforestry practices such as appropriate spacing for wind filtration, improved fallow, and contour farming.

Incentives and constraints for practicing agroforestry farming were identified. Some incentives included product variety, tradition, and a growing need for land-use efficiency. Identified constraints included time investment for production and poor labor resources, decreased profit when compared to mono-cultural farming, and the lack of planning prior to agroforestry implementation. The communal land tenure system acted as both an incentive and a disincentive for practicing agroforestry.

The initial classification of agroforestry systems included home tree gardens, mixed crop plantations, transitional systems, and open canopy with dispersed tree systems. Agroforestry systems existed along an ecological complexity continuum, where complexity was measured by species diversity and vertical structure.

A quantitative assessment of species composition and structure was used as a more objective approach to classifying local agroforestry systems. Non-metric multidimensional scaling was used to ordinate sites along a gradient based on species composition and structure. Several environmental and socio-economic variables were investigated to determine whether any of them demonstrated relationships with vegetative patterns. Species diversity, average number of canopy stratum layers, and elevation were three variables correlated with vegetative patterns. Sites that had high species diversity and were multi-structured were placed at the upper end of the gradient, while sites that had lower diversity with simple structure were generally placed at the lower end of the gradient. This supported the ecological complexity continuum. Less complex sites were associated with high elevations indicating that systems on the heavily populated lowland regions were more species rich and structurally diverse.

The classification based on the cluster analysis indicated that distinct groups did not exist, as there was significant overlap. In general, groups derived from the cluster analysis were similar to those based on the visual assessment. One difference was that in the cluster analysis taro and gatae (*Erythrina* spp.) dominated sites emerged as a separate group. In addition, the cluster analysis was able to distinguish several subgroups within the mixed crop plantation type.

No single socio-economic variable was correlated with vegetative patterns. This suggests that socio-economic variables do not determine vegetation in agroforestry systems and that human preference may be more of a driving factor than initially expected. It is likely that the availability of external resources allows for the selection of species within agroforestry systems to be based on choice rather than need. This trend is likely to increase as people become less dependent upon agroforestry systems to supplement needs.

Traditional and institutionalized agroforestry systems have the potential to contribute to increasing self-sufficiency among American Samoan households. Because the importance of these systems is often not realized, the active promotion and education of agroforestry practices is essential. The classification of agroforestry systems provides an organizational framework for future research to build upon. The concept of the ecological complexity continuum where agroforestry systems fall along major points may be useful for answering socio-economic and ecological questions related to local agroforestry production.

Agroforestry Farming in American Samoa: A Classification and Assessment

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DEDICATION

This thesis is dedicated to my father whose courage in difficult times has been my main source of inspiration, and to my mother, whose compassion, humor, and enthusiasm for life, is a constant reminder of how to live.

Chapter 1: Introduction to the Study

American Samoa is an unincorporated and unorganized territory of the United States located in the South Pacific Ocean. The territory consists of five islands and two coral atolls, with an accumulative land base of less than 200 square kilometers. As with many other Pacific Island nations, there has been a dramatic shift away from self-sufficiency over the past century. Much of this change is due to an agglomeration of several factors including global socio-political interactions, technological advancement, and cultural change.

The American Samoan islands are very limited in natural resources. Competition for land has significantly increased as a result of human population growth and changing economic priorities. Land-use patterns that are integral to sustaining the communal aspect of Samoan culture are being threatened by the breakdown of traditional communal land tenure and increasing urban growth and cash crop farming. Urban and agricultural development is most apparent on the largest and most populated island, Tutuila, where mature secondary forest and in some cases climax forest are being cleared for buildings or large plantations. Agricultural development is expanding in areas not traditionally farmed. Carefully planned and well-managed agroforestry systems may provide solutions to meeting conservation needs in American Samoa. Although traditional agroforestry systems already exist in the islands, there has been little documentation of these systems.

The objective of this study is to provide a foundation for the future development of agroforestry in American Samoa by documenting and describing current agroforestry farming in the territory. In addition to a literature review, this research is based on farmer interviews and farm surveys that were conducted in the southwestern region on the island of Tutuila during the months of June-September 2002 and March-September 2003. During these months I worked for the American Samoa Community College (ASCC) Community and Natural Resources (CNR) division where I received assistance in developing the study and making farmer community contacts.

This thesis is composed of three main chapters (chapters 2-4). Chapter two, titled "Perspectives of Sustainability in American Samoa" is an extensive literature review that includes a biogeographic, land-use, and land tenure description of the territory followed by a discussion of local environmental, socio-economic, and cultural sustainability issues. This chapter provides a comprehensive historical and cultural look at the nature of sustainability in American Samoa and explores hypotheses related to island carrying capacity, decision-making, and self-sufficiency. Chapter 2 also serves as an introduction to the islands and sets the stage for the next chapter on farming in American Samoa.

Chapter three, titled "Agroforestry farming on Southwestern Tutuila, American Samoa" is a general description of traditional agroforestry farming in the territory. Ethnobotanical uses, agroforestry practices, and farming incentives and constraints are documented and discussed. An initial classification of agroforestry systems is provided based on a visual assessment of farms. This chapter serves as a cultural record of farming practices while providing base-line information for future agroforestry development.

The fourth chapter titled "Classification of Agroforestry Systems" uses quantitative farm plot data on species composition and structure as an objective approach to classifying local agroforestry systems. Non-parametric statistical methods are used to summarize complex relationships among farm plots and investigate ecological and socio-economic patterns. A comparison between classification types based on the visual assessment vs. the more rigorous quantitative assessment is summarized.

The fifth and final chapter of this thesis includes a revisitation of study conclusions, a summary of needs and recommendations, and potential applications for this study.

Chapter 2: Perspectives of Sustainability in American Samoa

Introduction

The Pacific Islands are among the most remote islands in the world. Anthropologists, linguists, and biologists alike, have long debated the origin of the early people who migrated to these islands. The early pioneers learned to adapt to their new environments by adopting appropriate technologies while seeking opportunities to develop their surrounding habitats, eventually restructuring and shaping their environments (Kirch 1989). The resource use decisions of many early island inhabitants were based on what was available and how that availability could be maintained over time in order to ensure their survival. This is what we would now call "sustainable living" in an early form (Clark 1990). Unsustainable living practices also occurred throughout the Pacific Islands. The extinction of the large flightless bird (*Dinornis giganteus*) by the Maori people of New Zealand and the complete deforestation of Easter Island by Polynesian inhabitants are two well-known examples.

Use of the term "sustainability" in a resource context, gained wide popularity following the publication of the 1987 World Commission on Environment and Development's report, *Our Common Future.* The Commission's idea of sustainability emphasized meeting economic and ecological needs of the present generation without compromising the ability for future generations to meet their own needs (Brundtland 1987). Since 1987, the definition of sustainability has expanded to include socio-cultural, ecological, and economic factors, stressing the dynamic relationship between human and environmental systems. The obvious complexity of this relationship is realized when investigating the causes and consequences of environmental and socio-cultural change in a specific region.

Small islands are in many ways ideal for sustainability studies, as socio-economic, cultural, and geographic boundaries are more clearly defined than in large land mass regions with mobile human populations (Gale 2003). Furthermore, "experiments of sustainability on the islands can become models for developed countries which have not yet even recognized the degree to which they are unsustainable" (Gale 2003).

The American Samoan Islands are an excellent candidate for an investigation of sustainability as changes in economic status, cultural values, and land-use patterns have occurred relatively recently. Since 1899 the Samoan archipelago has been politically divided between independent Samoa, and the United States territory of American Samoa. Although language, culture, and genealogical origins are relatively homogeneous between the two political entities, a dichotomous pattern now exists with regards to socio-economic scales and resource consumption rates. The availability of substantial external resources has largely influenced the current sustainability status of American Samoa.

During the course of this study, underlying themes regarding the nature of sustainability emerged. Although the study is focused on American Samoa, similar themes may be relevant to other developing Pacific Islands. The following hypotheses were examined:

Human carrying capacity of an island (or any land mass for that matter) is conditional since it is dependent upon available technology, access to resources, and ongoing social change. In other words, carrying capacity is a conditional concept, not an absolute one.

Decision-making for the good of the group is more likely to lead towards long-term sustainability than decision-making for the good of the individual. Achieving sustainability is more difficult when decisions are made at an individual level, rather than a communalistic one.

The availability of external resources reduces the need to be self-sufficient and undermines resource sustainability and traditional knowledge. When self-sufficiency meant not destroying the island's ability to feed, house, and clothe its people, the equation was simpler.

Study objectives and methods

The overall objective of this study was to examine the nature and current status of natural resource and land use sustainability in American Samoa while providing a comprehensive introduction to the islands. In order to meet this objective, a biophysical and socio-cultural description is provided. In addition, land use and tenure patterns in both a historical and current day context are discussed. By examining the social, economic, and ecological components of sustainability, the causes and consequences of change are better understood and implications for the future of sustainability can be made.

A number of sources were used to collect information for this study. In addition to a traditional literature review, unofficial government documents and Internet websites from reputable sources were utilized. Aerial photographs were consulted in order to describe current land use classification. Finally, personal interviews with family chiefs and persons knowledgeable of local land tenure issues were also conducted between October 2002 and September 2003.

Biogeographic Description

Geography

The Samoan Islands are located in the western Polynesia region 14-15° south of the equator near the tropic of Capricorn. The volcanic chain of islands is situated 4,200 kilometers southwest of Hawaii and 1,000 km northeast of Fiji. The total land area is approximately 3,132 sq km, which includes nine islands, two coral atolls, and several small islets. (Figure 1.)

Figure 1. Map of the Samoan archipelago.

Political division now separates the eastern and western islands into independent Samoa and American Samoa, an unincorporated territory of the United States. Samoa consists of the western most islands, which include the largest islands of the chain, Upolu (1,110 km^2) and Savaii (1,800 km^2). The human population of Samoa is approximately 178,000 (CIA World fact Book 2003). These islands are relatively resource rich compared to American Samoa, which lies at the eastern end of the archipelago. American Samoa consists of five islands and two coral atolls. The total land area for American Samoa is 196 sq km with the main island of Tutuila 142 sq km in size. The human population of American Samoa is 67,000+ with over 95% of the population residing on the largest island of Tutuila (American Samoa Census 2000).

Climate

The climate of the American Samoan islands is tropical maritime. Annual precipitation averages 400 cm, but can be as high as 1000 cm depending on the slope and elevation (Amerson et al. 1982). Relative humidity is between 76-86 percent. Temperatures throughout the year range between 22-34° C with the slightly warmer and wetter season between the months of December-April (Whistler 1994a).

The wet season corresponds with tropical storm and hurricane season in the South Pacific region. Hurricanes occur irregularly in the Samoan islands. Recent hurricanes occurred in 1990, 1991, and January of 2004. Each of these events caused significant damage throughout the islands. Tropical storms can also cause severe destruction. In May of 2003, a tropical storm resulted in a major flood on Tutuila, which resulted in three fatalities. At the peak of the storm the island received over 20 cm of rainfall within two hours. Several landslides occurred, bridges collapsed and several homes and plantations were damaged.

Topography

The topography of the islands is steep and rugged with over 50% of the land exceeding a 30% slope (Nakumara 1984). The peak elevation for American Samoa is Mt. Lata on Ta'u Island, which rises 932 m. The second highest peak is on the main island of Tutuila, where Matafao Mountain rises 653m above Pago Pago harbor.

Tutuila is 19.7 miles in length (east to west) and six miles wide (north to south) at its widest. The island is deeply dissected by a rough coastline (Whistler 1994a). A continuous, heavily eroded ridge runs across the island. The most significant flat land areas of Tutuila are the Leone-Tafuna plains region located on the southern coast of the island and the Aoloau plateau, situated immediately north of the Leone-Tafuna plains.

Geology and soils

The Samoan archipelago was created from basaltic lava rising from the Pacific Ocean during the Pliocene era. A series of hot spot eruptions took place and the islands were sequentially formed in an easterly direction. Savai'i is the oldest, approximately two million years old, while the island of Ta'u is estimated to be 100,000 years old (Keating 1992). The island of Savaii is still volcanically active where the most recent eruption occurred in 1911. Several different types of basalt rock are recognized through the archipelago.

Soil type varies throughout the Samoan islands, however much of the soil is derived from weathered basalt, tuff, and alluvium. Shallow, excessively drained soils are often found along coastal areas while deep poorly to well-drained soils are found in the mountainous inland regions (Nakumara 1984). Although high rainfall and warm temperatures are favorable for rapid decomposition of vegetative matter and the formation of soils, these climatic factors also result in nutrient leaching. The low fertility, clay soil, which is typical of tropical regions, is generally not suitable for permanent agriculture (Whistler 1980a).

Flora description

The flora of Samoa includes approximately 550 angiosperms, 215 ferns and 13 fern-ally species. Flowering plants are divided into 350 genera and 95 plant families. Native plants include both endemic and indigenous species while alien species are either early Polynesian or modern introductions. The family of *Orchidaceae* has the highest number of native plants, approximately 100 species (Cribb and Whistler 1996). The rate of endemism of Samoan angiosperms is estimated to be 30 percent at the species level; however there is only one family (*Sarcopygme*) that is endemic to the archipelago (Whistler 1992a). Approximately 15 percent of the fern species are endemic (Whistler 1984b). It is estimated that 250 species, roughly 45 percent of the flowering plants of Samoa are introduced species that are now naturalized. Approximately 54 non-native species were intentional early Polynesian introductions. Many of these species included food crops and ornamentals (Whistler 1984b).

Vegetation types

Tropical forests are the characteristic vegetation of the wet tropics where there is hot climate and heavy, well-distributed rainfall (Richards 1952). Prior to human arrival on the islands, most of the vegetation of the eastern archipelago was lush tropical rainforest. The only exceptions are areas with dry, and/or nutrient poor soils (Whistler 1980a). However, the human introduction of new species along with 3,000 years of human occupation dramatically changed the vegetative landscape. Forestlands have been largely converted to other land uses, such as urban and agricultural development. This development has resulted in a mosaic of fragmented forested areas in various stages of succession. Whistler (1994a 2002) classified the vegetation of American Samoa into five broad vegetative categories: littoral vegetation, wetlands, rainforest, summit vegetation, and disturbed vegetation.

Littoral vegetation includes all natural vegetation residing by the shoreline. Vegetation within this zone is generally well adapted to the effects of salt spray, high winds, and intense sunlight. Littoral vegetation comprises the herbaceous strand, shrubland, and forest, which run parallel to the seashore in relatively narrow zones (Whistler 1994a). Wetland vegetation communities such as marshes, mangroves and freshwater swamps, have waterlogged soils (Whistler 1994a). Rainforest includes vegetative communities with relatively high species diversity. General rainforest vegetation zones are distinguished by species composition and include lowland, montane, and cloud forests. The most important factors that effect rainforest composition are elevation, topography, soil, and severity of disturbance (Whistler 2002). The summit vegetative zone includes summit and montane scrub communities typically dominated by low stature species. The two communities are distinguished by vegetative composition and location (Whistler 2002).

The last broad vegetation category occurs as a result of natural or human disturbance. Disturbed vegetation is broken down into several subcategories including managed land vegetation, successional vegetation, secondary forest, and fernlands. Managed land consists of all land that is actively managed by humans including cropland, yards, village *malae* (open grass fields), roadsides, and pastures. Successional vegetation refers to herbaceous, ruderal species that result from abandoned managed land. If left for a sufficient period of time, successional vegetation may eventually become secondary forest. Secondary forests are characterized by fast growing, helophytic trees that dominate the upper canopy. These forests are often remnants of old plantation or village sites. Climax species tend to grow in the understory of secondary forests and if left for succession to proceed, will eventually shade out the secondary tree species. (Whistler 1994a 2002.)

Land and Resource Use: a historical perspective

Settlement of the Samoan islands is believed to have occurred sometime around the second millennium B.C. (Kirch 1989). The people who migrated to these islands brought domesticated plants (such as taro, yams, and breadfruit) and animals (such as dogs and pigs) with them. Since there is no documentation of the native flora and fauna of the Samoan islands prior to European arrival, it is difficult to assess the specific impact the early migrants had on their environment. However, the introduction of animals and new plants significantly altered the biota of the island. As the human population of the Samoan islands increased, developmental expansion took place in the form of settlements and farmed lands, increasing human impact on the natural environment. The coastal location of plains, the most fertile soils, access to water, and important reef channels governed the distribution of human population settlements (Watters 1958).

Pre-contact Samoa

Samoan material culture prior to European contact was based on the surrounding forests, cultivated lands, and the ocean. There was a heavy dependence on forest products to provide materials for construction, medicine, clothes, tools, and wild foods. Cultivated lands provided food that supported a large proportion of the Samoan diet. Six staple crops monopolized the Samoan diet: taro, yams, *ta'amu* (giant taro), breadfruit, coconut, and banana. With a year around growing season, relatively fertile soils, and low maintenance crops, food production did not require regular diligent work. All were sheltered, fed, and lived rather comfortably with plenty of time for social and leisure activities (Coulter 1942). In addition to agricultural production, Samoan society was also marine-based, as many fish, shellfish, and turtle were included in the diet (Buck 1930).

Each village had a fresh water source (individual or shared with other villages) and plantations. Boundaries for land use were partitioned according to their specific purpose. For example, since many villages were located on coves, the land behind the villages (toward the base of the mountains) was generally used for mixed plantation production (Turner 1884). Plantation production was usually limited to areas close to the village, often located in lowland secondary forests. A definite distinction was made between secondary forests and primary forests. Secondary forests were often the result of shifting cultivation practices or natural disturbances. The primary forests are still called *vaomatua*, meaning old forests.

Marine resources were also controlled and allocated at a village level. The village high chief oversaw resources from reefs and lagoons that were within his/her political jurisdiction. This allowed for resource control in the best interest of the immediate community (Johannes 1978). Chiefs controlled the harvesting of fish by placing *tapu* (taboo) restrictions on harvesting. Some species such as tuna were reserved for the *ali'i* (high chiefs). The harvesting of particular reef fish could also be forbidden during certain periods such as a spawning season. This could potentially help conserve fish populations. It has been suggested that restrictive harvesting during spawning season is probably correlated with attempts to minimize waste. Since a large export market for fish did not exist, a catch of surplus fish would have been wasteful as there were few ways to preserve it (Johannes 1978).

Sustainable resource use existed in Samoa during the years prior to European contact. However, the environment of these islands was not static. The Samoan landscape was constantly changing as habitat was modified through introduced species, substantial forest clearance (especially in the lowlands), soil erosion, and extraction of resources. The motivations for sustainable resource use were probably not rooted in concern for future generations or long-term environmental health. Rather, sustainable use was most likely achieved because it was socially and environmentally practical given the human populations that it supported. Natural resource consumption was internally regulated so that it benefited families and villages. In addition, it was impractical to waste resources by harvesting more than one could utilize or trade. The socio-political structure of Samoa and the communal tenure system encouraged strong enforcement, thereby regulating resource use. Furthermore, the strong preference for significant social and leisure activities most likely did not inspire intensive agricultural production.

Land and marine resources were the basis of the early Samoan economy. Food and material production was generally carried out at the family or village level and the fruits of labor were divided among families. Economic sustainability was therefore directly linked to localized resource subsistence.

Trade within the Samoan islands was common, as particular areas were well known for their crop production or their fish. For example, the islands of Ofu and Olosega were well known for their *palolo*, a shallow coral reef worm considered a delicacy. The people of Ofu and Olosega would trade *palolo* for taro from the island of Ta'u. Interaction between Pacific island countries also occurred. Samoan oral tradition describes frequent contact with Fiji and Tonga. For nearly 200 years (approximately 1200-1400 AD) Samoa was ruled by Tonga, but trade interactions between the two island countries probably occurred long before this.

Archeologists suggest that Samoa may have been a regional trade center of fine stone tools. Evidence indicates that a very organized manufacturing system was in place and that stone products from Samoa were traded throughout the Pacific islands. The production line began on steep mountainsides where several basalt quarries were located and ended up near the ocean where final products such as adzes, chisels, and scrappers were polished (Weisler and Kirch 1996, Enright 2003).

The existing technology of tools and ocean transportation in old Samoa allowed for inter-island and Pacific regional trade. In essence, technology affected the rate of natural resource exploitation. The mass production of stone tools required the exploitation of basalt resources in return for outside resources. However, since relative costs and benefits remained fairly localized, economic subsistence was still met. In old Samoa, a balance existed between local production and local consumption.

Early contact and the beginning of commerce

The first documented contact of the arrival of a white man in the Samoan islands took place in 1722 when the Dutch Indian trade company anchored their ship off the west coast of the island of Ta'u. For the next hundred years there were sporadic documented cases of visiting European traders and natural historians. (Gray 1960)

In 1828 the first European Protestant missionaries arrived by way of Tonga. In 1830 John Williams with the London Missionary Society (LMS) arrived on the island of Savai'i on a ship called the *Messenger of Peace*. Williams had come by way of Tahiti and brought several new converts to assist in the establishment of formal missions. Among the new converts was an exiled Samoan, which may have contributed to the success of the LMS, since the Samoan was fluent in the chief's language (Rowe 1930). The LMS soon became the dominant religious denomination throughout Samoa.

The first Americans arrived in 1839 as part of a U.S scientific exploring expedition. Commodore Wilkes, the expedition leader was in charge of surveying the archipelago. During his five-week stay in the islands he appointed John Williams of the London Missionary society to represent American interests in the islands. Until Wilkes' arrival, imported items had been bartered for local products. Wilkes established a set of commercial regulations with the assistance of *Malietoa,* the highest chief in all of Samoa. This was the first time that money was used as a medium to exchange products (Gray 1960).

By 1842, Samoans were exporting coconut oil to Europe and America for candles and soap, and the idea of credit between merchants and villagers began to infiltrate island society. In 1860, Germans purchased large lots of land to establish commercial size copra plantations (Gray 1960.) Land and property disputes became common. Many Samoans felt that they had been dispossessed of their lands by unfair means and would sometimes use this as justification for theft on German plantations (Masterman 1934).

