SOCIOECONOMIC ANALYSIS OF AGROFORESTRY AND LIVELIHOODS ON A SMALL ISLAND DEVELOPING STATE: A CASE STUDY OF POHNPEI, FEDERATED STATES OF MICRONESIA

By

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The Small Island Developing States (SIDS), comprising more than 50 nations and territories worldwide, are challenged to establish sustainable development strategies consistent with their small size, remoteness, and fragile and limited natural resources. Agriculture is considered instrumental in furthering sustainable development of SIDS. Agroforestry, an age-old agricultural practice dominates many landscapes among SIDS, proving its ecological sustainability; yet little is known (quantitatively) about productivity, value, and use of agroforests or the role agroforestry plays in the livelihoods of SIDS. Such information is important to ensure that decision makers are able to establish sustainable programs for economic development. Research conducted on Pohnpei, Federated States of Micronesia, documented livelihood systems, quantified agricultural activities, and simulated the impact of potential policy scenarios on both agroforestry and livelihood systems. Sixty-four percent of households relied on three or more sources for cash income; the main income sources included formal employment, agriculture, remittances/pensions, and fishing. One-hundred percent of households were engaged in subsistence agriculture, and 88% and 90% of households used crops for cash income and

ceremonial purposes, respectively. Homegarden agroforestry practices provided between 24% and 98% of the total value of agricultural products. Agroforests contributed, per household, an average of \$4,242 yr^{-1} and island-wide contributed 18% to Pohnpei's GDP (total annual value of \$15.7 million). Limited market access was found to increase dependence on crops for cash income. In contrast formal employment was found to reduce dependence on crops for cash income. Using ethnographic linear programming, the results suggested that establishing a price policy and/or expanding market opportunities would contribute directly to households most reliant on agriculture for cash income but would have only marginal impacts on households reliant on fishing, remittances, and formal employment for cash income. Use of an expanded version of the traditional Policy Analysis Matrix methodology allowed for the internalization of environmental externalities contributing to a more accurate analysis of farming systems.

The results showed that even with such internalization of economic values, it would require additional policy action to provide sufficient incentives to persuade farmers to halt expansion into Pohnpei's uplands where ecological damage had been occurring. Desires for greater material wealth are threatening traditional cultures and limited natural resources on Pohnpei and SIDS world-wide. For those SIDS where agroforestry remains an important component of livelihood systems, development strategies should emphasize using agroforestry as a foundation for agricultural development as opposed to introducing new agricultural systems that have yet to prove their ecological or economic sustainability and/or superiority. To achieve development goals for all members of an island's society, it is critical to tailor development strategies to specific livelihood systems.

CHAPTER 1
INTRODUCTION

Small Island Developing States

More than 50 countries and territories of the world come under the category of Small Island Developing States (SIDS), the majority being in Latin America/Caribbean (23) and Asia-Pacific (22). Although world-wide SIDS encompasses an area of roughly one-sixth of the planet (Food and Agriculture Organization [FAO], 1999) as a group, they have received relatively little attention within the development community until very recently. At the Earth Summit convened in 1992, the FAO first sponsored the Inter-Regional Conference of Small Island Countries on Sustainable Development and Environment in Agriculture, Forestry and Fisheries held in Barbados. The main outcome of this conference was the Barbados Declaration which marked the beginning of formal recognition for the need to formulate an integrated approach to the development of SIDS world-wide (FAO 2004).

With subsequent global meetings held in Barbados in 1994 (resulting in the Barbados Plan of Action for Small Island Developing States) and more recently regional meetings convened in the Pacific and Caribbean (1996), and finally in Mauritius in 2005 (resulting in Mauritius Declaration for Small Island Developing States) global awareness of the special needs associated with SIDS has arrived (United Nations 2005).

Typically defined as having a population of less than 1.5 million (United Nations, 2003) populations of SIDS range from as low as 10,000 (Tuvalu) to upwards of more than four million if including larger island nations such as Papua New Guinea (United Nations, 2003). In area, SIDS varies tremendously from Nauru consisting of only 13 km^2 to Papua New Guinea covering an area of almost 500,000 km^2. Demographically, SIDS are also diverse with many having

annual population growth rates above 2.5%, notably, the Solomon Islands, Vanuatu, Palau, Papua New Guinea in the Pacific region (United Nations, 2003).

Recent indicators of development of SIDS illustrate their diversity and that the majority of SIDS are within the extreme groups-either the poorer groups having a large agricultural sector, or the wealthier group having limited agriculture: between 7%-58% of SIDS' populations are involved in commercial agriculture with 67% of the total population of SIDS having incomes of less than $4,000 of GDP/cap calculated based on the purchase power parity (FAO, 2004).

While diverse in population and geographic scale, collectively, SIDS share characteristics that differentiate them from land-locked nations and that require special consideration for their development. Economically, SIDS have narrow and limited resource base that when combined with small domestic markets often prohibits realization of economies of scale. Due to the remoteness of many SIDS, they are frequently isolated from major markets leading to higher transaction costs associated with the importation of production inputs and/or export of goods produced locally, both of which impact potential profits. During the 1990s, these characteristics, combined with societal changes have contributed to SIDS, as a group, transitioning from being net exporters of agricultural products to net importers (FAO, 2005). Additionally, given their smallness and increasing dependence on imported goods, SIDS are increasingly subject to world market fluctuations increasing their vulnerability to outside forces. Size and remoteness constraining access to markets also limits demand for certain goods and services which in turn limits local employment opportunities.

Ecologically, many SIDS are located within the tropics and are vulnerable to natural disasters such as typhoons, and sea level rise resulting from global climate change (Intergovernmental Panel on Climate Change [IPCC], 2001). Given the drive for economic

development, natural resources and the ecosystem goods and services they provide are under constant threat of over-exploitation or out right destruction.

In the face of these challenges, SIDS must deal with increasing populations leading to further demands on already limited and fragile resources. The challenge for many SIDS, therefore, is to ensure that these resources are developed in a manner that meets the needs of current and future generations while minimizing detrimental effects to their natural resources and the health of an island's population.

Agroforestry as a Component of Agriculture in Small Island Developing States

Agriculture remains the single largest sector of many island states, often contributing substantially to local employment, income, food security, and a significant portion of foreign exchange earnings. As a result, agriculture is an essential component of overall economic development strategies for many of these island states (FAO 1994; United Nations Development Programme [UNDP], 1996). For SIDS, developing their agricultural sectors will entail the introduction of entirely new technologies, improving upon existing agricultural practices, or some combination of integrating new technologies into current practices. Additionally, government interventions through the establishment of public policies, infrastructure improvement or technical assistance are necessary to promote change. In many areas limited human and financial resources have hindered the ability of policy makers from having at their disposal adequate knowledge to guide sound policy development. Nonetheless, before programs to develop agricultural sectors are established, decision makers need to be informed of the value and contribution of existing agricultural systems and what role agriculture plays in the livelihoods of island populations. In the absence of information to develop acceptable alternatives, and without assurances that adopting incremental or new technological change will benefit farmers, farming households are likely to resist change. Moreover, in many cases,

technologies that are proven successful resulting from farm-trials may not actually be desirable by the farming household due to the lack of farmer participation and involvement in developing such technologies (Adesina and Coulibaly, 1998; Versteeg *et al*., 1998). In such circumstances, not only are scarce funds allocated for agricultural development squandered, often what trust exists between farmers and those promoting change is eroded further.

Agroforestry is an integrated land-use practice incorporating agricultural and tree components. Agroforestry is also an age-old practice in many countries world wide. During the last three decades, increasing research and development interest has been focused on agroforestry as a land-use option particularly in the tropics. The result of these efforts has drawn attention to the benefits of agroforestry including the production of multiple agricultural and tree crops; enhanced organic matter production and nutrient cycling rates (Rao *et al*., 1998); more efficient utilization of water and light (Black and Ong, 2000); enhanced crop productivity (Kid and Pimentel, 1992; Nair, 1993); better soil conservation (Pimentel and Wightman 1999; Khamzina *et al*., 2006); greater biodiversity conservation (Nair, 1993; Kumar and Nair, 2004); accelerated rates of carbon sequestration (Wang and Feng, 1995; Oelbermann *et al*., 2004) and greater sustainability (Sanchez, 1995). Increasingly, there is also a growing consensus that agricultural systems that more closely mimic natural ecosystems are more ecologically viable, providing for sustainable output of goods and services (Ewel, 1999; Lefroy *et al*., 1999).