The Germans found it difficult to hire local Samoans to work the plantations, since they were seen as unsuitable for labor and criticized as being lazy (Masterman 1934). This 'laziness' was attributed to the fact that basic needs were easily obtained, that leisure was given high cultural priority, and that Samoans had little material wants. The lack of desire to amass wealth was viewed as a result of the communalistic system, which did not encourage individual wealth. Since goods were distributed evenly throughout the family, an individual had no incentive to work harder then the next person (Masterman 1934.) Since the Samoans thought it ridiculous to labor for several working hours, the Germans imported Chinese and Melanesian laborers. The Germans began to flourish in Western Samoa while the United States Government became increasingly interested in the Pago Pago harbor (on Tutuila) as a main depot for commercial trade and a port of call (Gray 1960).

During the mid 19th century a colonial power struggle over Pacific Island territories began between the United States, Great Britain, and Germany. These three major powers saw potential commercial investment in the coconut oil trade and military strategic placement in the islands (Masterman 1934). The three countries aligned themselves with different powerful chiefs in order to gain commercial and political advantage. Each country wooed contending chiefs and supported one against the other in political intrigue and open civil war (Farrell 1965). In 1899, a commission in Washington D.C. produced the Treaty of Berlin, which divided the eastern and western Samoan islands between the United States and Germany. Great Britain yielded claims to Samoa, favoring other German colonies in the Pacific. The territory of American Samoa (which at that time included the island of Tutuila and Aunu'u and called Eastern Samoa) officially became the possession of the United States in 1900, when paramount chiefs and a United States Naval Commander signed the Deed of Cessions. The Manua islands became part of American Samoa in 1904 after some resistance (Gray 1960).

Under the jurisdiction of the United States, American Samoa agreed that the U.S Constitution would act as the supreme law. The United States in turn, agreed to support Samoan culture and customs as long as they did not conflict with the supreme law. Samoan chiefs would continue to oversee families and communal lands. The same year that the Deed was signed, a conflict arose that challenged the traditional authority of chiefs (Gray 1960).

An untitled man named *Fagiema* was fishing when he caught a skipjack fish. Skip jacks were considered *tapu* to anyone except men of chiefly status. According to Samoan custom, *Fagiema* should have given the fish to the local chief. While *Fagiema* was cooking the fish, a High Chief named *Letuli* caught him. *Letuli* commanded the men of the village to uproot *Fagiema's* crops and burn down his house. *Letuli* condemned *Fagiema* to exile by taking away his rights to grow crops and fish. The Naval administration received word of this and *Letuli* was summoned to court. During the court proceedings, *Letuli* defended his right as a high chief to make such decisions, but the United States found *Letuli* guilty of improper conduct under the U.S Constitution. The court ordered Letuli to make restitution for the damaged crops. In addition, *Letuli* was confined to Pago Pago area for one year and could not carry out any chiefly duties during this time. The conflict between *Letuli* and the U. S Commandment set a historical precedent as the status of High Chiefs was publicly undermined in the shadow of the United States law. (Gray 1960)

Under the U.S administration

The first quarter of the 20th century brought more development and change to the American Samoan islands. The estimated human population of the territory was approximately 5,679 in 1900; twenty years later it was estimated at almost 13,000 (Coulter 1942). With the introduction of modern medicine, Samoan received vaccinations for common but sometimes lethal tropical diseases, inevitably prolonging the average Samoan lifespan. The increasing population required the expansion of agricultural development. Non-Samoans viewed local agricultural practices as "wasteful" and inefficient (Gray 1960). Under the Naval Administration the Department of Agriculture had an experimental farm where new crops were introduced and new methods to preserve local produce for emergency purposes were explored. However, Samoans did not demonstrate wholehearted interest in changing their traditional agricultural patterns (Farrell 1965).

Prior to World War II, the influx of outsiders was minimal. Although the military base had been established on Tutuila for over 40 years, outsiders generally remained in the relatively urban PagoPago bay area (Gray 1960). However, by 1942 a significant number of military men occupied the American Samoan islands; American Samoa essentially became the Pacific frontier of the United States during WWII. Several Samoans also joined the armed forces and were sent to the U.S mainland. The Department of Agriculture shifted production on the islands toward growing vegetables for American military forces and copra production was no longer a priority. Many agricultural and plantation lands were cleared for military outposts and training grounds (Farrell 1964).

The economic impact of the war dramatically shifted the economic status of many Samoans. Military personnel spent their money with local merchants allowing for a money-based economy to flourish. In addition, the development of the islands required a labor force. In order to support the large population, imports such as canned food and materials into the islands increased. However, all boats were being used for military purposes and the copra export business was halted (Gray 1960).

After the war, the American Samoan islands were left relatively wealthy compared to their island nation neighbors. However, when the military base was closed in 1951, the economy slumped. Emigration trends to the United States mainland and Hawaii began during the early 1950's in a dramatic response of the opening of the international airport in Tafuna (Chapman 1991). Children were often sent to the U.S to receive an American education and increasing numbers of young adults joined the military forces. Those who returned found new opportunities in the islands that sometimes conflicted with their own traditional social status and that of the village chiefs (Gray 1960, Holmes 1964).

Private industry took hold in the islands in 1953, when tuna canneries opened in Pago Pago harbor. American Samoa welcomed the opportunity for resource development and international trade. Since the naval base had shut down only two years earlier, American Samoa saw a great need for new economic development. The tuna canneries have remained a large contributor to household economies. To date, the two canning companies, StarKist (owned by Del Monte) and Samoa Packing (owned by Thai Union, based out of Thailand) are rated as the first and third tuna canneries in the world in terms of production (Wolman 2002).

Modern American Samoa

During the 1960's the United States administration poured millions of dollars into the infrastructure and development of the U.S affiliated Pacific islands. The intent was to jumpstart economies in this region so that they would eventually become economically independent. In American Samoa, a major campaign was undertaken to restructure education and bring the islands up to speed with modern technologies and conveniences. In the early 1960's education by television was introduced. This was a pedagogical experiment with a focus on "improving" the quality of education, modernizing Samoan youth, and promoting American values such as democracy and capitalism (Schramm et al. 1981). Although it largely served its purpose at the time, it also led to further cultural erosion. Wysong (2002) compared traditional plant knowledge of persons from all age groups and found a correlation between those who began school in the early 1960's and a drastic reduction of plant knowledge. Although no direct causal effect could be linked, the findings still typify the cultural impact on new generations as a result of American influence.

Current land use

Due to the steep topography and poor soils of American Samoa there is little land suitable for permanent agriculture. Out of the 49,000 acres of land, only 5 percent of it is arable (World Fact Book 2004). There is little commercial farming. Less than 1 percent of the farms included in the territory wide agricultural census were commercially based (American Samoan Census of Agriculture 1999). Commercial farms tend to grow a variety of introduced crops such as cabbage, cucumber, green onions, and melons.

Most families have access to farming areas. Areas are often cleared next to the home compound and planted with an assortment of fruit trees and staple crops such as banana (*Musa* spp.), taro (*Colocasia esculenta*), and ta'amu (*Alocasia macrorrhiza*). Taro is generally planted wherever there is available land. Several varieties of this crop allow production in a variety of agroecological zones. Secondary forests are cleared for banana and taro plantations. Families often have designated reserved areas of nearby forest that are used for shifting cultivation. On Tutuila, forestlands that are collectively owned by the village no longer exist; rather families claim lands from the fringing reef to the top of the mountain behind their home (Gold 1988).

Commercial forestry does not exist in American Samoa. Due to the significant amount of imported goods, the growing popularity of cement homes and territory-wide medical care, many families no longer depend on forest products to meet their basic needs. However, forests still play a major role in everyday Samoan life. Secondary forests provide fuel wood, poles for construction, and some food. Although most Samoan households can get almost all their forest products from nearby secondary forests, prized woods for carving, several medicines, and wild foods such as coconut crab (*Birgus latro*) are harvested from primary forests. Steep slopes that provide little access often protect montane primary forests. However, almost all of the lowland primary forest has been converted to urban and agricultural land uses.

The only official protected forestland within the territory is the National Park of American Samoa. The park was established in 1988 and includes land on three different islands totaling 9,000 acres of tropical forests, beaches and coral reefs. Lands are leased from the villages within park boundaries. Each village gets an annual payment for the lease in return for an agreement to abide by regulations and provide access to visitors and scientists. Designated areas are set aside for farming and harvesting of forest and marine products are restricted to traditional methods within the Park (P. Craig, personal communication, May 2004).

Urbanized areas in American Samoa are limited to the southern coast of Tutuila, primarily, the vicinity surrounding Pago Pago harbor and the Leone-Tafuna plain region. Pago Pago is the capital of American Samoa and the main economic region. The fish canning industries are located within the harbor area as well as several smaller private businesses that support the main industry. The Tafuna area is located near the center of the island and has become the fastest growing region in American Samoa. Half a century ago, the area had the largest intact lowland forests. The region now includes an industrial park, government housing, the airport, and the largest area of privately owned land. Tafuna has the largest human population at 8,409 (American Samoa Census 2000). Significant urban growth in this area is illustrated by the 32 percent increase in population over the past decade (Brinkhoff 2003).

The village malae

A long Samoan tradition of cultural significance is the village *malae,* which are open manicured spaces generally centered near the front of the village. The *malae* is known as the "eye of the village" and is communal space for activities such as ceremonies, sporting events, and celebrations (Aseta 1997). Each *malae* was named after important events that occurred on the *malae* or natural characteristics of the landscape. In their original form, the *malae* occupied anywhere from three to ten acres, was planted with trees and flowers, and was well maintained (Allen 1993).

During WWII, the landscape of many village *malae* began to change. Temporary roads were built through these areas creating fragments of open space. With the increase in U.S funds during the 1960's these same roads were paved and buildings such as schools were erected. Powerful religious leaders and chiefs began to build large permanent structures such as churches, concrete based homes, and parking lots on the village *malae.* In many cases the destruction of the *malae* has been irreversible. Talking chief Taelefusi spoke of the *malae* in the village where he resides:

> It is very sad to look at Leone because it has a very historically important *malae* there. The *malae* was abandoned in Leone. The attitudes about the land are very poor. The heavy waves are just hitting hard on the shores and no one cares. Nobody does anything to remedy the abandoned *malae* or pick up the rubbish. And when we talk about it, it's only a little place. The name is big historically, but the place is too little. It's a shame to see the *malae* get smaller and smaller. We only hear of them when you speak salutations and when you are in ceremony. It is then that they speak about the importance of the *malae.* But the physical aspect is small. You cannot see the natural beauty of the *malae.* Not only in Leone, but other *malae* are shrinking.

There appears to be a contradiction in the way the *malae* are spoken of and how they are cared for. The *malae* in Leone is a particularly good example of this contradiction, where it is hardly recognizable. A main road with two large churches, a few homes, and community dental clinic have replaced the *malae.* The preservation of village *malae* is currently included in local urban and community forestry program agenda as it is a culturally important land-use system (M. Misa, personal communication, June 2003).

Land Tenure

Social organization and the matai system

Land tenure can be viewed as social organization with a spatial dimension (Bohannan 1963). Decisions that delineate land division and define property rights are fundamentally linked to social relationships; property is essentially a social relations model (Singer 2000). In both Independent and American Samoa, the indigenous land tenure system is considered to be the foundation of the *fa'asamoa (the way of Samoa)*, which is a term that broadly represents Samoan culture and customs. Over the past 150 years, several changes in property ownership have occurred, but the core elements of land tenure have been retained. Stover (1990) identified two basic principals of social organization in the Samoan islands: locality and group descent. While group descent refers to kinship relations, locality provides a geographical context of these relations. The *aiga*, which is largely determined by group descent, is the basic social unit in Samoan society. The village is the locality for one to several kinship groups and is considered to be the major political unit (Holmes 1964; Mead 1969; Richards 1952).

Within each village lives one to several *aiga* that live under the *pule* (authority) of an appointed family *matai*. One of the most important duties of the family *matai* is to oversee communal land, by acting as the *aiga* trustee. Although successive titleholders have *pule* over communal land and its resources, the *aiga* is the primary landholding group and therefore the land remains with the *aiga* in perpetuity (O'Meara 1995). The land is what groups the *aiga* together under the protection of the *matai*. To be without a *matai* is to be "an asocial entity" (Nayacakalou 1960). Although an *aiga* generally refers to those grouped through blood descent or marriage, families often consist of additional members who are not actually related. Those who are unhappy with their appointed *matai* may seek to live with another family under the authority of a different *matai*.

Power, influence, and responsibilities of the *matai* depend on chiefly status, which is directly related to *aiga* size and land. *Matai* can be generally classified into *ali'i* (chiefs) or *tulafale* (talking chiefs) and within these title types are different social rankings. The highest chiefs are those with titles over entire districts (Lutali and Stewart 1974; Stewart 1974).

The *matai* has *pule* by controlling the distribution and occupation of land. He must grant permission to those who wish to clear, plant, or build on communal lands. Family members who live on communal land are required to provide *tautua*, which is viewed as service obligations to the family *matai.* This generally involves giving a weekly contribution of food or doing other chores or errands upon the *matai's* request. If the family does not demonstrate continuous service, the *matai* may deny the family of rights to live and work on the land. *Fa'alavelave* contributions are also considered of paramount importance within the village and the family *matai* often determine who must contribute what. In practice, *fa'alavelave* is a type of insurance at the village or *aiga* level, which requires the donation of food or money for a special event (such as a wedding or funeral) or emergency situation. These contributions help to sustain social relationships and ensure that family members will be cared for in time of need (Gold 1988).

Land tenure law

When the islands of Tutuila and Aunu'u were ceded to the United States in 1900, the Native Lands Ordinance was put into place, which forbade the alienation of Samoans from their land (Gray 1960). Prior to 1900, lands had been sold to foreigners. The U.S refused to recognize all claims with an exception of those that were granted by the high court in Apia (now the capital of Independent Samoa), prior to 1900. Native and freehold land were the only types of land tenure recognized upon cession. Native land, which claimed over 95 percent of the land area in American Samoa, referred to traditional communal lands (Stewart 1974).

Upon cession, the American Samoan Government became immediately involved with family land disputes that set several precedents in land tenure law. One of the most important precedents was the establishment of adverse possession rights. According to Tiffany (1973), judges believed that it was customary for Samoan families to obtain their land by clearing virgin forests for plantations and claming the land as their own. The right to adverse possession eventually led to a new form of land tenure called "individual land" defined as virgin bush land that has been cleared by a person acting in his individual capacity. The recognition of this tenure system ultimately favored those who cleared and cultivated the land rather than the *matai* (Stover 1990).

Individual land makes up approximately one quarter of the land registered in American Samoa (Stover 1999). The majority of these registered lands are located in the Tafuna plains area, where tracts of unique lowland rainforest were cleared. Most of the Tafuna rainforest has been converted for commercial, home, and church development. The first major development of this area was during the establishment of the airport along the Tafuna forest coast, just after the Second World War. The forest was cleared for road access and U.S battalion storage buildings. The initial development of this forest initiated further fragmentation as individual families began to clear forested areas for urban and agricultural purposes, claiming rights of ownership through utilization (L. French, personal communication, September 2003).

There are now only approximately 30 acres remaining of this forest, which is individually owned by a single family of Samoan and European decent. Since Tafuna was nothing but forest prior to the end of WWII, the area does not have the socio-political infrastructure of a village.

The most recent summary of land registration within the territory indicated that roughly 12 percent of the land in American Samoa is registered (Territory Registrar's Records, July 2003). This includes communal, freehold, and individual lands. Lands that are registered have been through survey and court processes. According to one local surveyor, most lands tend to be registered when there is contention over ownership rights (L. French, personal communication, September 2003).

Communal land and the changing matai system

In the last half century, the role of the *matai* has significantly changed. The drastic shift away from Samoan culture corresponded with educational and economic changes that took place in the 1960's. Prior to this change, the extended family group known as the *aiga,* depended on the *matai* to support them through the distribution of family land and goods. As economic opportunities were created, many people became financially independent of the family *matai.* This meant that people no longer had to work the communal plantation in order to receive only a portion of their labor efforts. With financial independence came a growing need for personal autonomy. Although money was still given to the family *matai* and distributed among the *aiga,* those who made the money essentially shared some of the same responsibilities of *matai* since they could financially support their families and represent them in government (Holmes 1971).

The significant emigration to more urban areas such as Hawaii, the U.S. mainland, and New Zealand has also played a role in the changing *matai* system. Money is often sent from these urban areas to their immediate families, contributing to the wealth of nuclear families. The alluring notion of an improved quality of life has also enticed many Samoans living abroad to return to the islands. The returning Samoans bring with them a greater sense of individuality that sharply contrasts with the *fa'asamoa.* When they arrive in the islands, many seek privatization of communal land to avoid living under the family *matai.* Although there are several benefits to this remigration such as incoming skills and business opportunities, there is a definite cultural impact, especially in regards to traditional communal land tenure.

> This is the thinking now days. They want to be independent of the *matai*, especially those who come back from the States. They have their own ideas about thinking. They have *palagi* (Caucasian) thinking, they care about the individual, not the group. In the *palagi* system, like the U.S., individual rights are more important. Of course we think they are important too but we look at the extended *aiga*, the extended family as a whole. What benefits the whole is more important than what benefits one individual. (Talking Chief Fofo, November 2002)

Since the majority of land in American Samoa is still communal, the *matai* remains an integral part of the land tenure system. The *matai* are increasingly dealing with more land disputes as returning Samoans and younger generations seek their communal parcel. Land disputes are common as contending *matai* often claim authority over the same property.

Current Sustainability Issues of American Samoa

The current population for American Samoa is estimated at 67,000, indicating that it has doubled in the past 20 years (American Samoa Census 2000). Immigration from Independent Samoa, has largely contributed to the population explosion and more recently, Korean and Filipino families have also immigrated to the islands. Resource use in the American Samoan islands has moved to a new level in the past two decades. Competition for land on the islands has significantly increased as a result of human population growth and a shift in economic priorities (personal observations 2002-2003). Over 95 percent of the population lives on Tutuila, the main island where the increase of urban and agricultural development is most apparent (American Samoa Census 2000). Urban development such as churches and new homes are being built at an alarming rate. Mature secondary forest and in some cases climax forest, is being cleared for buildings and/or large plantations. Agricultural development is expanding in areas that where not traditionally farmed. Many farmers have moved productions onto steep slopes contributing to soil erosion (Personal observations 2002.)

The American Samoan diet still includes many traditional agricultural foods such as taro and breadfruit. However, the diet has been heavily supplemented with increasing dependence on imported foods (Bindon 1981). Many of these foods are high in fat and have low nutritional value. The modernization of the Samoan diet has changed health status in the territory. Lifestyle changes resulting from the availability of external resources have contributed to severe health issues such as diabetes and cardiovascular disease (Bindon et al. 1991).

Coastal marine resources still remain a fair proportion of the Samoan diet. However, there is a noticeable decrease in the abundance of certain marine species such as *palolo (Eunice viridis).* Although some elders have stated it is because the rituals are no longer performed, scientists believe that it is due to poor coral reef health.

Another marine resource concern in American Samoa is the availability of pelagic fish. Local fishermen feel threatened by domestic commercial long-line fishing. At present, 38 large catamarans Purse seiners work out of Pago Pago bay. The fish obtained from these vessels go straight to canneries, never reaching the local community Western Pacific Regional Fisheries Council 2002). Fish are used for household consumption, income and *fa'alavelave.* Marine resources are therefore also considered a cultural resource and the overexploitation of these resources has several consequences.

Although there are obvious sustainability concerns with the canneries, because they support such a substantial proportion of the local economy America Samoans appear willing to accept the trade-off. Many of the Samoan immigrants come to work in the canneries where they can expect to make US$3.60 an hour. There has been a substantial effort to retain the low minimum wage level as a means of keeping the tuna industry in the islands. The canneries employ one-third of the workforce on Tutuila (Wolman 2002) thereby contributing to a large portion of the economy. Globalization is likely to have an enormous impact on the local economy. The threat of the canneries pulling out of American Samoa is constant as investors find new places with more relaxed environmental policies and lower wages in places such as Ecuador (Wolman 2002.)

The American Samoan Government also employs one-third of the workforce. United States monies largely fund salaries for government positions, as 63% of the territories revenue is derived from U.S grants (World Fact Book 2004). Social programs such as food stamps and WIC (Women, Infants, and Children) are widely used throughout American Samoa. The United States' plan to build economic independence has backfired and created a "handout mentality" where free services such as medical and dental care are viewed with a sense of entitlement (Reid 2001). U.S aid is constantly misappropriated as political and economic obligations often collide with kinship and social obligations. Overall, it appears that substantial U.S stipends have encouraged government and local consumption patterns that are unsustainable. The heavy dependence upon U.S Aid and other external resources has changed the way American Samoans think.

> The attitudes of people are changing. They think about what they need for themselves. Many of the young people especially think this way. This is very different than Western Samoa. Here there is a lot of surplus money is available. Anybody can get a dollar out of the street here. The economy in Western Samoa is smaller. They have a different attitude about the land. They utilize everything in order for that person to survive. That makes the eye of the landowner think differently. Here there are alternative ways to get money, like work for a company, the government, the military. There are a lot of services that people have access to. So they have different attitudes. We have other ways to feed the people here. We look to the green dollar here. (Talking Chief Taelefusi, November 2002.)

The availability of outside resources and new technology has increased the human carrying capacity well beyond what the island itself could sustain. At this time, the islands do not require self-sufficiency. Sustainability is only met in the sense that the current socio-economic system and natural resource availability appears temporarily stable due to a continual influx of outside resources. "Free" money, resource exploitation, and technology allow American Samoans to maintain consumption lifestyles beyond original carrying capacities. However, unsustainable practices and financial dependence contribute to the exhaustion of natural resources, economic insecurity, and cultural degradation.