While there have been significant strides in understanding the biophysical benefits of agroforestry, efforts towards understanding the socioeconomic benefits and role of public policy have been relatively small (Mercer and Miller, 1997; Nair, 1998; Sanchez, 1999; Franzel *et al*., 2001; Montambault and Alavalapati, 2005). More recently, there has been increasing awareness of the need to address socioeconomic aspects of agroforestry and the role of policy in order to

identify and promote agricultural technologies that are both economically viable and ecologically sound (Sullivan *et al*., 1991; Current *et al*., 1995; Sanchez, 1995; Nair, 1998; Alavalapti *et al*., 2004). Agroforestry is now recognized as being integral to meeting Millennium Development Goals (Garrity, 2004).

Agroforestry has been practiced in the Pacific for millennia, contributing, at one time to Pacific Islanders being among the most self-sufficient and well-nourished people in the world (Clarke and Thamen, 1993). Indigenous Pacific island agroforestry includes a tremendous diversity of food production systems, most of which have evolved in response to ecological, cultural, and socioeconomic changes through time (Thaman, 1975; Manner, 1981; Raynor, 1989; Raynor and Fownes, 1991a,b; Clarke and Thaman, 1993; Nair, 1993). Many of these systems have proven their stability, sustainability and substantial contribution to local food security (Thaman, 1975; Manner, 1981; Raynor, 1989; Raynor and Fownes, 1991a,b; Clarke and Thaman, 1993; Drew *et al*., 2005).

Not fully understanding the ecological and economic value of agroforestry in Pacific island settings has resulted in significant environmental damage and concomitant economic costs. In countries such as Tonga and the Cook Islands the promotion and adoption of intensive cash cropping systems comprising of melon (*Cucumis* spp.) and pineapple (*Ananas comosus*) production, have resulted in severe environmental degradation and losses of once productive natural resources (Storey and Murray, 2001). In Fiji, the drive for increased agricultural production through the establishment of monoculture plantations has led to extensive conversion of mangrove forests. Many of the systems that have replaced traditional agroforests are dependent on high energy inputs and mechanization that have proven to be uneconomical and biologically unsustainable (Asian Development Bank [ADB], 1992).

The lack of appreciation for existing agroforestry practices in the Pacific can be attributed to a lack of understanding about the important role that agroforestry practices currently play in food production, local economies, and ecological balance, or the potential of these systems for future agricultural development. Due to increasing population pressures, the drive for economic development and the detrimental impacts associated with climate change and sea level rise, there is an increasingly urgent need to determine the economic significance of current traditional agricultural technologies that have proven their ecological sustainability to prevent such occurrences from repeating themselves in other Pacific island settings. Moreover, understanding how agriculture fits within livelihood systems can increase the probability that agricultural development programs will achieve their desired objectives.

Study Objectives

The over all goal of this study is to obtain an understanding of the role and contribution of traditional agriculture to livelihoods residing on a Small Island Developing State located in the Western Pacific. A secondary goal of this study is to examine how potential policy scenarios influence cash income, use, and value of traditional crops for different segments of an island's population.

This study was guided by several research questions: (1) what is the economic value and contribution to household income derived from traditional agriculture? (2) How are traditional agricultural products used and what is the value per use? (3) How does market access and formal employment affect crop production, use and contribution to household income? (4) How does total household income based on an array of production activities differ for different segments (livelihood systems) of an island's population? (5) What are the potential impacts of policies on farmer profits and how are these profits influenced by incorporating values attributable to ecosystem services (soil stabilization and carbon sequestration)?

To achieve the above goals and answer guiding research questions, several specific objectives were established for this study, namely:

1. To quantify the productivity, use and value of traditional agricultural systems.
2. To determine significant predictors of the percentage of total household income derived from agriculture.
3. To quantify total household income for different segments of an island's population and model how those incomes would vary depending on pricing policies and market expansion scenarios.
4. To quantify private and social profits for agroforests allowing for the impacts of potential policies and market failures to be measured.

To address Objective 2 specifically, two hypotheses were tested: (1) that households having greater access to urban markets do not derive a greater percentage of total income than households located in more remote locales and (2) Households having at least one member formally employed outside the household do not derive a greater percentage of total income from agriculture than households not having any members formally employed.