Sustainability Themes Revisited

Human carrying capacity of an island (or any land mass for that matter) is conditional since it is dependent upon available technology, access to resources, and ongoing social change. In old Samoa sustainability was met because human survival depended upon it. Without sufficient technology, utilization of natural resources demanded practical and conservative methods. Although technological innovation allowed for limited resource exploitation and regional trade, the carrying capacity of the islands probably remained relatively stable as local resources still regulated human population fluctuations. The arrival of Europeans in the islands was a stochastic event that determined the pace and scale of socio-political and economic change in the Samoan islands. The adoption of new technologies and external resources has shifted the human carrying capacity level in American Samoa by incremental links to the global economy. However, this shift has not come without compromises and tradeoffs. This is most apparent on Tutuila, where arable land for crop production is becoming scarce, traditional land-use and tenure systems are eroding, and the largest area of lowland primary forest is now 95% converted to non-forest use. A host of problems associated with high urban population growth, such as increased crime and poor living conditions for immigrants, are also becoming common.

Decision-making for the good of the group is more likely to lead towards long-term sustainability than decision-making for the good of the individual. Decision making in Samoa has traditionally been group oriented as the *matai* of each *aiga* were represented in the village council. This ensured the welfare of each family and maintained social cohesiveness between *aiga*. The communalistic nature of Samoan society is an essential component of *fa'asamoa*. Each family member had a specific role, which contributed to the greater group effort to ensure the survival and political strength of the family and village. The beginning of individualism as a way of life arrived with European and American colonialism, but did not have a significant impact until the latter half of the twentieth century. Capitalism, television, and growing educational and economic opportunities provided an increasing availability of choices. Individualism was no doubt attractive to younger generations, as it not only justified, but also encouraged decision-making at all levels by empowering those who did not traditionally have power. The impact of individualism in American Samoan can be illustrated by the current landscape of Tutuila and changing cultural values. The erosion of the communal land tenure system has resulted in cement-walled, fragmented villages with nuclear family homes. The emergence of a modern class system has also developed in recent decades as migrants from Western Samoa have little political representation (Gold 1988).

The availability of external resources reduces the need to be self-sufficient and undermines resource sustainability and traditional knowledge. The mindset of the American Samoan has changed perceptibly over the past few generations. Natural resources seem expendable today since outside resources largely support the population. Outside resources act as a buffer by reducing the impact of negative feedback loops that would otherwise help to control consumption rates. As "free" money and social programs continue to create a false notion of sustainability in the islands, consumption increases while natural resources are degraded. The plantation now only supplements a diet based on imported foods such as white bread, corned beef, and beer. External food sources gradually undermine traditional knowledge about botanical usage, harvest taboos, cultivation methods, and food storage methods. Although American Samoa has changed far beyond the confines of the times when such traditional knowledge helped preserve a balance between humans and their ecosystems, the balance is nonetheless undervalued.

Self-Reliance and Sustainable Resource Management

Approaches to addressing the sustainability of specific areas are often vague, as they require consideration of several ecological, social, and economic factors, which vary greatly from place to place. In addition, multiple definitions of sustainability and social value differences of an improved state tend to further complicate matters. However, a common objective for improving sustainability in any region should include increasing self-reliance. Self-reliance depends on numerous factors including the extent and capability of local renewable natural resources to support a population, the development of a strong private commercial sector, and the willingness of a society to actively participate in resource management (U.S Congress 1987). Self-reliance also means acquiring a balanced ratio of imports to exports. The remaining of this section will focus on the four components, which determine self-reliance.

Natural resource capability and population

The extent and capability of natural resources play an important role in determining self- reliance of the American Samoan population. Since the limited natural resources have already been illustrated in the previous sections of this paper, a brief discussion on maintaining a viable human population in the islands is necessary. A large population on a small land base will inevitably affect the infrastructure and economy of the territory as well as limit options for sustainable land use and further erode traditional land tenure practices. In recognizing growing population trends, the American Samoa Government has assigned a population growth task force, whose duties include examining ways to reduce growth and improve living conditions within the territory (American Samoa Environmental Protection Agency 2002).

The Governor's Task Force on Population Growth has made several recommendations for reducing population growth including: overhauling the immigration process by redesigning forms that will make it easier to collect and interpret data as well as track immigrants, discouraging low-wage jobs that are generally filled by immigrants, and encouraging out-migration of educated individuals that may find better opportunities on the U.S mainland or in Hawai'i (American Samoa Environmental Protection Agency 2002). Overhauling the immigrant process and discouraging low-wage jobs appears to be a good start in addressing population issues. One major problem with discouraging low-wage positions is that it could inevitably jeopardize the economy, as the tuna canning business (which pays very low wages) is the only major private industry of the territory. Neither of these recommendations should be expected to solve immigration problems. Immigration is still a private decision and as long as the territory borders are open, immigrants will be lured by the American dollar, free social services, and the possibility of achieving U.S national status.

The recommendation to encourage out-migration of educated American Samoans as a way to decrease population numbers seems absurd. On the contrary, educated persons should be encouraged to remain in the territory, as they are more likely to contribute to a healthier economy and become the future leaders of the territory. In addition, because level of education in young women is often correlated with lower birth rates, it does not make sense to encourage those who may set examples for others to leave the islands. Population growth rates due to births have been decreasing in American Samoa within the past 20 years (from approximately 6.2 children in 1986 to 4.0 children in 2000) (American Samoa Census 2000; American Samoa Environmental Protection Agency 2002). Even at this decreased rate, population growth is high, roughly 2.5%. Large nuclear families are still very common especially among more traditional families.

Increasing population is a global concern and there are no clear solutions to solving the problem. Any potential solution to the American Samoa population crisis, if not extreme, would be temporary solution. Increasing awareness population issues, setting stricter policies of immigration into the territory, and encouraging higher education among young people may provide some relief from the problem until other solutions can be explored.

The private commercial sector

Strengthening the private commercial sector may be achieved through the diversification of local production and the development of skilled and technical labor. Diversification of markets at both local and regional scales could assist in stabilizing the local economy. Local markets assist in retaining revenues while regional markets provide country exports. The diversification of markets requires some innovation and risk. Properly trained management is needed to succeed in entrepreneurship. Greater opportunities to develop management, business, and applied scientific and technical skills are essential to the territory's success.

In order to offset the current trend of non-returning University graduates, greater incentives for college graduates should be put into place. One way to secure the return of graduates is to have enforced contract agreements, where the government and/or local private industry restrict scholarship funding to students who agree to return to the islands for employment. The breach of contract would result in the student repaying the government/ local private industry for the scholarship amount.

Recently, on-line undergraduate and graduate education programs have become popular in American Samoa. These programs may be promising for increasing technical and management skills in the islands. However, disciplines in applied sciences such as engineering, agriculture, or other natural resource related fields, are probably not ideal programs for on-line education unless work experience is directly linked to studies.

Resource management and society

Although the Government of American Samoa has developed policies and protocols for managing some of the local natural resources, enforcement of policies on communal lands is often weak. Dumping of hazardous materials in wetlands and directing piggery pollution into streams are two examples of illegal activities that are commonplace in many villages. When policies are not enforced the public has no incentive to follow them. The lack of implementation is partly blamed on the low level of authority given to natural resource enforcement agencies. It is therefore essential that those who oversee natural resources be given the responsibility to enforce policy through the distribution of fines or community work.

In addition to enforcement, additional policies must be put into place, which protect watersheds and soil resources while encouraging sustainable resource management. Policies, which require deep-rooted tree retention along waterways and steep slopes should be implemented and incentives for sustainable agriculture production and greater land-use efficiency should be put into place. One example of a potential incentive for sustainable agriculture could be preference for school-lunch contracts with farmers who adopt agroforestry practices such as contour farming on slopes or stream buffer zones. Large-scale agriculture that requires extensive forest clearance and a high level of chemical inputs should be limited in important watersheds. Placing urban growth boundaries and roadway restrictions in watersheds would further assist in protecting valuable water resources.

Individuals and village communities must also take responsibility in the management of local resources. Volunteer responsibility may require education of direct and indirect effects of protecting resources. Incentives for active participation and demonstrative leadership of village chiefs could also help promote individual and community responsibility. Community resources could be safeguarded and monitored by volunteer participants.

Balancing imports to exports

Small island nations such as American Samoa, cannot always apply the same economic concepts as larger, more developed nations. The small area of the islands and steep topography can limit large-scale production of natural resources. Although the canneries have been successful at large-scale production and manufacturing of tuna, they have not required extensive land use. The future of the canneries as the major export of American Samoa is uncertain. It is likely that there may not be an export replacement for the canneries, if they were to move manufacturing productions elsewhere. Balancing imports to exports therefore requires the reduction of some imported goods.

Although modern convenience requires materials and technology to be imported, tariffs on certain imported goods, such as food (especially those with excessive packaging) should be implemented in order to discourage unnecessary imports. Increasing household food production through growing diverse crops and adopting land-use efficiency practices should also be encouraged. Since food makes up a large proportion of imported goods, increasing local food security could help to improve the import-export ratio.

Conclusion

The future of sustainability in the American Samoan islands does not appear bright. At present, there seems to be no indication that development and population levels will slow within the next few decades. The combination of geographic isolation and limited natural resources does not make American Samoa a likely candidate for global economic success. The efforts to conform to the "western" model of development have resulted in environmental and cultural degradation, rising health concerns, an unequal distribution of wealth and an inability to remain self-sufficient (Gale 2003).

Achieving a realistic state of sustainability in American Samoan will probably require the abandonment of notions of economic success in a 'western" sense (Gale 2003).

Increasing local food security, decreasing consumption rates, and maximizing land use efficiency may prove to be important steps toward achieving greater sustainability by lessening the need for external resources. In addition, deliberate and intentional decisions regarding resource use and economic aid must be made with significant forethought, as these decisions will determine future options. Tradeoffs must be evaluated for not only the good of the current group, but for future generations of American Samoans. Considerations for decisions made beyond the islands must also be factored in, as nameless faces behind closed doors can determine the fate of sustainability for entire regions.

This balance cycle between human and environmental systems is dynamic, and unlikely to ever change, as it is dependent on a myriad of environmental, social-political, economic, and cultural factors. Multiple definitions, multiple approaches, and multiple stakeholders all contribute to the difficulty of managing sustainable resource use and promote it to the ranks of so-called "wicked problems" (Rittel and Webber 1973). The complexity of sustainability even on a small South Pacific island is astounding. The trend toward globalization will likely have a devastating effect on small islands all throughout the Pacific region. With limited resources, economic dependency, and little political authority, American Samoa has an enormous challenge ahead.

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Ch 3: Agroforestry Farming on Southwestern Tutuila, American Samoa

Introduction

Agroforestry is a collective name for land-use systems that combine aspects of forestry, agriculture, and range management on the same piece of land in a spatial arrangement or temporal sequence (Young 1988). There are several types of agroforestry systems ranging from those that have a single crop and a single tree species, to species rich and structurally diverse plantations and home gardens. These systems meet economic, ecological, and/or socio-cultural objectives of farmers. Although the science of agroforestry is relatively new, agroforestry has been historically practiced in many regions of the world, including the Pacific Islands.

Indigenous agroforestry has been especially prevalent in tropical humid regions. Traditional farming systems have incorporated agroforestry practices for perhaps thousands of years. In a Pacific Island context, agroforestry has been defined as any agricultural (agro-ecosystem) system in which planted or protected trees are viewed as economically, socially, or ecologically integral to the productive system (Clark and Thaman 1993).

Traditional Polynesian societies did not separate aspects of living such as forestry, agriculture, housing, medicine, and tool making into economic sectors. Instead, an integrated system of production that incorporated those activities was used to satisfy the needs of each island society (Clark and Thaman 1993). During the colonial period, single species plantations replaced many agroforestry systems throughout the Pacific Islands (Elevitich and Wilkinson 2000). This process known as "agrodeforestation," removed agroforestry systems and replaced them with large-scale cash cropping (Clark and Thaman 1993). In the past few decades there has been a re-emerging interest in promoting agroforestry systems in the Pacific Islands. The inherent small size and geographic isolation of many Pacific Islands makes agroforestry ideal for efficient land utilization and resource use (Adkins 1994). Promoting agroforestry practices in these islands encourages traditional conservation values. Although agroforestry is not the sole solution for meeting all economic needs, it provides some flexibility in carrying out diverse and productive management strategies in order to meet basic household needs (Von 1991, Adkins 1994).

In American Samoa, extended families family owned plantations that produce a variety of products as well as ecological services are relatively common. These systems are often the result of fallowed taro (*Colocasia esculenta*), banana, and/or coconut plantations that have been harvested and left to secondary succession. Additional useful species are frequently out-planted in the fallow plantations. Eventually a more complex vegetative structure develops and new species are planted and harvested. These mixed plantations become a source of forest products that aid in household subsistence.

Thus far, there are few agroforestry-based documents specific to American Samoa. In 1991, the American Samoa Community College (ASCC) Community and Natural Resource (CNR) Division published a technical report titled "Indigenous Agroforestry in American Samoa" (Misa and Vargo 1990). This publication was an introduction to the cultural importance of traditional agroforestry. It noted some of the major species in these systems as well as current threats to agroforestry. A second agroforestry study conducted in American Samoa focused on selecting appropriate woody species and conducting species trials (Adkins 1994). Although these studies helped provide important agroforestry information for American Samoa, base-line information on agroforestry in American Samoa is still needed.

A starting point for base-line agroforestry information is to describe what already exists. By classifying current agroforestry systems, documenting farming practices, and investigating agroforestry incentives and constraints, a foundation for future agroforestry research can be created. It has been suggested that the main purpose of classifying agroforestry systems is to provide a practical framework for the synthesis and analysis of existing systems and the potential development of new ones (Nair 1993). Nair proposed that any agroforestry classification scheme should: 1) include a logical way of grouping factors on which production systems depend, 2) indicate how the system is managed, 3) offer flexibility in regrouping the information, and 4) be easily understood and practical.

Incentives and constraints for practicing agroforestry can be deduced from interviews with farmers where questions relating to specific practices, interest in incorporating additional trees, land use, and land tenure are addressed. Collecting information relating to farmer household demographics is also useful because it allows a descriptive assessment of agroforestry farmers. Such background information is essential in order to formulate meaningful questions for further research and to find solutions to address local needs.

Research objectives

The overall goal for this study was to lay a foundation for future agroforestry research by collecting base-line information on agroforestry farmers and existing systems. The specific objectives of this portion of the study were to 1) document uses of woody components within local agroforestry systems, 2) document current agroforestry practices, 3) provide an initial classification of agroforestry system types based on a visual assessment, and finally 4) investigate potential incentives and constraints for conducting agroforestry.

Methods and Procedures

Research approach and design

This nature of this study is exploratory and descriptive. Its goals were to describe agroforestry farming in the Southwestern region of Tutuila, American Samoa. Agroforestry is an interdisciplinary subject that often combines both scientific and social aspects and requires cooperation between local people and natural resource professionals. The two-way exchange of knowledge is an essential component in integrating local knowledge and scientific assessment. The present study required participatory research, as data collection was subject to permission and involvement of farmers and village leaders. Prior to data collection, a formal presentation of the proposed study was delivered to the *pulenu'u* (village mayors). After the presentation the *pulenu'u* were asked to encourage farmer participation in the study.

Several cultural issues were considered during the research design. Using appropriate cultural protocols for communication and social status were essential to obtaining information. Due to the intrusive nature of some questions such as those pertaining to land tenure and socio-economics, farmers were encouraged to speak on a subject only if they were comfortable in doing so.

Data collection is divided into two sections: a farmer interview and a field survey. The interview portion consists of a formal survey with additional open-ended questions while the field survey includes site description as well as farming land-use and practices. Appropriate academic protocol for conducting participatory research was observed, as the formal farmer survey, open-ended questions, and the Informant Statement of Consent were approved by the Oregon State University Institutional Review Board (IRB) prior to contacting study participants.

Study area

The Leone-Tafuna plains and Alo'au-A'asu plateau regions are located in the western district of Tutuila. The Leone-Tafuna plains region is roughly 3,157 ha in size and makes up the largest continuous flat land in American Samoa with approximately half of the area does not exceed a 3% slope (Farrell 1965). There are 17 villages within this region, with the largest villages being Leone and Tafuna. Leone is one of the oldest and most historically important villages in American Samoa while the village of Tafuna only emerged in the last few decades with the clearing of lowland forest. The northern portion of the Leone-Tafuna plains ends abruptly with steep slopes (>15%) that form the base of the flat-topped Alo'au-A'asu plateau region. Alo'au and A'asu are two villages that relocated to the plateau from coastal areas after 1900. During WWII a paved road was built up to the plateau providing easier access for further development of villages. The combined areas of the Leone-Tafuna plain and Alo'au-A'asu plateau region comprise a significant proportion of the farming area in American Samoa (Farrell 1965).

Informant and site selection

Informants for this study were selected from a compiled client list developed by ASCC CNR. Clients came from one of two original lists: the Agricultural Extension list and the Forest Steward Program (FSP) list. The Agricultural Extension list consisted of farmers who received help from either ASCC extension agents or from the American Samoa Department of Agriculture (ASDA) over the past ten years, while the FSP list consisted of clients who requested trees from the ASCC Forestry Program over the past five years. Clients that lived in the Leone-Tafuna plain and Alo'au-A'asu regions were extracted into a separate list that totaled 307 persons. Each client was assigned a random number and clients were contacted in ascending numerical order, until the study included 38 participants.

Initial contact was made by telephone. Several of the farmers had contact numbers, but lived at a neighboring residence. A major challenge for recruiting participants was that several of the clients on the combined list were no longer farming, had died, or had disconnected numbers. Where the client was no longer living, a request was made to speak with the person who was currently in charge of the farm/plantation. Those who had disconnected numbers or claimed that they were no longer farming were deleted from the list and no further attempts were made to contact them.

Once the clients were contacted, a brief explanation of the study was given followed by three preliminary questions. The questions were: 1) Does your household have a piece of land set aside for growing food crops or trees 2) Does your household grow trees or woody shrubs in or around your cropping area, and 3) Is this area currently being managed. If the client answered, "yes" to all three questions then a request for volunteer participation in the study was made. Face-to-face interviews were scheduled with persons willing to participate in the study.

In general, interviews and field surveys were conducted on separate days. Each farmer was asked to identify an area of their land where they were actively managing trees and crops within the same system. Site selection corresponded with the participant farmers (sample units=38) and sites varied in size. Each management unit was identified as a site and only one site was selected for each participant. If the farmer had more than one distinct agroforestry management unit, then one was randomly selected.

Interview methods

All interviews were conducted between May and August 2003, with the assistance of Mr. Pito Malele, the FSP coordinator for CNR. Mr. Malele holds a *matai* (family chief) title and acted as a cultural representative as well as an interpreter when necessary. The interview combined both a formal structured and semi-structured format. The formal portion of the interview included a survey containing 35 questions that were broken down into five major sections: woody species uses, livestock, inputs and soil, land tenure, and farmer demographics. Survey questions were read directly from the survey sheet, ensuring greater consistency in question wording among informants. Time between questions was given to allow for elaboration and comments. When necessary, a Samoan translated version of the survey was read and the response was interpreted back in English. After the formal interview was completed additional open-ended questions were asked. The open-ended questions had a directional agenda in that they helped to clarify previous comments that the informant had made and asked for elaboration on questions such as land tenure. The request for additional open-ended questions was determined by the apparent willingness and comfortableness of the farmer to disclose information. Written notes of the farmer responses were taken throughout the interview. Ethnobotanical uses of woody components were placed into product/service categories and quantitative values were summarized. Each section of the formal interview was summarized through descriptive statistics.

Field survey methods

Each plot was mapped using a Geoexplorer global positioning unit (GPS) unit (Trimble®). Since each agroforestry area was determined by planting patterns, the size and shape of each plot was variable, ranging between 0.25-3.0 ha in size. Basic topographical information such as elevation, slope, and aspect were collected for each plot. Site descriptions such as watershed region (based on American Samoa Government

Department of Commerce delineations), presence of riparian areas, and proximity to the home compound were also included. A sketch was drawn for each plot that indicated major species and their arrangement as well as the layout of roads, buildings, or waterways. Agroforestry practices mentioned during the interview process that could be observed on site were documented. Finally, each agroforestry site was placed into an initial classification type based on a visual assessment of plot size, species diversity, and vertical vegetative structure.

Results and Discussion

Utilization of woody species

A total of 54 woody species were identified as being planted or purposely retained in agroforestry areas by the 38 farmers included in this study. Over half (54%) of the species mentioned were well known cultivated species often found around home compounds and included several fruit trees, ornamental trees and shrubs, and one introduced timber species. The remaining woody plants that were identified were secondary forest species (22%), lowland and/or montane forest species (20%), and littoral forest species (1%). Ethnobotanical uses of woody species were classified as either products or services. These two categories were then further divided into subcategories of each. Several of the species were multipurpose trees that yielded products such as food, medicine, and fuel wood while also providing services such as shade, mulch, boundary markers, and/or beautification.

Woody species that were mentioned by at least 35% of the farmer informants (13 individuals) were considered to be common on agroforestry sites. Twelve of the 54 woody species met this criterion and are included in Table 1. Seven of the twelve species are commonly cultivated fruit producing trees. All 38 farmers claimed to have planted and/or retained coconut and breadfruit within their agroforestry area. This was expected since these two species provide traditional staple food crops. Other fruit producing trees included mango (71%), lime (79%), avocado (47%), guava (47%), and cocoa (37%), all of which are European introductions. The timber species poumuli (*Flueggea flexuosa*) was the third most commonly mentioned species among the agroforestry farmers. This medium sized introduced tree is widely used throughout the Samoan islands for poles on *fale* (traditional style homes).

Table 1. Twelve most frequently mentioned woody species.