The significance of this study is that it offers evidence of how important traditional agriculture/agroforestry is to a Small Island Developing State using Pohnpei as a case study. Many Small Island Developing States have chosen to replace traditional agricultural practices with "intensive" monoculture agricultural systems with the intent of filling niche export markets. Yet in many of these same States, the benefits of such changes have been short lived due to unstable market conditions, rapid deterioration of natural resources and/or natural disasters. Indeed, many of these same States (Tonga, for example) are attempting to reintroduce traditional agroforestry systems to address food security and a deterioration of limited natural resources (Wolff, 2001). Understanding the economic importance of traditional agriculture is necessary to justify policy decisions that may affect income opportunities and livelihoods more broadly. Understanding how traditional crops are used is important to more fully appreciate the multiple

ways in which agriculture is intertwined in island life and the potential tradeoffs between maintaining, modifying or replacing existing production systems. This research answers these questions. Additionally this research expands on the traditional Policy Analysis Matrix to include values associated with ecosystem services and thereby provides the means to more fully measure benefits and costs of agroforestry systems. Apart from contributing to the body of knowledge specific to Small Islands Developing States, this study contributes to the broader body of knowledge associated with the economic value and biological productivity of agroforests and specifically homegarden agroforestry systems of which is currently limited (Kumar and Nair 2004).

It is hoped that the results of this study will provide relevant information to help guide future development and management of Pohnpei's limited natural resources. Using Pohnpei as a case study, the results of this study may have useful application for other SIDs in other regions of the world seeking alternative livelihood strategies in support of economic development.

Presentation of Dissertation

This dissertation analyzes livelihoods and the role of agriculture on Pohnpei. What follows next is a chapter describing Pohnpei, the setting, followed by Chapter 3 which describes the research design and data collection methods employed for the research conducted. In Chapter 4, the analysis centers on the productivity, value and use of agriculture. The analysis first provides a descriptive statistics of households and agricultural production activities. Chapter 4 also examines the variation among households and agricultural activities with a specific focus on whether market access and wealth are influencing which crops and how much is being produced. Chapter 5 broadens the focus from agriculture to livelihood systems in order to better understand the role of agriculture within the broader context of households on Pohnpei using ethnographic linear programming. Chapter 6 examines the role of policy and market failures on agricultural

profitability using the Policy Analysis Matrix (PAM) framework. A second objective of Chapter 6 is to illustrate the potential of the PAM methodology to analyze multi-cropping systems and expand upon the tradition PAM model to incorporate non-market values to more fully account for the true costs and benefits of agroforestry systems. This dissertation closes with a brief concluding chapter reflecting on the findings, approaches used and their relevance to other Small Island Developing States. Additionally, the final chapter includes some comments regarding future research needs.

CHAPTER 2
RESEARCH SETTING

Geographic and Biophysical Setting

Located about three-quarters of the way from Hawaii to Indonesia, the Federated States of Micronesia is made up of more than 600 islands scattered across over 2.5 million square kilometers of water in the Pacific (Figure 2-1). Though the FSM claims an area of ocean two-fifths the size of the U.S. mainland, the islands themselves combined make up only 450 km^2 of land-about a quarter of the size of Rhode Island. Pohnpei is one of four states comprising of the Federated States of Micronesia. At 6^0 54'N latitude and 158^0 14'E longitude, Pohnpei is the second largest island in the Caroline Islands group with a land-base of 216 km^2. It is a high volcanic island having a steep mountainous interior region, the highest point being 772 m above sea level. Average annual rainfall is approximately 4,800 mm evenly distributed over 300 days of the year (National Oceanic Atmospheric Administration [NOAA], 1987).

In 1995, 15% of the island was covered by intact upland forests, with an additional 15% consisting of disturbed upland forests (ADB 1996). Traditional agricultural systems known on Pohnpei as agroforests covered 37% of the island, with coastal forests (16%) and secondary forests (12%) comprising much of the remainder of the island. Extensive mangrove forests and a fringing reef surround much of the island. In the lowlands, highly weathered Oxisols are the most common soils whereas Inceptisols are more commonly found in the interior and upland regions of the island (Laird, 1987).

Due to the relative age and isolation of Pohnpei, the upland forests are very rich in biodiversity with high levels of flora and fauna only found on Pohnpei. Thirty-four percent of the 767 plant species that have been recorded on Pohnpei are native to the island's upland forests (Merlin *et al*., 1992). One hundred and eleven plant species are endemic to the island and 90% of

these are found in upland forests. In addition, 16% of the island's 50 bird species are endemic to the island (Merlin *et al*., 1992). Pohnpei remains one of the most biologically diverse of any island in Micronesia (Merlin and Raynor, 2005).