Samoan	Common	Scientific	% of Farmers
Niu	Coconut	*Cocos nucifera*	100
Ulu	Breadfruit	*Artocarpus altilis*	100
Poumuli		*Flueggea flexuosa*	87
Tipolo	Lime	*Citrus aurantifolia*	79
Mago	Mango	*Mangifera indica*	71
Gatae	Coral tree	*Erythrina spp.*	55
Moso'oi	Ylang Ylang	*Cananga oderata*	53
Avoka	Avacado	*Persea americana*	47
Fau	Beach hibiscus	*Hibiscus tiliaceus*	47
Kuava	Guava	*Psidium guajava*	47
Papata		*Macaranga harveyana*	39
Koko	Cocoa	*Theobroma cacao*	37

Major uses of the twelve common agroforestry species are found in Table 2. The most common uses for the 12 species were defined as those in which at least 35% of the farmers mentioned a similar product and/or service derived from a particular species. Because seven of the species were fruit producing, the most frequently mentioned use was food. The second most common use of the twelve woody species was fuel wood. Mago (mango), avoka (avacado), kuava (guava), and lau papata were frequently mentioned fuel wood species. Fuel wood was a secondary product for the fruit trees, but a primary product for lau papata, which is a secondary forest tree that is often retained on agroforestry farms. Because almost all households in American Samoa have access to electricity and/or gas, fuel wood is not the primary means of cooking, but rather reserved for traditional Sunday meals cooked in the *umu* (underground oven). Fuel wood is also sometimes used for burning leaves or trash, which is a regular chore for young men in the family.

Table 2. Frequently mentioned ethnobotanical species and uses of twelve common agroforestry species.

Samoan	**Scientific**	**Food**	**Medicine**	**Commercial**	**Fuel wood**	**Construction**	**Technical**	**Handicrafts**	**Feed**	**Shade**	**Mulch/soil improvement**	**Boundary markers**	**Crop structural support**	**Wind protection**	**Ornamental**
Niu	*Cocos nucifera*	X				X	X		X			X	X		
Ulu	*Artocarpus altilis*	X					X								
Pomuli	*Flueggea flexuosa*					X						X		X	
Tipolo	*Citrus aurantifolia*	X	X	X											
Mago	*Mangifera indica*	X			X					X					
Gatae	*Erythrina* spp.									X	X				
Moso'oi	*Cananga oderata*			X				X		X					X
Avoka	*Persea americana*	X		X	X										
Fau	*Hibiscus tiliaceus*					X							X	X	
Kuava	*Psidium guajava*	X	X		X										
Papata	*Macaranga harveyana*				X					X				X	
Koko	*Theobroma cacao*	X		X											

The selling of fruit products from woody species is also common. Families with large plantations can be seen selling their products in front of their homes or making weekly trips to sell products at the downtown market. Households that have small agroforestry plantations or home gardens will also occasionally sell products in front of their homes when they have an excess amount of produce. Tipolo (lime), avoka (avacado), and koko (cacao) were three subsistence level commercial fruit tree species that were frequently mentioned by the farmers in this study. Although there is some commercial potential for selling other types of non-timber forest products (NTFP), the practice is limited. Perhaps the most common non-food commercial NTFP are flowers used to make leis. Trees such as moso'oi (*Cananga oderata*) are commonly used for this purpose and can be seen planted in home garden-like systems in or around the household compound. Women and children usually make the flower leis, which can be sold at the airport during weekly incoming/outgoing flight schedules. The same flowering species are also used to scent coconut oil that is sold in village stores.

Although there are several woody species within agroforestry systems that are used for medicinal purposes, only two of the twelve woody species were mentioned as being used for medicinal purposes. The leaves of tipolo are infused and used to treat mouth infections and sometimes skin inflammations while the leaves of kuava are used to treat stomach ailments associated with diarrhea or dysentery (Whistler 1996). Medicinal species are generally restricted to household or extended family use and not sold commercially. This may be because most medicinal agroforestry species tend to be common. Only one farmer in the present study cultivated a medicinal plant for commercial use. This farmer cultivated several types of lowland and montane forest trees on his land for both NTFP potential and conservation purposes. One of the species that he outplanted from the ridge above his village was ma'anunu (*Terenna sambucina*), which is commonly used to treat stomach ailments. Several healers who heard he had the tree approached the farmer to harvest some medicine, rather than making a trip into the forest. Seeing this as an economic opportunity, the farmer outplanted several more ma'anunu trees on his farm and currently sells bark scrapings at the weekly downtown market.

The most frequently mentioned service from woody species in agroforestry sites was shade. Included in this subcategory was shade for humans and shade for crops. In most cases shade was not the primary use for a species but was considered a valuable secondary use. Of the twelve most common woody agroforestry species, mango (*Magnifera indica*), gatae (*Erythrina* spp), moso'oi (*Canaga oderata*) and papata

(*Macaranga harveyana)* were frequently mentioned as being used for shade. While mango, moso'oi, and papata can have extensive canopies, gatae generally does not. The mention of using gatae for shade may be because gatae is one of the few species planted among taro crops. Gatae is nitrogen fixing and the leaves are commonly used for mulch. The height and width of the tree is often maintained so that it does not significantly outshade the taro crops, which are generally grown in full sun. The minimal shade from gatae may offer farmers some respite from the strong South Pacific sun.

Although gatae (*Erythrina* spp.) is the only nitrogen fixing species used for soil improvement the leaves of 17 additional species were mentioned for mulch use. In each case mulch was not the primary use, as many of these trees were also used for food and fuel wood. Crop structural support was another commonly mentioned service from farmers in the study. Thirty percent of the farmers in the study mentioned using trees or branches from trees to support vine crops. The two major species used for this purpose was fau (*Hibiscus tiliaceous*) and coconut. In general, the branches from fau were cut from the tree and used as a support stick for vine crops such as cucumber or tomato, while the trunk of the coconut tree supported sweet potato.

Additional services from common woody species mentioned by farmers included property borders, wind protection, and beautification. Coconut trees have been used as a boundary marker throughout Samoan history and are still commonly used for that purpose. Poumuli is often planted along roads and driveways and therefore also acts as a border. This same species is sometimes used for wind protection around home compounds. The most important trees mentioned for wind protection were mango, fau (*Hibiscis tiliaceous*), and papata (*Macaranga harveyanna*). However, wind protection was not a primary use/service for each of these species. Of the twelve species, only moso'oi (*Canaga oderata*) was frequently mentioned as being planted or retained for beautification purposes.

The twelve frequently mentioned woody species appear to be common among agroforestry systems in other Pacific Islands. Many of the staple food trees such as coconut and breadfruit as well as introduced fruit trees are found across the Pacific. An agroforestry study conducted by Raynor (1990) regarding common species found in

Pohnpei systems included eleven out of the twelve species frequently mentioned by Samoan farmers. The only species common among farmers in American Samoa that was not common in Phone was papata (*Macaranga harveyanna*). However, a species that shared the same genus was also found in Pohnpei systems and used for wood products. Uses of the eleven species were similar. Coconut appeared to be the species with the most uses followed by *Hibiscus tiliaceous.* A major difference between woody species in Pohnpei agroforestry systems and those in American Samoa was the number of species. Pohnpei appeared to have a greater diversity of upper canopy species, fruit trees, and shrubs. This is somewhat expected since the natural vegetative diversity increases westward across the Pacific Islands. However, it is possible that a greater dependency on various NTFPs may be another factor contributing to higher species diversity among agroforesty systems in Pohnpei.

The utilization of woody agroforestry species remains an important practice among farmers in American Samoa. Many of the woody species planted or retained in agroforestry systems are multi-purpose, as they may provide a variety of products as well as services. With an exception of poumuli (*Flueggea flexuosa*) and gatae (*Erythrina* spp.), species that are planted are primarily used for food but yield other minor products or services. Woody species that are retained within a system are generally secondary forest species that provide non-food products such as fuel wood or services such as shade and/or wind protection.

Agroforestry practices

Nine agroforestry farming practices were found among farmer sites in this study (Table 3). The most common agroforestry practices that were observed were the use of trees or shrubs for borders and/or fences. Because trees are viewed as permanent forms of agriculture that determines ownership, they are often used to define boundaries. The use of fallow was the second most common practice observed among farms in this study. Cropping areas within a farm that had slowed in production were left to rest. The practice of fallow appeared to be most common in mixed plantations areas that had been dominated by taro and/or banana crops. Once production of these major crops slowed they were abandoned and left to succession.

Improved planted fallow, which is the practice of planting woody species to enhance natural fallow vegetation, was observed on four farms. This practice may be more common, but because many agroforestry trees have multi-uses, it was difficult to obtain this information.

The agroforestry practices of intercropping and multi-story cropping were frequently found on farms in the study. Intercropping with combinations of banana and coconut or taro and gatae (*Erythrina spp.*) were common. A mixture of other crops such as breadfruit and other fruit producing trees could also be found planted in the same area. Intercropping was generally associated with mixed style plantations. Multi-storied cropping practices were also found on farms with mixed plantations, where food producing crops and trees occupied the low, middle, and upper strata layers of the agroforestry canopy.

Four out of seven of the farmers who had streams running through their farmland had a riparian buffer zone where trees were planted and/or retained along stream banks. All four farmers in the study claimed that the major purpose of having a buffer zone was to stabilize stream banks and help protect crops from stream flooding. There was no mention by any of the farmers of using buffer zones for stream protection from agricultural run-off.

The use of woody species for both shade and support was observed on approximately half of the farms in the study. Single large trees provided shading for plantation shacks as well as crops and ornamentals. Windbreaks were observed on 45% of the farms. In most cases, the windbreaks consisted of one large or several trees where the farmer claimed to have strategically planted or retained for wind protection. Technical windbreak designs such as those promoted by the Natural Resource Conservation Service (NRCS) that include several rows of tree and/or shrub species at different heights were not observed on any of the farms. Rather, on many farms the windbreaks appeared to be placed somewhat haphazardly in different areas around the cropping system and home compound.

The least common practice that was observed on farms was the inclusion of a woodlot. Only one farmer had a separate area where he was growing trees for potential commercial and preservation purposes. This farmer happened to be working closely with the ASCC research forester on an old-field reforestation project.

Table 3. Agroforestry practices observed among farms.[1]

Agroforestry Practices	# of Farmers	% of Farmers
Borders/fences	31	82%
Fallow	28	74%
Improved fallow	4	10%
Intercropping	22	58%
Multi-story cropping	24	63%
Riparian buffer	4	58%
Shade/support	20	53%
Windbreaks	17	45%
Woodlot	1	3%

The incorporation of animals into or around the agroforestry site was also observed in the study. Pigs were present on over half of all the farms. These animals were usually kept in pens within the plantation area. Unless a septic tank especially made for piggery runoff was on the premises, pig waste often drained into waterways such as streams. Two farmers in the study utilized piggery waste by mixing it with mulching material and applying to ornamentals and banana crops. Roaming chickens were also present in nearly half of all the farms, however ownership of them was unclear. Only a small portion of the farmers claimed to actually own the chickens. Some farmers said that

[1] With the exception of riparian buffers, the percentage of farms where practices were incorporated was based on the sample size of 38. Percentage of farmers with riparian buffers was based on a sample size of 7, the number of farms that had streams running through their sites.

the chickens on their land belonged to neighboring family members. The majority of farmers in the study claimed they did not know who owned the chickens and were generally indifferent to their presence on their farm even after mentioning soil benefits from their waste. Aquaculture farming of talapia (*Oreochromis niloticus*) and giant clams (*Tridacna* spp.) is becoming increasingly popular among farmers in American Samoa. Although only one farmer in the study had a commercial talapia tank set up on his farm, two additional farmers in the study were planning on incorporating aquaculture practices in the upcoming year.

Inputs and soil

Three different types of soil inputs were assessed in this study including the use of green mulch, manure from on-site animals, and chemical fertilizers. Table 4 shows the percentage of farmers who use different soil inputs. Green mulch was the most common soil input, as 82% of the farmers in the study claimed to use this as fertilizer. The use of on-site animal waste was mentioned by 16% of the farmers in the study. Every farmer who used on-site manure also used green mulch. Nearly half of all of the farmers in the study (47%) use chemical fertilizers on their crops. Pesticide use was also common, as 42% of farmers claimed to use pesticides. Thirty-two percent of farmers claimed to use both chemical fertilizers and pesticides.

Table 4. Farm input types and the percentage of farmers that use them.

Input Type	% of Farmers
Green mulch	82%
Manure	16%
Green mulch and manure	16%
Chemical fertilizers	47%
Pesticides	42%
Chemical fertilizers and pesticides	32%

The overall purpose of this assessment was to determine the percentage of farmers who relied solely on internal inputs versus those who used both internal and external inputs. Green mulch was the most frequently used input by all the farmers, however chemical fertilizers were also used on many of the same farms. The farmers who relied exclusively on internal inputs from green mulch and manure was estimated at 31% (Table 5.) Farmers that used green mulch and manure as well as external inputs such as chemical fertilizers and pesticides was estimated at 53%. Thirteen percent of farmers relied on external inputs only while 5% of the farmers in the study did not use either internal or external inputs, relying solely on fallow methods.

Table 5. Internal and external inputs. System inputs based on internal (green mulch and/or on-site animal waste) and external (chemical fertilizers and pesticides) types.

	External inputs	**No external inputs**
Internal inputs	53%	31%
No internal inputs	13%	5%

Of particular interest was whether farm size determined the use of external inputs. A two-sample t-test indicated that farmers who used only green mulch and/or on site animal waste had a smaller average farm size than farmers who used chemical fertilizers and/or pesticides (two-sided p- value = 0.01, 36 df). The average farm size for farmers who used external inputs was 0.93 ha, while the average size for farmers who used internal inputs only was 0.33ha. This suggests that smaller agroforestry farms are more likely to rely on internal inputs such as green mulch or manure.

In addition to soil inputs, questions concerning soil erosion where also addressed. Specific questions were asked regarding whether the farmer felt that soil erosion was a problem on their land and if so, whether they used any methods to protect their land from erosion. Forty-five percent of the farmers in the study said that they had soil erosion problems on their land. Soil erosion appeared to be a problem for farms located on flat land as well as those on slopes. The main approaches that farmers claimed to use in order to reduce soil erosion was to plant or retain trees on their land, leave slash on the ground, and/or divert waterways. Some of the farmers in the study claimed to have soil erosion problems evident by stream bank erosion and high amounts of silt. These same farmers tended to plant trees along stream banks.

Over half of the farmers in the study said that they were not concerned with soil erosion of their land. When these same farmers were asked whether they would be interested in using soil erosion control methods, 20% of the farmers said they would be willing. The remaining 80% did not think it was necessary or appeared indifferent. Although soil erosion is a major concern for government agencies in American Samoa many farmers in this study did not recognize and were therefore reluctant to implement practices to help control it. Those who did not see soil erosion as a problem stated that there was no evidence of it on their land. However, many of them acknowledged it as a problem for other farmers.

Land tenure

Farmers in the study had one of three types of land tenure status: private, communal, and communal with a legal separation agreement such as a long-term lease. Three farmers in the study purchased their land and had freehold ownership rights. Two of the farmers in the study lived on communal lands but had legally separated agreements with their family *matai.* Although both of these farmers continued to pay service to the overseeing *matai* in the form of weekly food contributions, they claimed to have greater personal authority over land use decisions. The remaining thirty-three farmers in the study lived on communal lands under the authority of a family *matai.*

Less than half of the farmers expressed concern over the future of their land tenure status. Most farmers felt that their rights to live and work on their land would not be disputed by other people. However, there were a few cases where farmers felt threatened by encroaching neighbors. Because occupation and management of land is proof of ownership, when land is not occupied by crops or appears to be neglected, there is always a possibility that the farmer may loose his rights to farmland.

Several of the farmers in the study mentioned that they had been approached by relatives who asked for parcel divisions of their land. In most cases, these relatives were from Western Samoa. In general, farmers in this situation claimed that they did not mind sharing their portion as long as they had enough farmland to support their household needs. However, there were also farmers in the study who were concerned about the future status of their farmland due to extended family claiming rights to land. According to some farmers in the study, those who claimed rights to land were retuning Samoans from Hawaii or the U.S mainland.

Although there are several farmers in the study who have large farms and are not concerned about their land tenure status, it appears that the majority of the land tenure concerns came from those who occupied larger areas of commercial size. This may be because most of the larger continuous tracts of land on the island have already been fragmented into smaller household size units. Although no direct trends could be made, it is also interesting that several of the farmers who spoke of land-tenure concerns had also spent time living on the U.S mainland. It is possible that individualistic attitudes may be more prevalent among these farmers due to living in the U.S for extended periods of time.

Farmer demographics

A total of 10 questions were asked regarding farmer demographics. Socio-economic questions regarding household size, household income and the distribution of farm products are also included in this section. The purpose of collecting this type of information was to determine whether socio-economic and demographic trends could be found across the study participants. The results indicate that farmers came from a wide variety of demographic and socio-economic backgrounds. (Figure 2 a-f.)

Approximately 70% of the farmers in the study were male. Since farmers were identified based on who oversaw the farming operation, there a relatively large proportion of informants were female. In general, the women in the study that oversaw farm operations were either widows or housewives that included the farm as their domain. Many of the women in the study lived on communal land that was passed down by their side of the family, which may also explain the number of women who considered themselves to be the caretaker of the farm even though several of them had young men to do the farm labor.

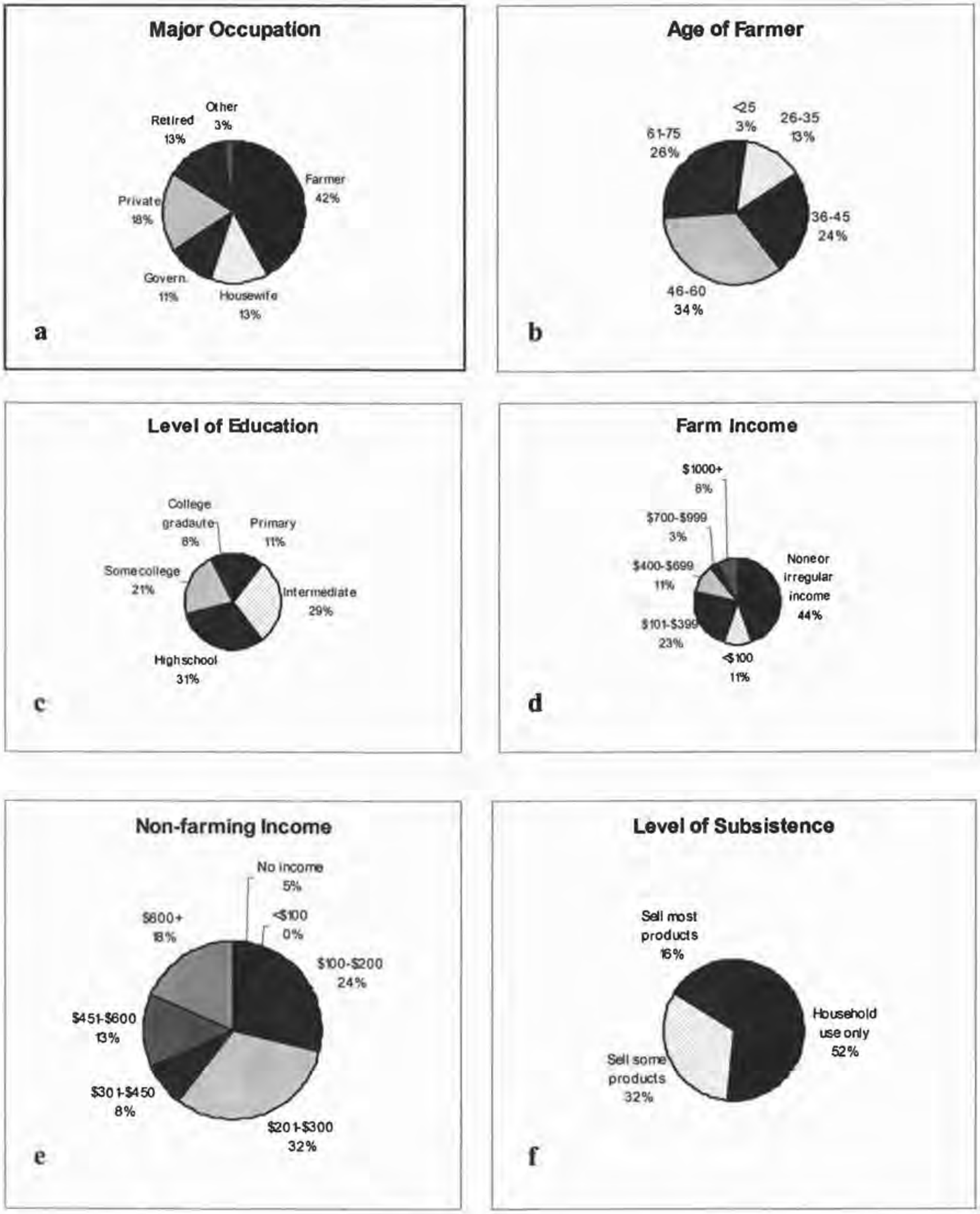

Figure 2 (a-f). Farmer demographic results.

Out of the 38 farmers in the study, 41% said that farming was their major occupation. Other common occupations were housewives and retired persons. Several of women in the study viewed themselves to be caretakers of the home and family first and farmers second. Farmers who claimed retirement status were those that generally conducted hobby farming or farming for subsistence only. The remaining major occupations were broken down into American Samoan Government, canneries, private industry or other.

The most common age group among the farmers in the study was between 46 and 60 with the least common under age 25. Although there may be several young men who work a farm, those in charge tend to be older. The lack of farmers found in the younger age classes may also reflect a growing disinterest in farming among younger generations. The second most common age bracket among the farmers was between the ages 61 and 75. Three of the farmers within this age bracket no longer did any of the actual farming, instead giving direction to younger relatives or hired help from independent Samoa. In all three cases, the farmer was no longer physically capable of farming.

Level of education among farmers was another demographic interest of the study. Thirty-one percent of the farmers in the study had the equivalent of a high school education, while 29% had an intermediate level or 8^{th} grade level of education. The farmers with the lowest amount of education, tended to be in the oldest age bracket. Roughly 20% of the farmers had attended community college or a biblical seminary school. Three of the farmers in the study had earned 4-year degrees from off island. There were no farmers in the study that had graduate education.

Socio-economic information regarding farm income was addressed in two questions. The first question was specific to farm income while the other referred to non-farming income. Over 40% of the farmers in the study claimed to not have a regular weekly income from farming, suggesting that a subsistence form of farming for household consumption or *fa'alavelave* use is most common. The weekly income among farmers who sold products regularly ranged between less than \$100 to over \$1,000 with the largest income bracket between \$100-\$400. Three of the farmers in the study (roughly 8%) who had commercial size farms made \$1000+ every week. These farmers had contracts with the government school lunch program, which currently pays the highest value for farm food products. Two of these farmers who made this high farm income also had the highest level of education and had spent 20+ years living on the U.S mainland. Ninety-five percent of the farmers in the study had non-farming household income, with the largest income bracket between two to three hundred dollars a week. Farmers at the lower end of the economic bracket relied more heavily on farm income or farm products for subsistence to meet household needs.

Farming subsistence level was also addressed in the survey. Four levels of subsistence were recognized ranging from household use only to mostly commercial use. For a large proportion of the farmers in the study (43%), farm products were restricted to household and fa'alavelave use. In general, farmers who fell into this subsistence level had home-garden type plots or small plantations. The second most common subsistence level was intermediate subsistence (31%). This category included farmers who sold some of their products to those who sold up to half of their farm products. Farms that fell into this category ranged from small to larger sized plots. Twenty-six percent of the farmers fell into the commercial based subsistence level. Commercial based farms tended to be larger plots with hired workers from Western Samoa.

Interest in growing more trees

Nearly 75% of the farmers in the study expressed some interest in growing more trees on their farm. Although there were a few farmers who wanted additional trees for services such as wind protection and wildlife habitat, in most cases the trees of interest were for food, construction, or ornamental purposes. When the farmers were asked why they had not yet planted the desired trees, the most common response was that they did not have a seed/seedling source for the plant. Other frequent responses to this question included the lack of time and or labor to produce trees, and a poor survival rate of the desired species on their farm. Approximately, one fourth of the farmers in the study stated that they were not interested in growing any additional trees on their farm. In general the major reason for this was that they were already satisfied with tree productivity of their farm or did not require any more products/services from additional trees.

Classification of agroforestry systems

The classification of agroforestry systems used was based on four components including species composition, arrangement, function, and socio-economic scale. No measurement data was used for the pre-classification, as its sole purpose was to describe system types that could be recognized by understanding the farmer's intentions of the land and making a visual assessment of the farm.

Three types of agroforestry systems were recognized in the study which included home tree gardens, mixed crop plantations, and open canopy plantations with dispersed trees. *Home tree gardens* are multi-storied small to medium sized plots that contain a variety of cultivated food crops, multi-purpose trees, and ornamentals. These plots tend to vary in species composition and are generally subsistence based. In general, these systems have vertical and horizontal complexity and high species diversity.

Mixed crop plantations are characterized as small to large farm plots having 1-3 dominant crop species such as taro, banana, and/or coconut. Major crops tend to be arranged in blocks with other less important crops, trees, and shrubs found growing in lines or dispersed as individuals throughout the plantation. These systems are sometimes, but not always vertically complex and may be either subsistence or commercially based.

Open canopy with dispersed tree systems are generally medium to large plots with low growing herbaceous crops. In general these systems have relatively very little canopy cover (<10%). Crops tend to be arranged in blocks and trees are arranged in lines or dispersed as individuals. These systems are simple compared to home tree gardens and mixed crop plantations, as they tend to contain fewer species and have a more simple vertical structure. Open crop with dispersed tree systems are usually commercially oriented.

In addition to the above agroforestry types, a transitional system type was also recognized. This *transitional* type shares characteristics of both home tree gardens and mixed crop plantations. Transitional systems tend to have high species diversity and structural complexity, but appear to be dominated by a few major crops. Although no temporal information was used for the classification, it appears that these transitional plots are older mixed crop plantations that were no longer maintained. Fruit trees, ornamentals, and other multi-purpose species are found in the mid and upper canopies of these transitional systems. Giant taro *(Alocasia macrorrhiza)*, often dominated much of the understory, indicating that these systems may be converting back to forest. Evidence such as slowed production of main crop(s), as well as apparent prolific regeneration of secondary forest species was used to determine this sub-type.

Mixed plantation systems appeared to be the most common agroforestry type among the farms in the study. A total of 24 farms (63%) were classified as mixed plantations. This was representative of Tutuila, since most families have some type of plantation system on their land. Eight systems were classified as home tree gardens (21%) and four systems (11%) were classified as intermittent or transitional. Open canopy farming with dispersed trees were the least common system in the study as only two farms (5%) fell into this classification type.

Conclusion

The practice of combining trees and crops into the same agro-ecosystem has been a long tradition in American Samoa. By conducting farmer interviews, incentives for incorporating mixed species and agroforestry practices became apparent. Tradition was a powerful incentive for farmers. Many of the farmers in the study stated that one of the reasons they planted trees and crops together was because they had observed this practice from their parents, grandparents, or some other extended family elder. In some cases, the farmer appeared to have little agro-ecological knowledge, maintaining that the reason for mixing crops and trees was because “that’s how it’s always been done”. Several of the farmers who grew a variety of traditional fruit and/or nut trees on their farms claimed that they wanted their children to grow up eating the same sorts of foods as they did.

Another incentive for growing a variety of crops and trees on farmland was to help secure a variety of household food and to provide food or other products for extended family and church social obligations. Farmers who had a variety of vegetative species could help supplement monetary donations by providing staple foods such as banana, taro, and breadfruit, along with fruit items, flower leis, and other ornamental decorations. In a few cases, wood for construction was also given to the family *matai* in order to help build traditional structures. Because living on communal lands often requires continues service to the family *matai* through the giving of food and/or other forms of contribution, having a variety of items on the farm can be beneficial.

The increasing fragmentation of communal lands due to the growing human population numbers may also offer an incentive for agroforestry. Maximizing land use efficiency can allow for greater productivity on a smaller land base. The average size of most family compounds in the Leone-Tafuna plains region is around an acre and in many cases these small areas are being divided further. This may result in more home tree garden systems in the near future.

The frequency of tropical storms and hurricanes provide an additional agroforestry incentive. The island of Tutuila is exceptionally vulnerable to flooding and wind damage in cropping systems. Heavy rainfall that rushes from steep mountains (that have sometimes been cleared for mono-cultural production) to the lowlands combined with poor urban and road planning result in flash floods and landslides that inevitably cause crop damage. Abrupt forest edge effects that are particularly vulnerable to high winds, also contribute to severe crop damage during tropical storms. Herbaceous tree crops such as banana are particularly vulnerable to wind damage due to their average height and weak root support system. Incorporating efficient windbreaks that are strategically placed to filter wind can help control crop damage. Farmers who have waterways running through their land are especially vulnerable, as small streams can become dangerous rivers that quickly erode stream banks and flood homes and cropland. Planting tree species along streams creates a riparian buffer that may offer some protection for farmlands.

The communal land tenure system of American Samoa can act as both an incentive and a disincentive for agroforestry practices depending on who conducts the farming. The planting of trees on communal land can help to establish occupation.

Because the average life span of trees is significantly older than that of herbaceous crops, planting and maintaining trees can help to ensure longer farming rights to an area. However, planting trees can only be done with the permission of the family matai. Farmers who come from Western Samoa to work on American Samoan plantations may be less interested in planting additional trees since it is not certain that they will reap any benefits of them. Farmers without secure land tenure are more likely to be interested in maximum profit within a limited time frame.

Although there were several incentives for agroforestry that could be identified, there were also a number of constraints. One of the major constraints that several farmers in the study spoke of was the initial time investment for agroforestry farming and the lack of labor resources. Although households tend to distribute farm labor throughout the household, in many cases several of the household members held jobs outside of the home. Another important constraint is the allure of increased profit from mono-cropping bananas and taro. As mentioned earlier, the local school lunch program buys vegetables and currently pays the best price for them. Larger tracts of land are required to have maximum profit and chemical inputs are used to maintain high production levels. The economic benefits of agroforestry appear minimal when compared with immediate benefits of cash cropping.

The lack of recognition of soil erosion problems is a major constraint for incorporating agroforestry practices that may help to control this. Soil erosion education should be a priority for local agricultural agencies. At the time that the farmer interviews were conducted, the recent flood had brought soil erosion concern to the forefront. Many of the farmers in the study, especially those living near streams claimed to have realized the immensity of the problem. Farmers living in the plateau region were less likely to see soil erosion as a problem. Among the farmers in the study that believed soil erosion to be a problem, there were no farmers who practiced contour farming. Although several farmers said that they knew of this practice, most thought that it was too much work and that by retaining trees they could still minimize erosion.

Many of the agroforestry practices that were observed on-site could have been improved by adopting institutionalized agroforestry practices. Institutionalized agroforestry practices are agroforestry activities that are promoted by government agencies, research institutions, and public interest groups. These include but are not limited to specific methods for contour farming, wind protection, animal husbandry, and soil improvement. In general, these practices require careful planning prior to implementation. The lack of planning and a short time sense is a major constraint for American Samoans. It is not difficult to convince American Samoan farmers that having a well thought out planting strategy can improve the benefits of wind protection and soil erosion control. However, getting farmers to implement long-term planning is a major challenge, especially if the activity requires additional labor and no immediate economic benefits. The strong preference for leisure time also makes the initial labor investment of implementing institutionalized agroforestry practices unappealing.

Incorporating institutionalized agroforestry practices into traditional agroforestry systems requires educational workshops and extension specialists that can advise farmers. A collaborative effort between agriculture and forestry programs is necessary in order to encourage maximum production of each component. At present, there is little, if any collaboration between the American Samoa Department of Agriculture and the ASCC CNR Forestry Section. Within the ASCC CNR collaborative efforts have been made between the Agricultural Extension and Forestry divisions with relation to agroforestry education. However, the number of ongoing projects combined with limited staff inhibits the promotion of agroforestry in the territory.

Agroforestry farmers in American Samoa come from various socio-economic and demographic backgrounds. The trend toward greater individualized rights to farm plots has encouraged farmer diversity. In more traditional times, the young untitled men of a family carried out all the farming under the supervision of family matai. Now days, women, untitled men, as well as returning retired Samoans also oversee farming operations. American Samoan agroforestry systems include a broad spectrum of agricultural plots ranging from small subsistence based home tree gardens to large commercial oriented mixed crop farms. Although a large percentage of the species grown on farms are for consumption, farmers also plant and retain woody species for a variety of useful NTFPs and ecological services. It is likely that agroforestry will continue to be an important aspect of American Samoan agriculture and land use practices. However, there is a growing concern that the increase in cash crop farming and the importance of agroforestry not realized may lead toward greater agrodeforestation. Reversing this trend will require the promotion of traditional agroforestry systems along with continuous research on how best to improve them. Combining inter-agency collaboration and farmer involvement will be an essential component for success.

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Ch 4. Classification of Agroforestry Systems

Introduction

Agroforestry has evolved into sustainable, diverse, and productive land use systems in many areas throughout the Pacific Islands (Kunzel 1993). It is the dominant form of agriculture on several islands, although practices vary widely with climate, topography, and culture (Raynor 1993). Clark and Thaman (1993) defined Pacific Island agroforestry as any agricultural ecosystem in which planted or protected trees are economically, socially, or ecologically integral to a system. Over the past two decades, there has been a growing interest in research and promotion of these systems in U.S. affiliated Pacific Islands. Recent agricultural trends regarding the increase of agricultural monocropping, pesticide use, and a general loss of traditional farming interest all threaten the existence of these native systems (Raynor 1993, Misa and Vargo 1993). The promotion and future development of agroforestry may be essential to preserving ecosystem health in areas where land is managed for subsistence production or commercial use.

Agroforestry is a relatively common practice throughout the Samoan islands. In American Samoa it is estimated that nearly 5,000 acres of secondary vegetation on the island of Tutuila is composed of agroforests in various stages of succession (Cole et al. 1994). Much of these agroforests are remnants of former villages or old coconut or banana plantations. A quantitative assessment of the area occupied by urban agroforests has not been conducted. With the exception of estimates of agroforestry vegetative cover, there is little documentation of agroforestry systems in American Samoa.

Classifying agroforestry systems is essential in formulating meaningful questions for further research and to find approaches that may address local needs. The four major components that have been used to classify agroforestry systems include: structure, function, agroecological zones, and socioeconomic scales (Nair 1985). Structure refers to the nature (for example crop/tree or tree/pasture) and arrangement of components while function includes species composition, production, and services. Agroecological zones are broad classifications of systems that exist under ecological conditions specific to geography and climate. For example, in the Southwest region of Tutuila the agroecological zone is considered to be humid lowland tropics. Socio-economics deal with classifying systems based on the scale of production and level of subsistence (Nair 1993).

Agroforestry system types exist along an ecological complexity continuum, where complexity is measured as species diversity and vertical structure. (Figure 3.) Simple agroforestry systems that include a single crop and tree species are at the lower end of the continuum while multi-storied, species-rich systems are found at the higher end.

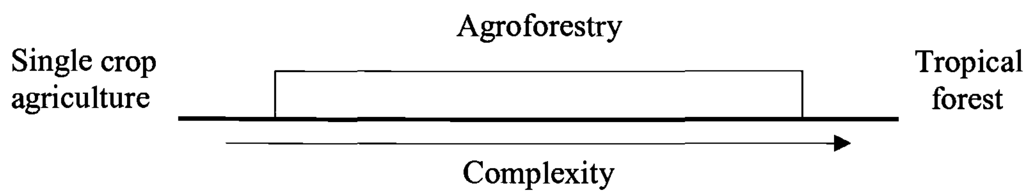

Figure 3. Ecological complexity continuum. Complexity increases with greater species diversity and structural complexity.

A thorough quantitative assessment of structure, composition, and socio-economic variables that make up various agroforestry plant communities allows a more objective approach to classifying systems. Methods used for ecological community analysis can be helpful in determining appropriate classification schemes. McCune and Grace (2002) consider plant community structure as a set of associations between species. Likewise, examining the relationship among species along environmental and socio-economic gradients can be useful in understanding the composition and distribution of agroforestry plant communities. It can also help to distinguish them from one another.

Research objectives

The specific goals of this study are to 1) describe patterns of vegetative species composition and vertical structure within agroforestry communities on the island of Tutuila, American Samoa 2) determine the most appropriate way to classify local systems, 3) investigate whether patterns exist among species composition and environmental and social variables, and finally 4) determine whether an a priori classification based on a visual assessment of plant communities is similar to classification based on a more rigorous measurement of vegetation.

Methods

Study area

The American Samoan Islands are an unincorporated territory of the United States located in western Polynesia approximately 14° - 15° south of the Equator. The climate of these islands is tropical maritime with an average temperature ranging between 26°C and 28°C, relative humidity between 76-86% and annual average rainfall of over 400 cm (Amerson *et al.* 1982). The main island of Tutuila is approximately 142 km^2 in size with a maximum elevation of 650 m (Mueller-Dombois and Fosberg 1998). The study site is located on the southwestern end of the island, which includes the Leone-Tafuna plains area and the Alo'au plateau. This region is one of the most populated areas and is the central farming region, as it comprises a significant proportion of the flat land on the island (approx. 3,238 ha).

Data collection

Thirty-eight farmers were randomly selected from a compiled client list from the American Samoan Community College (ASCC) Community and Natural Resource Division (C&NR). Details of the selection process are included in chapter 2. A formal survey was conducted with each farmer to collect household socio-economic information. The farmers were then asked to identify a management unit of their land where they were actively growing trees and crops within the same system. Thus, each managed unit corresponded with the participant farmers (sample units=38) and was variable in size (ranging from 0.25 ha to 3 ha). Each management unit was identified as a site and only one site was selected for each participant. If the farmer had more than one distinct agroforestry management unit, then one was randomly selected. The perimeter of each site was mapped using a Trimble Geoexplorer global positioning unit (GPS). Basic topographical information such as elevation and slope was collected for each site.

Prior to vegetative sampling, plots were classified based on a visual assessment of species richness, species diversity, size, and vertical structure. The classification was divided into four types. The first group was home tree gardens, which were generally small multi-storied permanent plots located immediately next to the home. This type included a variety of species including understory crops, medicinals, ornamentals, fruit trees and other useful trees. The second type was mixed crop plantations, which were dominated by 1-3 food crop species such as banana (*Musa spp.*), coconut (*Cocos nucifera*) and/or taro (*Colocasia esculenta*) but were often mixed with other species. Sites in this group had plant species that often occupied various canopy strata layers. The third agroforestry type, 'transitional', shared characteristics of both home tree gardens and mixed plantations. Transitional systems resembled mixed plantations, but generally had several additional species that were planted or retained within or immediately adjacent to the farming area. The fourth agroforestry type was open canopy with dispersed trees. This type tended to be plantations where introduced crops such as cucumber and cabbage grew among occasional dispersed tree crops such as coconut and papaya (*Carica papaya*). This type of system appeared to have less species diversity and was not multi-storied.

Due to the irregular shape and variable size of each site, the following method was used to locate plots for vegetative sampling. Using the GPS unit an approximate center point of the site was found. Each site was then divided into four plots: NE, SE, SW, and NW (Figure 4). Within each plot, a random azimuth and distance was selected and a circular subplot was placed at that locus. Subplot centers were marked and all useful vegetative species within a 2.5m radius were determined. The number of subplots in a plot depended on the size of the site. Sites with an area less than 0.5 ha had one subplot per plot and with each increase of 0.5 ha, one more subplot was added to each plot. This ensured that 1.5-2% of the area in a site was sampled. If the plot was larger than 2 ha, the number of subplots per plot was reduced to a minimum of four subplots per plot, if no new species were detected.

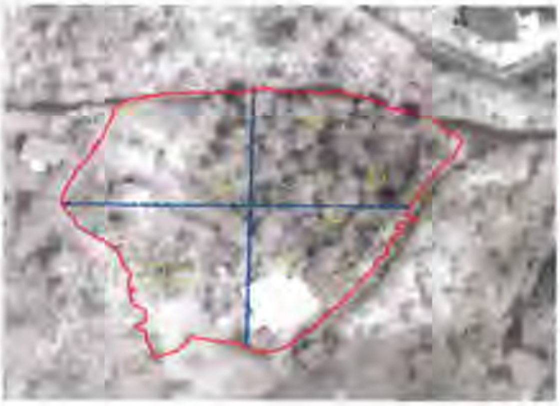

Figure 4. Mapped site with subplots.

Vegetative data collection for subplots was divided into five vertical layers strata layers, primarily by height: 1) low crop (<1.5m), 2) shrub/sapling (1.5-4m), 3) small tree (4-10m), 4) large tree (10+m), and 5) climbing vines. For each subplot all ethnobotanically useful plant species were identified. Species that were not known to have any uses were not included in the sample. Percent cover of useful species in each stratum layer was estimated and assigned a cover class (0-4%, 5-14%, 15-29%, 30-69%, 70-84%, 85-94%, 95-100%). Subplot cover classes were averaged to obtain a single site estimate for each species in each stratum.

Data compilation

To begin classifying and describing relationships between agroforestry sites, three data matrices were constructed for statistical analysis. The community matrix included 38 sites (rows) and 144 species found in various stratum layers (columns). If a species was found in more than one stratum layer then a column for each stratum layer was constructed for that species. Each species within the community matrix was a quantitative-type variable.

The environmental matrix was composed of 38 sites and 5 variables including: agroforestry type (based on preliminary classification), alpha diversity using Simpson's Index, the average number of canopy strata, plot size (ha), and elevation (Table 6.) Simpson's index was used because it emphasizes common species, is little affected by the addition or loss of rare species, and is therefore relatively stable to sample size (McCune and Grace 2002). Species diversity, the average number of canopy strata, plot size, and elevation were continuous quantitative variables while agroforestry type was a categorical variable.

The social matrix consisted of the 38 sites and 8 variables corresponding to farmer socio-economics and demographics including: occupation, education, age, gender, household size, farm income, non-farming income, and subsistence level. All of the variables for this matrix were categorical.

Table 6. Environmental and demographic variables.

Environmental Variables	**Variable Type**	**Demographic/Socio-economic Variables**	**Variable Type**
1) Agroforestry type (HTG, MCP, TS, OC)	categorical	1) Major occupation	categorical
2) Alpha diversity (species richness at the plot level)	quantitative	2) Highest level of education	categorical
3) Average number of strata layers	quantitative	3) Age	categorical
4) Plot size (ha)	quantitative	4) Gender	categorical
5) Elevation (m)	quantitative	5) Household size	categorical
		6) Weekly gross farm income	categorical
		7) Weekly non-farm income	categorical
		8) Subsistence level	categorical

HTG: home tree gardens, MCP: mixed crop plantations, TS: transitional systems, OC: open canopy with dispersed trees.

Data adjustments

Alpha, beta, and gamma diversity (Whittaker 1960, 1965, 1972) of ethnobotanically useful species were determined for each site and estimated for the sample population of sites. Total species richness (γ diversity) was calculated from 87 species with 35 in more than one stratum (144 total observations). The average diversity within each plot (α diversity) was 19 observations. The amount of compositional heterogeneity represented in the sample was calculated using Whitaker's (1972) beta diversity equation:

$$\beta_w = S_C/S - 1$$

where β_w is beta diversity, S_C is the total number of observations, and S is the average species richness among the sample population of sites. This method divides gamma diversity by alpha diversity and subtracts 1 from the ratio. By subtracting one, beta diversity is equal to zero and corresponds with zero variation of species presence. Compositional heterogeneity is used as a gauge for predicting the difficulty of using particular ordination methods for a dataset (McCune and Grace 2002). In general, a beta diversity value >5 presents challenges for analysis. Because of high beta diversity (6.6) rare species (those which occurred in <5% of the sites) were deleted from the data set, reducing the number of variables by 54 species. This reduction resulted in a matrix with 38 sites X 90 species in various stratum layers with a *Bw* of 4.5. In addition to allowing greater statistical convenience, the deletion of rare species generally tends to enhance the detection of patterns and relationships between species composition and variables of interest.