Political Setting

Pohnpei is divided into five municipalities, with the island's main urban area of Kolonia located within the municipality of Nett (Figure 2-2). Pohnpei is also home to the capital of the Federated States of Micronesia, Palikir. The formal government structure resembles that of the United States at the national level consisting of judicial, legislative and executive branches. Like the U.S. system, most major governmental functions other than the conduct of foreign affairs and defense are carried out by the State governments. The State Government under their Constitution is structurally similar to that of the U.S. utilizing three branches as well. For each of the five municipalities, an elected Mayor governs.

Parallel to the formal government of Pohnpei is a traditional political entity ruled by district chiefdoms. Five traditional chiefdoms exist, one within each of the municipalities of Madolenhimw, U, Kitti, Nett, and Sokehs. Within the scheme of the district chiefdoms, the *kousapw*, or "village" is the primary socio-political unit comprising of a collection of farmsteads and ruled by a local chief or *soumas* (Dahl and Raynor, 1996). Each of the five kingdoms is governed by a Nanmwarki and Nahnken, the former serving as the paramount chief and the latter serving as chief advisor and liaison between the paramount chief and the community. Raynor (1991) describes the traditional chiefdoms in the following manner:

> …Both cheifships are hereditary, with succession based on matrilinity. These leaders exert administrative, judicial, and legislative powers by the authority of tradition, and through the control of a stock of titles. The lower people in each municipality are hierarchically organized by these ranked statuses or titles into a stratified society, although there are no distinct classes. The chiefs also function as the center of the prestige economy, based on complex rituals of redistribution of agricultural products…

Raynor (1991) goes on to note:

> The chiefs, through redistribution of agricultural tributes, continuously encourage the cycle of reciprocity. Subjects who continuously accumulate and increase their tributes are recognized by the chiefs through the bestowing of a higher title, thus encouraging continued participation in the traditional system among all subjects. Thus, the agroforestry system is intimately linked with the local cultural system…

Thus Pohnpei is politically dualistic, comprising of traditional chiefdoms having a significant influence over a prestige economy and a modern political system structured around a capitalistic economy. Over the last 15 years Pohnpei has rapidly developed as the most westernized state within the FSM. This is primarily a function of the national government's being located on Pohnpei, the urban town of Kolonia and the increasing travel taking place by Pohnpeaens between Pohnpei, the U.S. mainland, Hawaii and Guam. As the trend towards westernization continues the influence of traditional chiefs is thought to be eroding, particularly related to the production and use of crops for both ceremonial and commercial purposes.

Socioeconomic and Demographic Setting

From the early days of U.S. control just after World War II, rather than investing in Micronesia to develop the local economies of the island states, the U.S. had emphasized political development ensuring close political relationship between Micronesia and the U.S. (Peoples, 1985). While the FSM has achieved a form of sovereignty through Free Association with the U.S, its economy has remained almost entirely dependent on U.S. aid.

In 1986, the Federated States of Micronesia entered into a 15-year Compact of Free Association with the U.S., which guaranteed payments of approximately $1.5 billion in exchange for exclusive military access to the area's waterways (Osman, 1995). Just under 60% of these funds were spent in support of the day-to day operations of the national and state governments primarily through the development of a large civil servant workforce (Osman, 1995; United States Department of Interior 2004). The Compact also provided the means for residents of the

FSM to travel and work freely within the U.S and its territories creating opportunities for employment and educational outside of the FSM to be realized more easily. The first Compact also provided for the renegotiation of certain terms of the agreement after a fixed period be conducted in support of the establishment of a second Compact agreement (Compact II). The renegotiation for Compact II formally began in 2003. In 2004 Compact II was ratified by all four states and approved by the by the United States. While much of the components of Compact I were carried over into the Compact II agreement, one of the major changes of the renegotiations was an overall reduction of overseas funds to the FSM. Compact II will provide decreasing payments to the National and State governments through 2023. Beginning in 2023, direct payments from the United States will cease and the FSM will become reliant on the interest from a Development Fund created as another component of the Compact II renegotiations. However, for both the National and State governments, these payments will decline during the 20 year Compact period with the objective of slowly encouraging the FSM to become self-reliant by developing its economy and securing other sources of funds as the Compact comes to a close.

Osman (1989) presents the results of Compact I succinctly:

> Since the U.S. has delivered a steady flow of economic assistance to the FSM over the last four decades, the distribution of the aid and its utilization have become government's predominant business. As a result, there is no primary production economy to speak of in the FSM, at least for which reliable data exist. A subsistence production economy that was fairly self-sufficient decades ago has been almost completely replaced by one that is now almost entirely dependent on imports. In other words, U.S. funds are the only real source of income.