Monotonic transformations, which are transformations that are applied to each element in the matrix without changes to rank, are often used to add clarity by improving assumptions of normality. Data in the form of proportions and percentages tend to be non-normal because many of the observations fall outside the 30-70% range. The arcsine square root transformation is often useful for normalizing such data. For the present study, monotonic data transformations were not needed because the data were collected using cover classes that were narrow at the extremes and broad at the middle, thus approximating the arcsine-square root transformation (McCune and Grace 2002). To determine whether other data adjustments were needed for the species matrix, summary statistics for the rows (sites) and columns (species) were calculated using PC-ORD V. 4.25 software (McCune and Medford 1999). Sites were relativized by their row totals in order to account for variability in site size. Relativization is an important analysis tool that rescales rows and/or column of the matrix to provide greater consistency. The initial summary of row and column data showed that the coefficient of variation of species totals was high (245.6%) indicating that there was considerable variation in abundance of particular species. Relativization by species maximum (highest value of each species) allows all species equal weight during analysis, thus the influence of minor species (those with lower abundances) is expressed. An initial screening of outliers indicated that there were both moderate site and species outliers. After a reexamination of field notes, it was determined that the strongest site outlier would be removed from the study since it was located next to a stream that had flooded just days before vegetation was collected. This reduced the sample size to 37 sites. Once the community matrix was relativized by site totals and species maximum, outlier analysis indicated that the remaining site and species outliers were weak.

Data analysis

All multivariate analyses were conducted on the reduced and relativized species matrix using PC-ORD (McCune and Medford 1999). Multi-response permutation procedures (MRPP) were first conducted to test whether the predetermined agroforestry types differed in species composition. Additional categorical variables from both the environmental and socio-economic matrix were also included in the analysis to assess whether groups could be distinguished based on those variables. MRPP is a non-parametric statistical method that uses distance measures to test the hypothesis of no difference among *a priori* groups by providing a p- value and effect size. The effect size is measured by the chance-correlated within group agreement *(A)*. While the p-value is a measure for evaluating how likely the observed difference among groups is due to chance, the effect size describes the within group homogeneity, compared to the random expectation.

Non-metric multi-dimensional scaling (NMS Kruskal 1964; Mather 1976) analysis was used to investigate patterns among agroforestry sites as well as relationships between the sites and social and environmental variables. NMS is an ordination technique where strong patterns in the data are selected and objects are placed along a scale (or axis) accordingly, forming a configuration. The scope of inference for an ordination technique such as NMS is limited in that it can be used to explain observed associations, but cannot infer causal relationships. NMS extracts a small number of dimensions (axes) in species space that capture most of the variability of the original higher dimensional species space while minimizing stress of the final configuration. Stress is measured as a departure from monotonicity (dissimilarity) in the plot of distance in the original *n*–dimensional space *Vs* the distance in the reduced ordination space (McCune & Grace 2002). The Sorensen distance was chosen to calculate distances between sample units in ordination space, as it has been shown to perform well with community data. Appropriate dimensionality and statistical significance were evaluated using the Monte Carlo test of significance. The Monte Carlo test determines whether NMS is extracting stronger axes than expected by chance by comparing the stress obtained from using a real data set with the stress obtained from multiple runs of a randomized data set. Using the "autopilot" mode in PC-ORD, a random starting configuration was selected and 40 runs of the real data along with 50 runs for the randomized data were used to determine the final stress. Graphic overlays of selected variables were used to determine patterns in the ordination. Joint plots were graphically rotated to line up variables of interest along particular axes to facilitate interpretation.

Agglomerative hierarchal cluster analysis was then conducted to classify agroforestry sites. Hierarchal clustering nests groups within other groups, but does not require specification of the number of groups to be clustered. The cluster analysis developed linkages among the 37 sites in the community matrix. Each site was progressively joined with another site based on similarities in species composition. For this analysis, the Sorensen distance measure was used with Flexible Beta linkage method (β= -.025). Flexible beta is a combinatorial linkage method that provides flexibility in controlling space conserving properties (McCune & Grace 2002). Evaluating the effectiveness of the cluster analysis was based on the percentage of chaining which occurs with the sequential addition of single items to existing groups. With a large percentage of chaining (>25%) clustering is made difficult since its purpose is to classify sample units into a small number of groups (McCune and Grace 2002). Wishart's (1969) distance objective function also provided an effective way to evaluate cluster groups. This function measures the loss of information as groups are fused; where at 0%

information remaining there would be no division among groups. The distance objective function demonstrates the compromise of obtaining a low number of groups while maximizing the information retained.

Indicator Species Analysis (ISA) (Dufrene and Legendre 1997) was conducted to examine species composition of groups derived from the cluster analysis. ISA combines information on species abundance within a particular group and faithfulness of that species to occur exclusively within the group. An indicator value is assigned to each species within each group and then tested for statistical significance using the Monte Carlo test. One-Way Analysis of Variance using S-Plus 2000 software (Mathsoft Inc.) was also conducted to determine whether alpha diversity could determine groups derived from the cluster analysis.

Results and Discussion

MRPP results and discussion

MRPP was used to test whether the initial classes of agroforestry types based on the visual assessment were different. Groups included home tree gardens (n= 24), mixed crop plantations (n=8), transitional sites (n=4), and open canopy with dispersed trees (n=2). A significant p-value of <0.001 suggested a strong difference among groups. However, the chance-correlated within-group agreement was low (A = 0.05). Although low values are typical of community data (often less <0.1) (McCune & Grace 2002), the resulting A statistic indicates a fair amount of heterogeneity within groups. This result suggested that further analysis of group differences using NMS could be useful for recognizing patterns.

All categorical variables in the socio-economic matrix were used to define type membership and determine whether any of the variables explained patterns in NMS. Out of the 8 variables that were assessed, only age of the farmer was statistically significant. Farmers were broken down into 5 age categories: 15-25 (n=1), 26-35 (n= 5), 36-45 (n=9), 46-60 (n=13), and 61-75 (n=10). A low p-value of <0.01 suggested that there were group differences. However, the chance-correlated within-group agreement was also low (A= 0.03), again emphasizing the need to further investigate group differences by farmer age.

NMS results and discussion

A 3-dimesional (3-Axis) configuration, which minimized stress at 19.2, was produced for the community matrix (p-value for Monte Carlo test = 0.02). The final instability of 0.0001 indicated that a stable solution had been found. The cumulative r^2 for the final 3-dimesional configuration accounted for 64% of the species variation with increment r^2 values for Axis 1, Axis 2, and Axis 3 of 0.40, 0.09, and 0.15 respectively. Axis 1 explained most of the variation, while Axis 2 and 3 explained little of the variation. The somewhat high stress of 19.2 was expected since there were a large number of species with low abundance values, and the data were relativized by species maximum. Allowing the minor species to be expressed inevitably increased the complexity of the configuration. According to Clark's (1993) "rule of thumb," stress values approaching 20 have some potential to be misleading, but can still be useful as long as too much reliance is not placed in the details of the ordination graph.

Relating variables to the ordinations is the principal way to investigate and interpret them (McCune and Grace 2002). By using overlays and correlation coefficients, underlying patterns were revealed. Environmental variables were overlain onto the ordination to determine if classification type, alpha diversity, the average number of strata, elevation, and/or site size, could explain patterns in the ordination. A definite pattern emerged when classification type was used as an overlay. Since this variable was categorical no correlation coefficients were generated. Home tree gardens (Type 1) were grouped along the upper end of Axis 1 while transitional plots (Type 3) occupied a region toward the middle to upper end of Axis 1. (Figure 5) Home tree gardens appeared to be the most distinctive group while transitional sites (Type 3) occupied a space adjacent to home tree gardens toward the upper middle of the axis. Mixed crop plantations (Type 2) had the broadest range along Axis 1, with sites falling along the lowest to the upper middle end of the axis demonstrating high species variation within this classification type. Open canopy with dispersed tree types (Type 4) fell along the lower to middle range along Axis 1. The fact that there were only two sites in the open canopy with dispersed tree classification type made it impossible to determine a grouping pattern. Although the ordination of agroforestry types showed that groups occupied different regions of species space there was significant overlap indicating that group boundaries were not distinct.

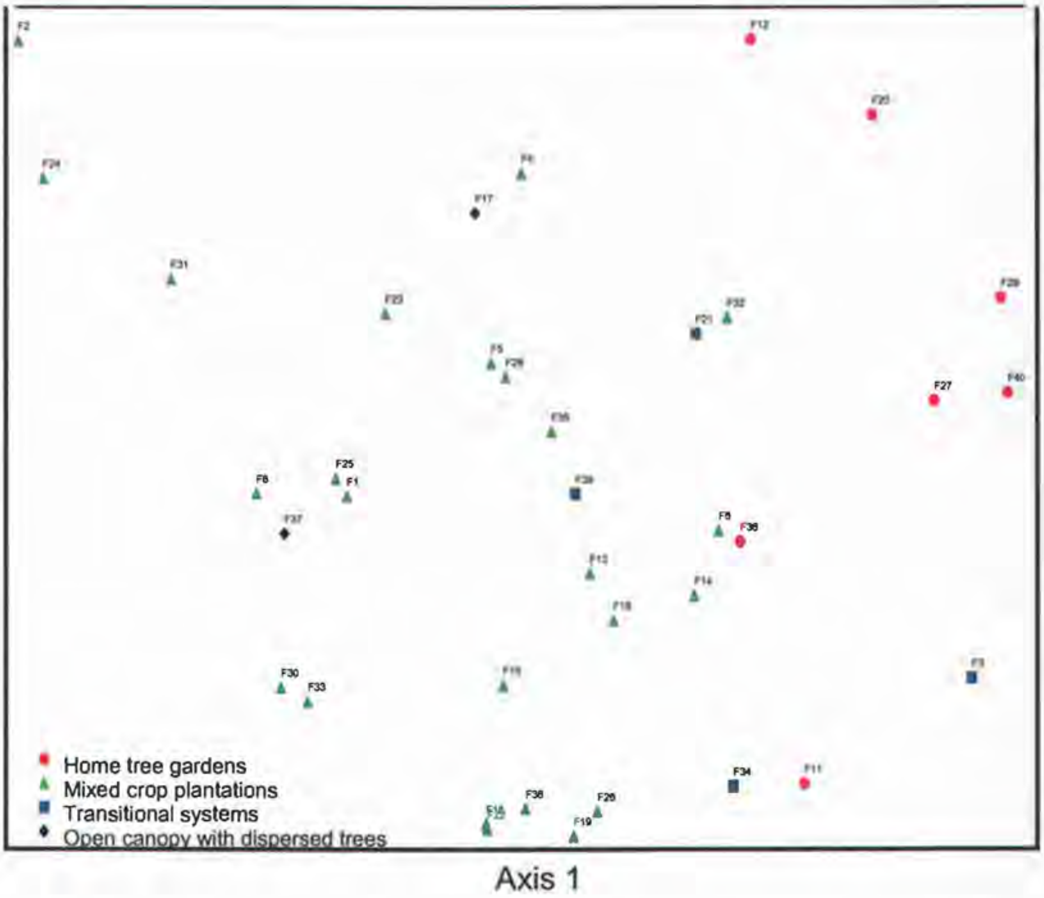

Figure 5. NMS ordination with *a priori* classification types. *A priori* agroforestry classification types demonstrating group patterns.

Correlation coefficients were used to investigate linear relationships of species, environmental, and social variables to the ordination axes. For the environmental matrix, three significant variables emerged including alpha diversity within each site (r = 0.72), average number of canopy strata for each site (r = 0.49), and elevation (r = -0.46). (Figures 6-8.) Superimposed on the scatterplots for figures 6-8 are two types of fitted lines. The envelope lines were fit by PC-ORD as smoothed lines that include points falling between two standard deviations of a running mean. The straight lines are least regression lines. Alpha diversity, average number of canopy stratum, and elevation were all correlated with Axis 1. There were no environmental variables that explained gradients along Axis 2 or 3.

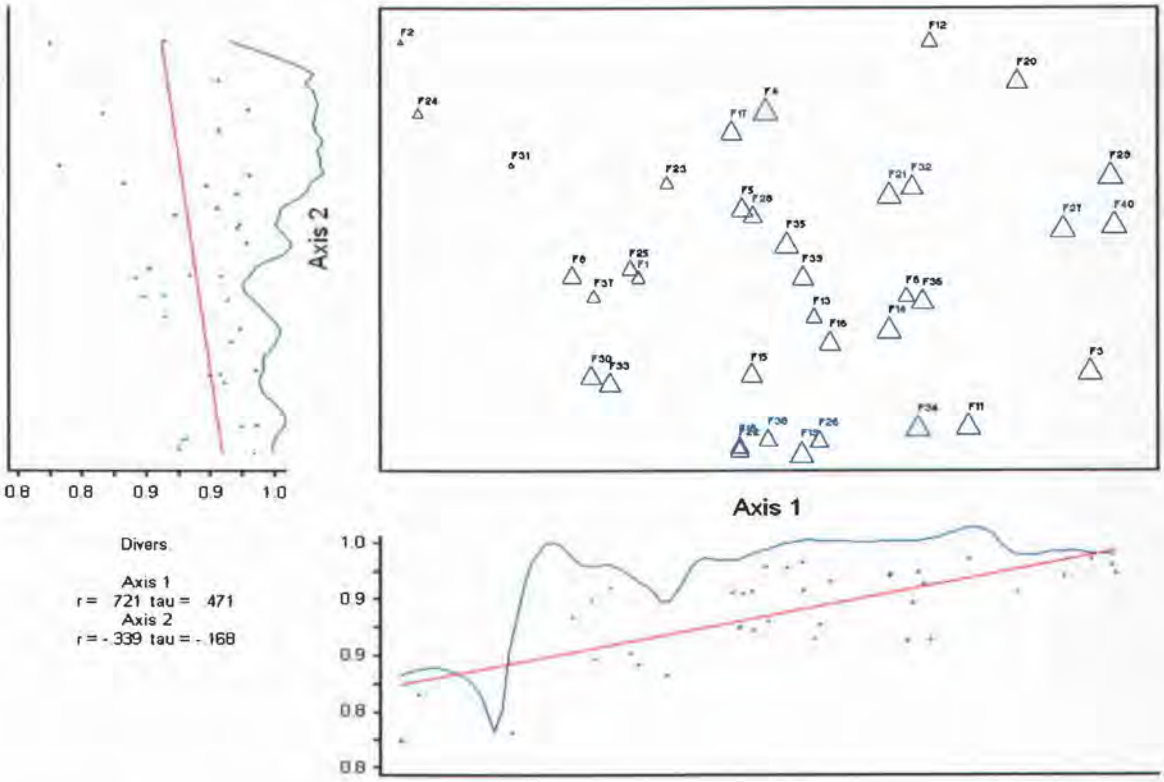

Figure 6. NMS ordination and scatterplot of alpha diversity. Triangle size of each site increases with larger quantitative values of alpha diversity. Alpha diversity (r = 0.72) shows a strongly positive relationship with Axis 1 and a negative relationship with Axis 2. Superimposed on upper left and lower right graphs are smoothed envelope lines and least squares regression lines.

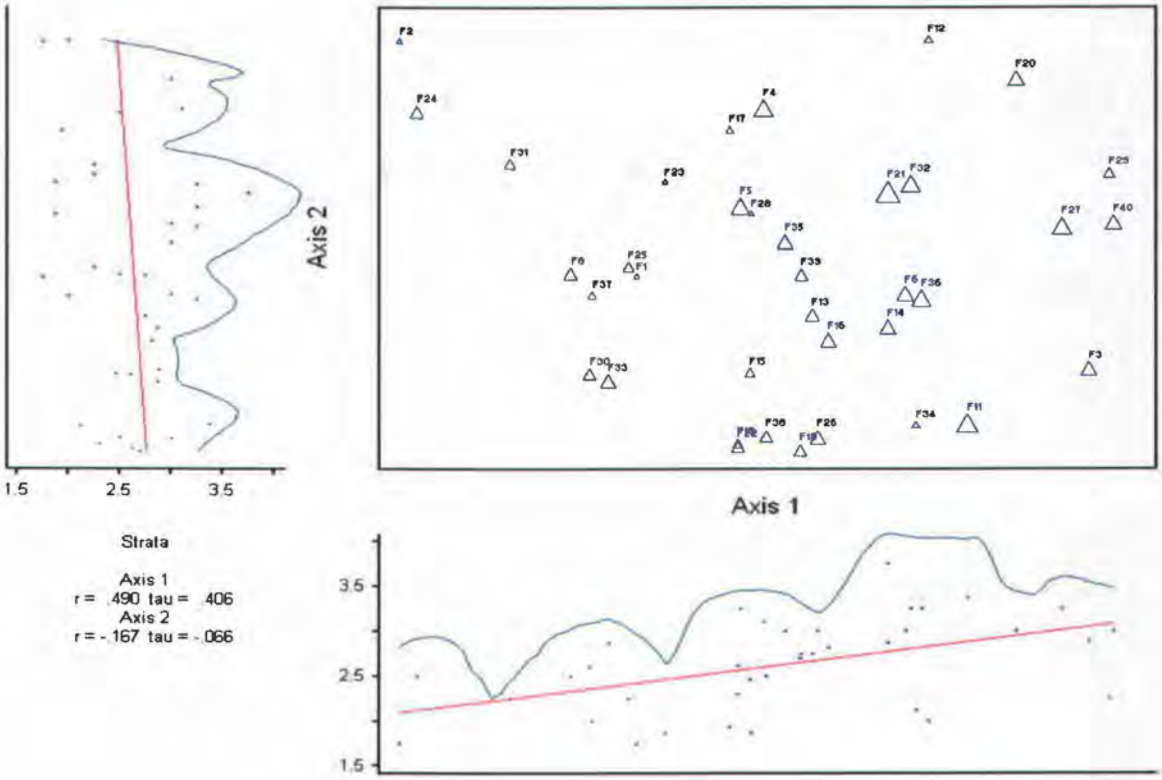

Figure 7. NMS ordination and scatterplot of average number of stratum. Triangle size of each site increases with larger quantitative values of the average canopy strata. Average number of canopy strata layers within each site shows a positive relationship with Axis 1 (r = 0.49). Superimposed on upper left and lower right graphs are smoothed envelope lines and least squares regression lines.

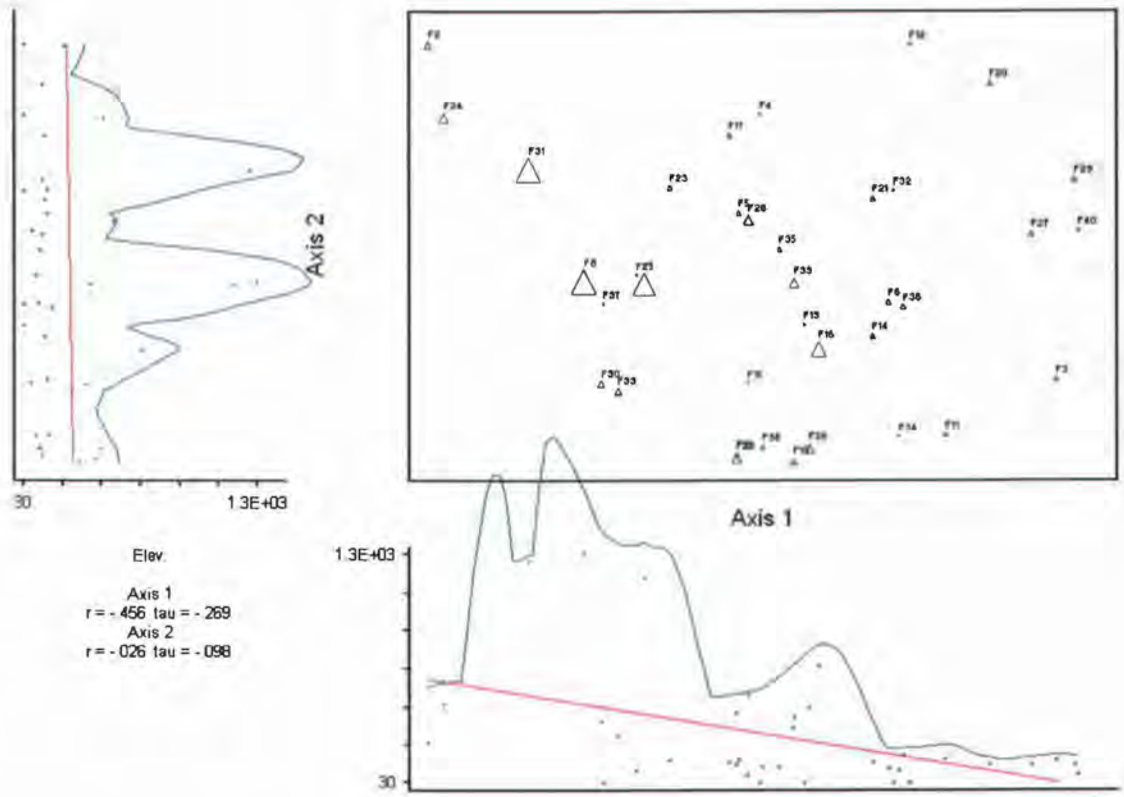

Figure 8. NMS ordination and scatterplot of elevation. Triangle size of each site increases with larger quantitative values of elevation. Elevation appears to be negatively correlated with Axis 1 (r = -0.46). Superimposed on upper left and lower right graphs are smoothed envelope lines and least squares regression lines.

A joint plot of Axis 1 vs. 2 was constructed to further investigate the relationship of the significant environmental variables to the ordination scores. (Figure 9.) A joint plot is of vectors that radiate from the center of the ordination and are associated with particular axes. Each vector represents a different significant variable and the direction of a vector describes a positive or negative relationship with corresponding axes. The length of the vector is proportional to the r^2 value of the two axes.

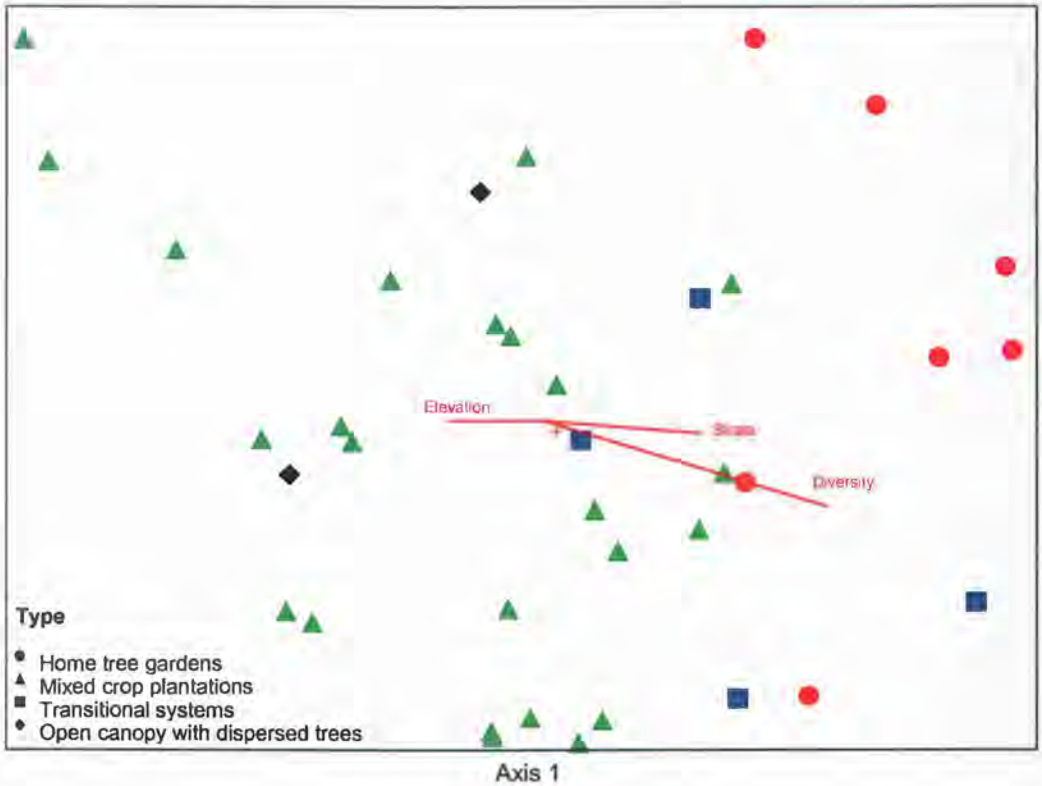

Figure 9. Joint plot of diversity, strata, and elevation. Each vector runs somewhat parallel with Axis 1 indicating that these are important gradients for this axis. Alpha diversity is the strongest gradient with the longest vector. Strata and elevation have roughly the same vector strength although the latter shows a negative relationship with Axis 1. The overlay of agroforestry "Type" demonstrates how diversity, strata, and elevation are associated with Type.

The visual display of vectors on the ordination axes demonstrates that the strongest gradient explaining species composition along Axis 1 is alpha diversity. The average number of canopy strata, which is probably directly associated with alpha diversity, is also an important gradient driving species composition along Axis 1. As both diversity and strata increase, elevation appears to decrease along Axis 1. This negative relationship was attributed to several mixed crop plantation sites that were located in the Alo'au-A'asu plateau region (elevation = 365+ m) that had low alpha diversity. This may be because in this region there are large tracts of land available for farming compared to those located closer to the ocean. Larger tracts of land allow for more expansive farming practices where areas may be devoted to growing a few species. Since alpha diversity was measured as the average species richness within the subplots for each site, it seems reasonable that these mixed plantations would have a lower alpha diversity and number of canopy stratum. The lack of large tracts of land located near the coastal areas may also explain why home tree garden types were at the lower end of the elevation gradient. Home tree gardens generally have several species concentrated in a smaller area. Although site area was not significant enough to be displayed on the joint plot (r = -0.029), the correlation coefficient for this variable showed a negative relationship with Axis 1 indicating that it was somewhat correlated with elevation.

Variables from the socio-economic matrix were also used to determine whether any variables could be correlated with species composition. Of particular interest was age of farmer since MRPP suggested that it could be a significant grouping factor. However, there were no clear patterns with any of the socio-economic variables in species space.

Correlation coefficients from the community matrix were assessed to aid in understanding which types of species were associated with the axes. Values greater than $|0.45|$ were considered for interpretation in this analysis. Table 7 lists the species within a particular stratum with significant correlation coefficients for each axis. Axis 1 had the greatest number of species with significant correlation coefficients. Species associated with Axis 1 included the timber species poumuli (*Fleuggea flexuosa*), the ornamental species vaipa'a (*Strelitzia reginae*), breadfruit, pineapple, and cocoa. These species were associated with multi-storied home tree gardens with high alpha diversity. Two additional species were negatively associated with Axis 1 including the root crop taro and the nitrogen fixing species gatae (*Erythrina* spp.). Taro is often the first crop grown after secondary fallow has been cleared and is generally grown in full sun. Gatae is often planted with talo for its soil improvement properties. The negative association of these two species with Axis 1 indicates that they are correlated with low alpha diversity and simple canopy structure. Because elevation is also negatively associated with Axis 1, the data suggests Axis 1, the data suggest that taro and gatae is associated with sites at higher elevations. Although taro is grown in both the lowland and plateau regions, it is possible that agroforestry systems dominated by these species occur less frequently in lowland populated urban settings. However, due to the very small sampling size of plots dominated by taro and gatae, there is inconclusive evidence that this is the case.

Table 7. Correlation coefficients for selected significant species within their corresponding vertical canopy strata layers.

Axis	Species	Strata	r
1	poumuli (*Fleuggea flexuosa*)	2	0.609
1	poumuli (*Fleuggea flexuosa*)	3	0.477
1	poumuli (*Fleuggea flexuosa*)	4	0.471
1	vaipa'a (*Strelitzia reginae*)	2	0.467
1	breadfruit *(Artocarpus altillus)*	1	0.461
1	pineapple (*Annas cosmosus*)	1	0.455
1	cocoa *(Theobroma cacao)*	3	0.449
1	gatae (*Erythrina spp.*)	2	-0.622
1	taro (*Colocasia esculenta)*	1	-0.602
1	gatae (*Erythrina varigata*)	1	-0.622
2	gatae (*Erythrina varigata*)	2	-0.487
2	taro (*Colocasia esculenta)*	1	0.513
2	banana (*Musa spp.)*	2	-0.637
2	banana (*Musa spp.)*	1	-0.489
2	coconut *(Cocos nucifera)*	2	-0.481
3	poumuli (*Fleuggea flexuosa*)	3	0.560
3	ti (*Cordyline fruiticosa*)	2	0.451
3	coconut *(Cocos nucifera)*	1	-0.619

Gatae (*Erythrina* spp.) and taro were also associated with Axis 2, however this relationship was positive and less strong than the relationship with Axis 1. As the gradient along Axis 2 increased, so did the abundance of taro and gatae. Species that were negatively associated with Axis 2 included banana (in both the low crop and shrub canopy layers) as well as coconut in the shrub canopy layer. Although there were no environmental or socio-economic variables that could explain a gradient driving the distribution of species along Axis 2, it seems as though Axis 2 shows a continuum of mixed plantation types. At the low end of the axis there are mixed crop plantations that have taro and gate, and at the other end are plantations that include banana and coconut. Both taro and banana are major cash crops and likelihood that the two species are found at opposite ends of a continuum is because they are grown in more distinct management units since banana can out shade taro. Although coconut is commonly seen growing with either banana or taro, when coconut is in the upper canopy, it produces little shade. This may be the reason why only coconut growing in the shrub layer was associated with mixed banana plantations and not mixed taro plantations.

Axis 3 had the least number of species correlation coefficients, which made the interpretation of patterns along this axis difficult. Two species that were positively associated with this axis were poumuli (*Fleuggea flexuosa*) in the small tree layer and ti (*Cordyline fruiticosa*) in the shrub layer, both of which are commonly found in home tree garden types. The only significant negative correlation coefficient was coconut in the low crop stratum. There were no clear patterns to explain the distribution of species composition along Axis 3 and no environmental or socio-economic variables that indicated a potential gradient. Sites that were at the low end of Axis 3 were compared with those at the higher end and a reexamination of field notes was conducted, however, this did not result in a better understanding of this axis.

In summary, it appears that Axis 1 supports the notion of an agroforestry complexity continuum. In general, sites with simple structure and few species were located at the lower end of Axis 1, while those with greater species diversity and structural complexity were located at the upper end of the axis. Predetermined agroforestry types fit relatively well along this continuum. There does not appear to be a separate group of clusters between mixed crop plantation types and open canopy farming with dispersed tree types. Axis 2 reflects a continuum within mixed plantation types dominated by either taro or banana. Axis 3 remains unknown as no underlying gradients or species composition patterns could explain this factor.

Cluster and indicator species analysis

The agglomerative cluster analysis resulted in a dendogram with 13.5% chaining. (Figure 10.) Chaining is defined by the addition of single items to existing groups. As chaining increases it becomes more difficult to classify groups. With approximately 45% of the information remaining there were 10 cluster groups, 3 of which included a single plot. This result suggested that these single plot groups were distinct from the others. Two of these three groups were originally been classified as home tree gardens. There appeared to be some similarity among groups that were defined in the predetermined classification and groups defined by the cluster analysis. Since groups are nested within other groups, those that are adjacent to each other are more similar than groups that are farther apart. With the exception of one transitional site, all of the sites within groups 1-5 of the cluster analysis were classified as mixed crop plantations or open canopy with dispersed tree types. Group 7 included 3 of the 4 transitional plots and 1 home tree garden. The remaining cluster groups (6 and 8-10) contained only sites that had been classified as home tree gardens. There were two major differences between the *a priori* group types and the cluster analysis groups. The first difference is that the cluster analysis distinguished several subgroups within the mixed crop plantation predetermined type. A closer examination of these subtypes was conducted using Indicator Species Analysis. The second major difference is that the cluster analysis did not differentiate the open canopy with dispersed tree type as a separate group. Overall, it appears that the cluster analysis produced groups that fell along a continuum similar to the pre-determined types.

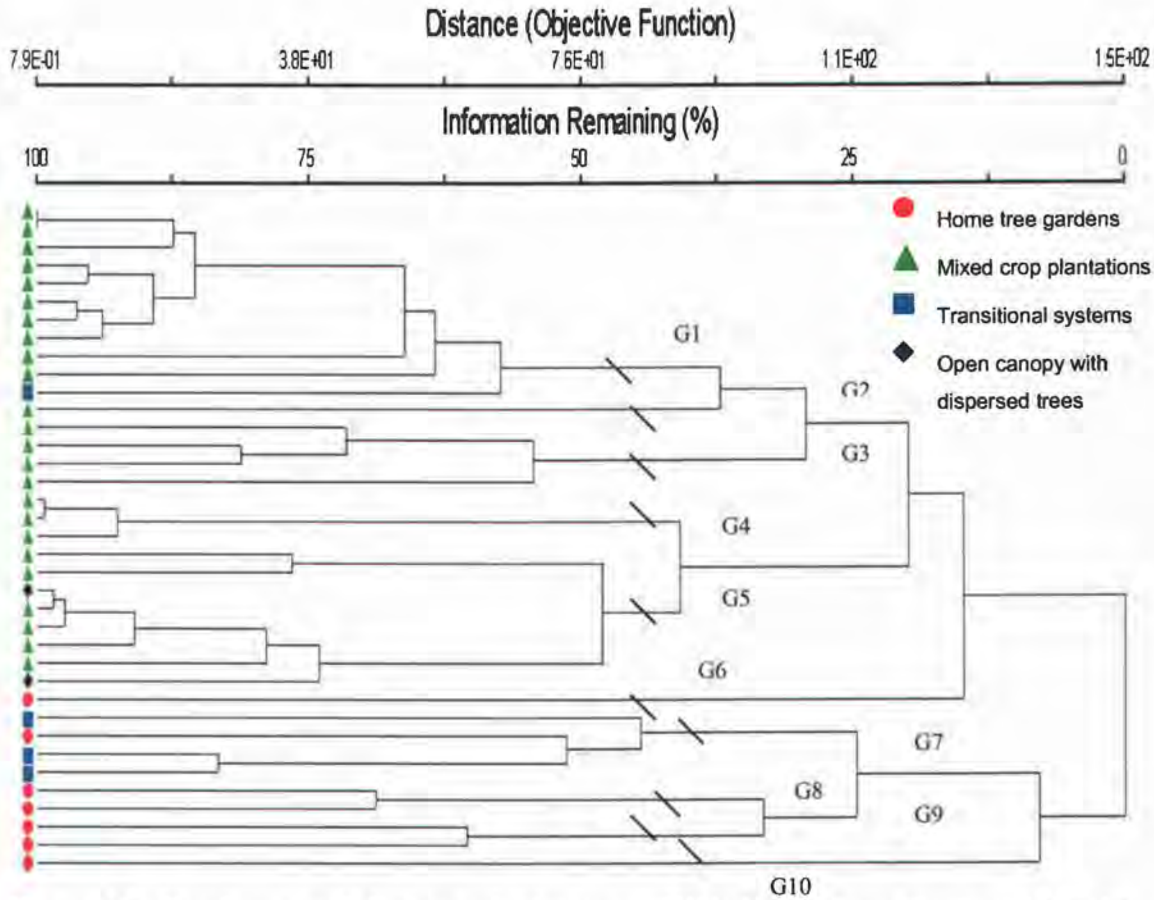

Figure 10. Dendogram of cluster analysis groups. With 45% information remaining 10 cluster groups were formed, three of which contained a single plot. Groups 1-4 are dominated by mixed plantation type plots (Type 2) while Group 5 contains both mixed crop plantations (Type 2) and open canopy with dispersed tree types (Type 4). Groups 6, 8, 9, and 10 include home tree garden types only (Type 1) while Group 7 includes a home tree garden and transitional types (Type 3).

Indicator species analysis (ISA) was used to investigate which indicator species were associated with particular groups derived from the cluster analysis. Groups 2, 6, and 10 were excluded from this analysis since they only included a single site. The maximum indicator value (IV) for each variable was significant for 16 species within various strata layers. (Table 8.) Group 5 was the only cluster included in the analysis that did not have any significant indicator species. The reason for the low number of significant variables among the cluster groups is probably attributed to the lack of faithfulness for species' to occur within a single group.

Table 8. Significant indicator species for groups derived from cluster analysis with 45% information remaining.

Variable	Strata	Group	IV	P
banana (*Musa spp.)*	2	1	33.8	0.013
cacao (*Theobroma cacao*)	2	3	47.3	0.043
ylang ylang (*Canaga odorata*)	2	3	43.0	0.048
gatae (*Erythrina variegata*)	2	4	93.5	0.001
gatae (*Erythrina variegata*)	3	4	50.4	0.043
taro (*Colocasia esculenta)*	1	4	35.7	0.032
teulia *(Alpinia purpurata)*	2	7	89.0	0.001
teulia *(Alpinia purpurata)*	1	7	75.0	0.012
oli oli (*Cyathe spp*)	5	7	50.0	0.032
lau fao (*Heliconia paka*)	2	7	50.0	0.030
maniok (*Manihot esculenta*)	2	8	55.6	0.049
poumuli (*Securinega flexuosa*)	2	8	50.6	0.025
breadfruit (*Artocarpus altilis*)	1	8	45.9	0.037
poumuli (*Securinega flexuosa*)	4	9	85.3	0.003
pineapple (*Ananas comosus*)	1	9	70.0	0.007
vaipa'a (*Strelitzia reginae*)	2	9	67.1	0.015

Group 1 included only one significant indicator value, which was banana located in the shrub layer (IV = 33.8). Significant maximum indicator values for Group 3 included cacao (IV = 47.3) and the ornamental tree ylang ylang (*Cananga odorata*) (IV = 43.0) in the shrub canopy layer. This secondary forest tree species is often cultivated for its flowers used to scent coconut oil. Group 4 had the strongest indicator value (IV = 93.5) for gatae in the shrub canopy layer. Gatae that occupied the small tree canopy layer as well as taro also had significant indicator values and were associated with this same group. Significant indicator variables included in Group 7 were all ornamental species generally associated with home tree gardens. Groups 8 and 9 were composed of both ornamental and food crop indicator species, which are also commonly associated with home tree garden types.

To better understand the cluster groups, non-significant indicator values from ISA were also considered for each group. Group 1 described mixed plantation types dominated by banana. Although there were no other significant maximum indicator values, other species that were associated with this group included several secondary forest species such as fogamamamla (*Omanthalus nutans*), mati (*Ficus tinctora*), and maota (*Dysoxylum maota*) at the low crop canopy level. The fact that these secondary species are not found in other canopy layers suggests that Group 1 refers to actively managed mixed banana plantations. The second major subgroup within mixed plantations included plots that were clustered into Groups 3 and 5. Although there were only two significant maximum indicator species for Group 3 and none for Group 5, species associated with these groups included a wide variety of major crops such as coconut, giant taro, and breadfruit, as well as secondary species such as lau papata (*Macaranga harveyana*), nonu (*Morinda citrifolia*), and fau (*Hibiscus tiliaceous*) at various canopy layers. This subgroup within mixed plantation types appears to reflect more compositionally and structurally diverse plantations compared to mixed plantations dominated by banana. These diverse mixed plantations may be older and/or less actively managed. The third major subgroup of mixed plantations is found in Group 4. These include structurally and compositionally simple plots dominated by taro and gatae.

Groups 6-10 included plots that had been classified as transitional plots and home tree gardens. Group 7, which included three of the four transitional plots, did not have species that were very different from the groups with only home tree garden plots. Groups 6-10 all included a wide variety of major and minor crops, fruit trees, and ornamentals. A reexamination of field notes regarding these plots allowed closer investigation of differences between these groups. One of the major crops included in sites within groups 6 and 7 was banana. Although these plots also contained a number of other species, the presence of banana may explain why they fall somewhere between groups dominated by mixed plantations and those of home tree gardens. It is possible that the single plot within Group 6 should have been classified as a transitional type rather than a home tree garden.

There were little differences in species composition and structure between sites within Groups 8-10. Perhaps the only difference was that sites within Group 8 contain fewer species than sites that fell into Group 9. Group 10 appeared to have a higher number of ornamental species. Retaining the general classification type of home tree gardens for sites within groups 8-10 makes most sense.

NMS and cluster results with one-way ANOVA.

Groups derived from cluster analysis were used as a graphic overlay in species space. (Figure 11.) This presentation allows an investigation of how cluster groups were distributed along the axes. In addition, direct comparisons could be made between cluster groups and predetermined types. In general, groups derived from cluster analysis fell along the same continuum as those in the predetermined types. Alpha diversity and stratum were underlying gradients that helped to determine cluster groups. Groups 6-10 were located at the higher end of Axis 1. Groups 1, 3, and 5 were distributed along the lower to upper middle of Axis 1. The single plot in Group 2 was located at the lower middle of Axis 1 while Group 4 was located at the lowest end of Axis 1.

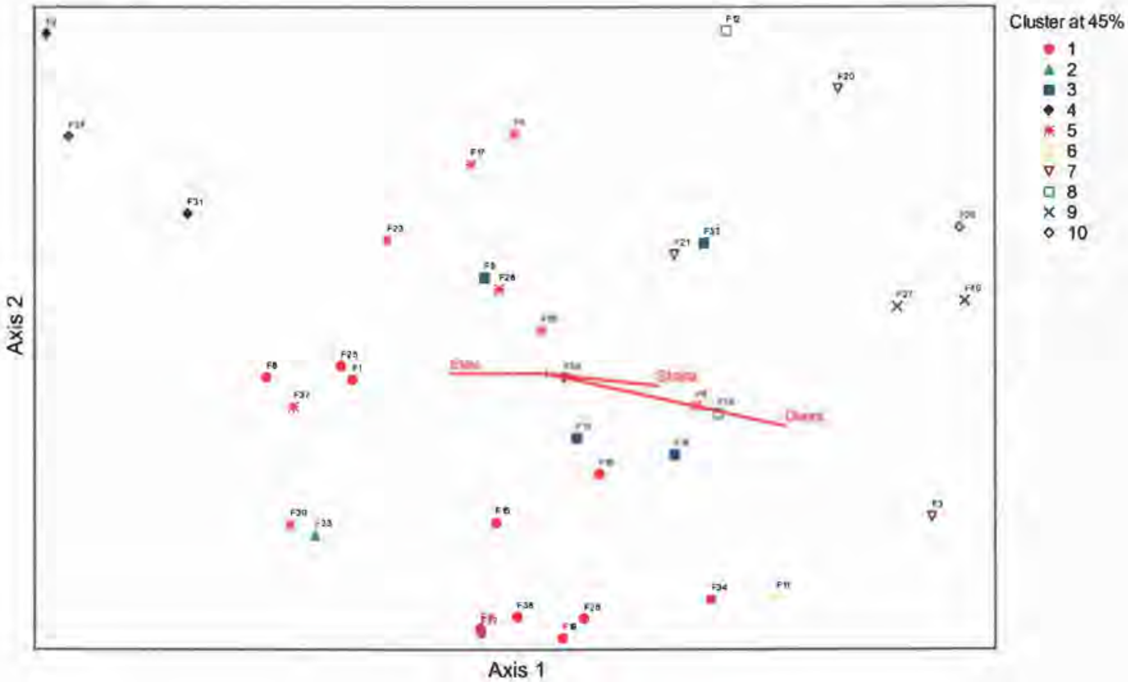

Figure 11. NMS ordination with cluster groups. NMS ordination with an overlay of groups derived from cluster analysis with 45% information remaining. Groups 1-5 generally include plots that were classified as either mixed plantations or open canopy with dispersed tree plots in the predetermined type. Groups 6-10 were classified as transitional plots or home tree gardens in the predetermined type.

Cluster groups were associated with species diversity. Cluster Group 4 was dominated by two species (talo and gatae) that are generally grown on recently cleared lands, was located at the low end of Axis 2 and seemed to be the most distinct group. These sites had low alpha diversity values. Cluster groups 7, 9, and 10, had the highest alpha diversity. Each of these groups included sites that were classified as home tree gardens in the predetermined types. Both the predetermined types and the cluster groups were correlated with alpha diversity and average number of canopy layers. However, one-way ANOVA used to test mean alpha diversity and strata differences between groups from both the *a priori* types and the cluster groups, indicated no evidence of group differences (p values >0.1). This suggested that although cluster groups may show an association with species diversity, there were no clear distinctions between groups based on these attributes.

Conclusion

The classification of agroforestry systems in specific regions has been an important element of agroforestry research. Classifying such systems can be difficult because they tend to be complex and are often subject to varied socio-economic needs. As most classifications are meant to provide useful information for farmers/landowners and natural resource extension workers, they are generally logical, easily understood, and practical (Nair 1993). The classification of systems using multivariate analysis allows for a more thorough and objective investigation of species composition and structural patterns. In the present study, multi-response permutation procedures were conducted to determine whether group differences existed among the *a priori* groups from the predetermined classification or from any other categorical variables from the environmental and socio-economic matrices. Non-metric multidimensional scaling was used to describe plot positions along species compositional, environmental, and social gradients and to compare the predetermined and cluster derived groups in ordination space. Cluster analysis helped to define groups based on a classification derived from the community matrix and indicator species analysis was used to identify key species that distinguished the groups.

Socio-economic and environmental agroforestry systems in southwestern Tutuila exist along a continuum that is not easily captured through multivariate community analysis. Because these systems are largely based on people's choices, the underlying continuum is a complex gradient with interacting socio-economic variables and personal preferences. No single socio-economic variable demonstrated patterns that suggested an underlying gradient driving species composition or structure. Although environmental variables such as elevation and site size showed some association with particular species, no clear inferences could be made. Alpha diversity and average number of canopy layers were associated with Axis 1 and provided some insight into how groups were clustered.

Classifying agroforestry communities based on cluster analysis is useful, as long as patterns can be explained and the groups make sense. Having a predetermined group type was also useful in that it provided a reference for groups based on criteria that are often used to classify agroforestry systems in other regions of the world. For this study, classifying local systems by combining information from both the pre-determined types and the cluster analysis seems most appropriate. The final classification includes: 1) taro and gatae (*Erythrina* spp.) dominated plantations, 2) mixed crop plantations, 3) home tree gardens, and 4) transitional systems. Mixed crop plantations can be broken down into three subgroups including: open canopy with dispersed trees, banana dominated mixed species plantations, and multi-storied mixed plantations with secondary forest species. Although there may be successional correlations between some of these subtypes, no temporal data was collected for this study. Due to significant overlap in vegetation composition of transitional type sites, they may be best classified as either an additional subtype of mixed plantations or home tree gardens depending on the size of the area, the level of subsistence, and the farmer's intent. The heterogeneity of species composition in home tree garden systems makes them more difficult to classify into subgroups, therefore, the general home tree garden classification type is recommended. Recognizing however, that home tree gardens may combine different combinations of several ornamental, food crop, medicinal, and timber tree species is essential to understanding these systems.

Overall, it appears that there were very few patterns in the data that would indicate distinct agroforestry groups exist. Classification is however, still useful as long as definitions account for the variability and the overlapping of groups. Classification of non-distinct systems is complex, since it imposes group structure on systems that appear to have continuous variation. Underlying gradients that determine species composition patterns are not clear. Much of this lack of clarity is due to the fact that unlike natural systems, agroforestry patterns are an expression of human preference, which is the result of combined cultural and socio-economic factors that are not easily captured with standard survey procedures and quantitative results.

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Ch. 5: Study Conclusion and Recommendations

Agroforestry is a traditional farming practice in American Samoa that has helped to sustain the livelihood of the native population for centuries. The year-round growing season, relatively fertile soils, and low maintenance crops allowed for a comfortable life-style where all were fed, clothed, and sheltered (Coulter 1942). Cultivated products as well as forest and water resources were regulated at the village level. Although continuous change in the landscape occurred through the development of coastal areas, sustainability was achieved because of the small human population that the islands supported.

The state of sustainability has dramatically changed since colonization. The once self-sufficient islands have become economically dependent on U.S monies and other external resources. This dependency has caused a shift in the natural carrying capacity of the islands and has changed cultural attitudes regarding land-use. The availability of external resources has reduced the need for self-sufficiency and has undermined the value of resource sustainability and traditional knowledge. With shifting cultural and economic priorities, decision-making has moved from what is best for the group to what is best for the individual. This attitude is expressed in the changing landscape of agricultural and communal lands. Preserving traditional agroforestry practices and improving these systems may be an important factor contributing to the future ecological, economic, and cultural sustainability of the territory. The documentation of agroforestry farming in American Samoa provides base-line information regarding the utilization of agroforestry species, agroforestry farming incentives and constraints, and current practices and systems.

Agroforestry farming systems continue to be an important cultural and product resource in American Samoa. Although there is no longer the same level of dependency on these systems for meeting basic needs, agroforestry products continue to supplement household diets and are utilized for a variety of non-timber forest products and ecological services. Fruit trees are an important component of agoforestry systems, as fruit production often drives the desire for planting woody species in local systems. Secondary products of fruit trees often include medicine, fuel wood and mulch, or services such as wind protection and shade. With a few exceptions, most non-food trees are retained rather than planted.

Several agroforestry practices were observed among the farms in the study. These practices included the use of woody species for fallow, shade, structural support, intercropping, multi-cropping, wind protection, and erosion control. However, the effectiveness of several of these practices such as windbreaks, fallow, and erosion control could be greatly enhanced through the implementation of institutionalized agroforestry practices such as appropriate spacing for wind filtration, improved fallow, and contour farming.

Because most households in American Samoa have access to homegardens or plantation land, American Samoan farmers come from diverse demographic and socio-economic backgrounds. Thirty percent of the farmers in the study were women, demonstrating cultural change in traditional farming practices. Farmers in the study represented all education levels and included a wide range in both farming and non-farming income levels. Sixty-eight percent of the participants in the study stated that farming was a secondary occupation. Hobby farming was therefore common practice. Most agroforestry farmers utilized products to supplement household consumption and fa'alavelave obligations. However, there were also a considerable number of farmers that sold products commercially.

Having a variety of crop species and being able to provide food for *fa'alavelave* obligations are important incentives for conducting agroforestry. Tradition is also a major incentive, as several farmers claimed that they combined crops and trees because that is how it has always been done. The increasing fragmentation of land and growing human population numbers (especially in lowland regions) may also provide an incentive for multi-storied diverse agroforestry systems, as the need for land-use efficiency becomes increasingly obvious. The communal land tenure system can act as both an incentive and a disincentive for practicing agroforestry. Because planting trees can help establish the occupation of land, farmers may be encouraged to plant trees in order to reserve rights to land for future agricultural use. However, family *matai* may not give permission to plant trees for this same reason. Farmers who come from Western Samoa to work on American Samoan plantations may also be less interested in planting additional trees since it is likely that they will not reap the benefits of them.

Additional constraints for agroforestry production included: time investment for production and the lack of labor resources, decreased profit when compared to mono-cultural farming, failure to recognize the significance of soil erosion problems, and the lack of planning prior to agroforestry implementation. Although there were several agroforestry constraints that were identified, it seems likely that the practice will continue to be an important aspect of American Samoan farming. However, incorporating institutionalized practices in order to improve traditional systems will be a difficult challenge, as they require more planning, may have a higher initial investment in time and labor, and require technical knowledge that is not readily available to farmers.

Based on a visual assessment of 38 farms in the southwestern region of Tutuila, three major types of agroforestry systems were recognized. These systems included home tree gardens, mixed tree plantation, and open canopy farming with dispersed trees. Home tree gardens were multi-storied small to medium sized plots that contained a variety of food crops, multi-purpose trees, and ornamentals. Mixed crop plantations were characterized as being small to large size plots having 1-3 dominant crop species such as taro, banana, and/or coconut. These systems also contained a variety of less important utilized tree, shrub and herbaceous species. Open canopy with dispersed tree systems had little canopy cover and were dominated by low crop species. In addition to the three major classification types a transitional subtype was also recognized. These "transitional" plots appeared to share characteristics of both home tree gardens and mixed crop plantations. Each agroforestry system type appeared to exist somewhere along an ecological complexity continuum, where complexity was measured by species diversity and vertical structure.

A quantitative assessment of species composition and structure was used as a more objective approach to classifying local agroforestry systems. Using ordination techniques, relationships between agroforestry sites were explored. Ordination allowed for a graphic representation of how sites were related to one another by "ordinating" them along synthetic axes and extracting a few dominant patterns of species composition.

A relatively large number of environmental and socio-economic variables were explored as potential patterns driving the arrangement of sites in ordination space. However, the only strong patterns that emerged were species diversity, canopy stratum layers, and elevation. Sites that had high species diversity and were multi-stored were clustered at the high end of the gradient while sites with lower species diversity and simple vertical structure were clustered at the lower end. This supported the ecological complexity continuum hypothesis. Less complex sites were associated with higher elevations indicating that systems on the heavily populated lowland region were more species-rich and structurally diverse than sites at higher elevations. Sites with fewer species and simple structure were associated with taro production.

The classification based on the cluster analysis indicated that distinct groups did not exist, as there was significant vegetation overlap. In general, groups derived from the cluster analysis were similar to those based on the visual assessment. The major difference between the two classification schemes was that the cluster analysis did not include open canopy with dispersed tree system types as a separate group. A second difference was that the cluster analysis was able to recognize subgroups within the mixed crop plantation type. These subtypes included banana dominated mixed species plantations, multi-storied mixed plantations with secondary forest species, and low diversity taro and gatae (*Erythrina* spp.) systems. Although there may have been successional correlations between these subtypes, because no temporal data was collected, this could not be confirmed.

No single socio-economic variable was correlated with vegetation patterns. This suggests that either the sample size of farmers was not large enough to detect patterns or that socio-economic variables do not determine vegetation in agroforestry systems. If the latter is the case then perhaps personal preference is driving vegetative patterns. The inability to include choice as a variable in the ordination makes it difficult to investigate this consideration. It is very likely that the availability of external resources allows for the selection of species within agroforestry systems to be based on choice rather than need.

This trend is likely to increase, as people become less dependent upon agroforestry systems to supplement needs.

Agroforestry needs and recommendations

The overview of sustainability in American Samoa provides essential information needed to begin to address sustainability needs in the territory. Perhaps an initial step toward addressing these needs is to increase economic self-sufficiency in the islands. Although it is unlikely that self-sufficiency levels will be ever return to a historical state, it may be possible to improve self-sufficiency by incremental steps. Deliberate and intentional decisions regarding resources and land use as well as economic aid must be made. Diversification of local markets must be explored and household food security from family owned agricultural plots should be increased.

Traditional and institutionalized agroforestry practices have the potential to contribute to increasing self-sufficiency among American Samoan households. Because the importance of these systems is often not realized, the active promotion and education of agroforestry practices is essential. Including *matai* in the target educational audience will be important since they tend to have the final word on land-use decisions. In situations where a hired farmer is not interested in trees, a *matai* may require the planting or retaining of trees on land he oversees.

Agroforestry education should include easy access to information regarding appropriate species, potential economic returns, and establishment and maintenance costs so that farmers and *matai* can make informed decisions. Although user-friendly agroforestry guides and research documents may be available for extension personnel, this knowledge does not seem to be transferred to farmers. American Samoan farmers could therefore benefit by having a local agroforestry specialist. The person would be responsible for providing technical assistance and educating farmers on potential benefits of institutionalized practices and land-use efficiency, while facilitating inter-agency collaboration to address local agroforestry needs. One example of interagency collaboration that could potentially improve economic incentives for sustainable farming practices could be between the Natural Resource Conservation Service (NRCS), the

American Samoan Department of Agriculture (ASDOA), and the American Samoa Department of Education (ASDOE) that houses the school lunch program.

Because there is considerable room for improvement of existing systems, non-formal education in the form of workshops and on-site demonstrations would enhance knowledge transfer. Workshops could include topics on agroforestry planning and management or focus on specific practices for wind protection, soil improvement, and soil erosion control using multi-purpose trees. Conducting agroforestry demonstrations within the villages would also be important for knowledge transfer since it would require active community participation. The establishment of a community agroforestry group where members could exchange labor, management advice, and plant materials could help to offset some of the constraints mentioned by farmers in the study.

Application of agroforestry classification

The classification of American Samoan agroforestry systems does not have a specific utility for farmers, rather it provides an organizational framework for future research to build upon. The concept of the ecological complexity continuum where agroforestry systems fall along major points may be useful for answering socio-economic and ecological questions related to agroforestry production. One example of an application would be to use the continuum for determining how complex or simple agroforestry production would have to be in order to provide minimum or maximum economic viability. The classification could be used as a guide to help extension agents determine appropriate system types for farmers with different economic needs. Agronomists could use the continuum to determine how agroforestry complexity affects soil nutrient levels. Biologists could also use the complexity continuum to answer questions related to the presence of wildlife in agroforestry systems. A question of interest could be: at what point along the agroforestry complexity continuum does wildlife diversity decrease. In general, the classification scheme can be thought of as a foundation for other ideas.

The results of this thesis are limited to the southwest farming region of Tutuila. It is likely that if the same study were conducted in other areas of the Samoan archipelago, results would differ due to differences in sustainability issues, socio-economic needs, access to outside resources, and biogeographic variations among islands.

Conducting research on traditional agroforestry systems in American Samoa posed unique challenges. Cultural sensitivity regarding the communal land tenure system was required and permission from farmers, *matai*, and in some cases conflicting chiefs and families, had to be sought to gain access to farming plots. The ability to select a balanced number of agroforestry plot types was therefore limited. Another difficulty was determining whether socio-economics contributed to vegetation patterns in traditional agroforestry systems. Although agroforestry has played a major role in the livelihood of the population, the current availability of external resources has allowed for greater human choice, adding complexity to an already complex problem. Challenges aside, I am hopeful that this study will provide information that can be utilized in some capacity for future agroforestry and sustainability research in American Samoa.

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Appendix

Informant Survey

Sample number ______
Village ____________
District ____________
Date ____________

0.0: Background Information

Name of farmer/household head ____________________________________

Family matai ______________________________ Matai's village ______________

I would like to begin by asking you some questions about the trees and shrubs on your land....

1.0 Woody Components

1.1) What species of trees have you intentionally planted or kept when you cleared land for your farm? Why did you plant or keep these trees/shrubs? (After this, ask the same questions about woody shrubs)

Tree/shrub species	Habit	Planted /left	Food	Medicine	Com crop	Fuel	Con/Tech	H. craft	Feed	Fodder	Shade	Eros. ctrl	Fert/Mulch	Nitrogen	Boarder/fence	Support	Wind prot.	Orna/Beauty	Other
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1.2) Have you planted any species for the protection of your crops?

No…………1 → Skip to question 1.3
Yes………..2 Please be specific:

Trees/Plant species	Purpose

1.3) Are you interested in growing more trees for any reason on your farm?

No…………1 → Skip to question 3.3a
Yes………..2 Please be specific, then go to 3.3b

Trees/Plant species	Purpose

1.4a) Why are you not interested in growing more trees?

No cash incentive……………………………………1
Not enough labor……………………………………..2
Already satisfied with farm productivity……………3
Do not require tree services………………………….4
Other (Please be specific)…..………………………..5

1.5b.) Why have you not gown these trees?

Time or labor resources…………………………..….1
Lack of seed/seedling source………………………..2
Poor survival rate…………………………………...3
Lack of market……………………………………..4
Lack of cash to buy inputs………………………….5
Other (Please be specific)…………………………..6

2.0: Animal Component

2.1) Do you have livestock?

NO……………..1 ⟶ Skip to question 2.4

YES…………...2

2.2) I will read you a list of farm animals. As I read each one please tell me whether or not you have them on your property.

Present

a. Moa ____
b. Pigs ____
c. Cows ____
d. Horses ____
e. Talapia ____
f. Other ____
(Specify: ________________________________)

I will now ask you about inputs and soil on your land.

3:0 Inputs and Soil

3.1) Do you use any pesticides in your plantation?
No…………1
Yes………..2

3.2) Do you use any chemical fertilizers in your plantation?

No…………1
Yes…………2

3.3) Do you use any green mulch for fertilization?

No…………1 → Skip to question 3.4
Yes………..2

3.3a) If yes, what types of mulch.

Species	Plant parts used

3.4 Do you use any animal manure for fertilization?

No............1 → Skip to question 3.5
Yes...........2

5.2a) If yes, what types of manure

Manure	Use

3.5) Do you feel that soil erosion is a problem on your land?

No............1 → Skip to question 3.7
Yes...........2 (Please Explain)

3.6) Do you use any methods to protect your land from soil erosion?

No............1 → Skip to question 3.7
Yes...........2 (Please Explain)

3.6a) What methods to you use to help conserve soil?

Bench terracing.................................1
Leaving slash when plantation is cleared....2
Planting trees and grass (specify)...........3

____

____

Others (specify).................................4

____

____

3.7) What do you think about using soil erosion control methods on your land? (Do not ask question if informant answered YES to question 3.5.)

Not Necessary.....................................1
Indifferent.. .2
Necessary, but not willing........................3
Interested..4
Essential..5

Now I will ask you questions and land ownership.

4.0: Land Tenure

4.1) Who owns this farm/plantation? (Circle one)

Individual/Private......................................1
Communal/Matai.......................................2
Communal with legal separation/lease agreement..3
Church ______________________..................4
Government...5

4.2) If communally or privately owned: what is your relationship to the person who oversees the land?

Self/ or spouse..1
Immediate aiga...2
Extended aiga...3
No blood relation.....................................4

4.3.) How do you respond to increased land pressure for farming?

Have not had to worry about this......................1

By moving to new land and clearing it.................2
By converting land-use to another type................3
By tolerating reduced yields............................4
By decreasing the length of fallow......................5
By increasing yields per unit of land....................6
Other (specific) ____________________________.....7

4.4) Are any plantation workers on this farm that are sponsored from Western Samoa?
No..........→..1 Skip to section 8.0
Yes..........2

Now I will ask you some personal demographic questions.

5.0: Demographics

5.1) What is your major occupation?

farmer 1
housewife...........................2
government/federal job............3
canneries.............................4
private................................5
retired/ (hobby farmer)............6
other ____________________.... 7

5.2) What is your highest level of education that you have completed?

primary school (level 6 or less)....1
secondary school education.........2
high school graduate................3
some college.........................4
college graduate.....................5
graduate school......................6

5.3) How old are you?

15-25.............................1
26-35.............................2
36-45.............................3
46-60.............................4

61-75...............................5
75+................................6

5.4) What approximately, is your weekly gross farm income?

no income.........................1
less than $100...................2
$100-$399.........................3
$40-699...........................4
$700-999..........................5
$1,000 6

5.5) What approximately, is your weekly household income from non-farming employment?

no income/only farming.........1
less than $100.....................2
$100-$200.........................3
$201-$300.........................4
$301-$450.........................5
$456-$600.........................6
$601+..............................7

5.6) How are your farm products distributed?

Household and fa'alavelave use only (I do not sell my products)..............1
I sell some of my products, but most are kept household/fa'alavelave.........2
I sell about half of my products and keep half for family/fa'alavelave.........3
I sell most of my products and keep only some for family/fa'alavelave.......4

5.7) How many people work the land/farm every week (including yourself)?

Additional Interview comments:

____

____

____

____

____

____

Field Survey

Sample number _______
Village_______________
Date _______________

1.0: Site Geography

Geography or Topography	Description
Distance from home	
UTM	
Current agroforestry area	
Elevation	
Slope (0-3)	
Aspect	
Streams/Gullies	
Watershed	

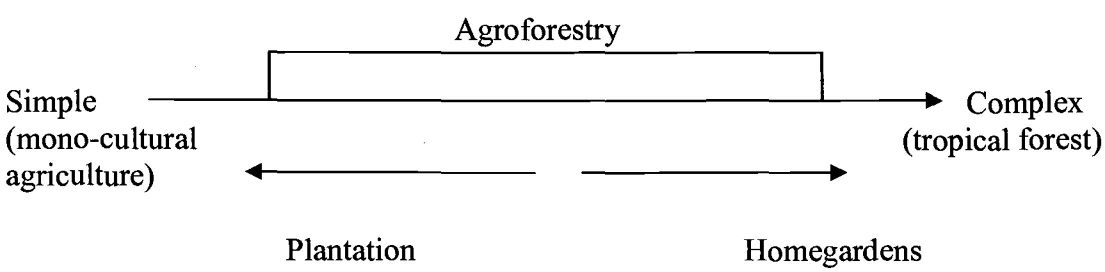
Code for distance: 1= next to home, 2= within 0.5 mile, 3=0.6-1.0 mile, another village
Code for slope: 0= flat (0-4%), 1= gentle (5-7%), 2= moderate (8-30%), 3= severe (31%+)

2.0: Agroforestry Practices and Land Use

Agroforestry Practice	P/A	Description
borders/fences	P A	
contour hedgerows	P A	
green/manure mulching	P A	
alleycropping/ intercropping	P A	
improved fallow	P A	
Multi-story cropping	P A	
riparian buffer	P A	
shade for crops/support	P A	
windbreaks	P A	
woodlot	P A	
fallowed land	P A	
piggery	P A	
aquaculture	P A	
pasture	P A	

3.0: Qualitative description of stratification

4.0: Impressions of Agroforestry System Type and Additional Comments (Mark where you feel this site is on the scale below or whether you think the scale is appropriate here. Elaborate in comments section.)



5.0: Sketched Description of Land (include shape of property, location of buildings, fields, major species, waterways.)

t= taro	V= vines
B = Banana	O= ornamentals
U= Ulu	F = fruit tree
C= niu	T= timber/fuel tree
G= gatae	Sm= small tree
P= pineapple	VC= vegetables