Of all pre-Compact economic activities, agriculture has probably been affected the most. With an already stagnated private sector, new employment not only provided opportunities to earn relatively high wages[1] it also reduced the reliance on subsistence agriculture. Continued

[1] Compared with the private sector, public sector salaries are between 1.5 and 2 times that of comparable private sector positions (Government of the Federated States of Micronesia, 2002).

decline of Compact funds will result in a further reduction of public sector employment. One impact of such a reduction will likely be a more concerted effort to develop a more commercially oriented agricultural sector.

The population of Pohnpei in 2000 was 34,400 people and is estimated to increase to over 48,600 by 2014 (Office of the Governor, 1996; Government of the Federated States of Micronesia, 2002). Pohnpei has one of the highest population densities in the Pacific, estimated to be just over 160 persons km^2 (Government of the Federated States of Micronesia, 2002). The age distribution is heavily skewed to younger ages with over 50% of the total population under the age of 25 (Government of the Federated States of Micronesia, 2002).

In 1994, 72% of the working labor force was employed in the formal sector (51% in the public sector), and the remaining 28% worked in the informal sector that include agriculture, fishing, and subsistence activities (Office of the Governor, 1996). During the period between 1994 and 2000, the percentage involved in the formal work force had declined to only 52% with 48% engaged in informal activities coinciding with the final step down in Compact I funding (Government of the Federated States of Micronesia, 2002). Indicative of the effects of declining Compact funding and a stagnating private sector, in 2000, the median household income was $6,609, down from $8,039 in 1994.

Agricultural Setting

Agroforestry on Pohnpei

Agriculture has been an important part of life on Pohnpei for centuries and remains so today. Agroforestry has been practiced for centuries on Pohnpei (Huan, 1984) and was the predominant land use activity at the time of this research (ADB, 1996). Traditionally, almost all production, be it for subsistence, local market, or export is by family units using localized agroforestry systems, providing employment, food security, and income while maintaining the

cultural and ecological integrity of the island and its population (Raynor, 1991). Over time, numerous crops have been introduced through continued waves of migration, and more recently, through the efforts of colonial administrations (Barrau, 1961; Ragone *et al*., 2001). Homegardens are the most common form of agroforestry on Pohnpei. Homegardens incorporate multipurpose trees and shrubs in intimate association with annual and perennial crops, and often domestic animals, adjacent to homes (Fernandes and Nair, 1985; Raynor, 1989; Falanruw, 1993; Kumar and Nair, 2004).

Pohnpei, like many other Pacific islands, is at a crossroads whereby traditional norms are changing to more western oriented desires, particularly desires for increasing material wealth. Whereas only two decades ago, prestige was largely defined by village members who provided the largest and rarest variety of traditional crops such as yams to the local chiefdom, today where possible, these crops are being sold to purchase cars, televisions, and CD players. Moreover, with close to 60% of the population under the age of 25 and very limited employment opportunities in the formal economy (Government of the Federated States of Micronesia, 2002), Pohnpeaens are searching for alternative ways to accommodate their changing lifestyles. It has yet to be seen how the dynamic situation will ultimately affect Pohnpei. For the present time these changes are leading to increasing pressure to intensify (or in some cases replace) current agricultural practices in ways that may not be suitable to Pohnpei's ecological, social, cultural, or economic setting (Kostka and Raynor, 2000). Given the long history of agriculture on Pohnpei and the uncertainties about its economic prospects, future developments of Pohnpei's agricultural sector should be based on a more informed understanding of agriculture's current role and how future development strategies may influence farmer decisions (Pohnpei Office of Agriculture and Forestry, 1996).

A stated objective of the national and state governments is to promote import substitution policies to reduce dependence on imported food and increase household incomes (Office of the Governor, 1996; Government of the Federated States of Micronesia, 1999). Yet specific strategies have not been identified, largely due to the lack of baseline data about the production and economic value and use of existing agricultural systems for which comparisons can be measured.

Crops and Pohnpei's Agroforests

Locally produced indigenous food crops cultivated within agroforests dominate Pohnpei's agricultural sector. Traditionally, almost all production, be it for subsistence, or commercial purposes, is by family units using localized agroforestry practices, providing employment, food security, and income while maintaining the cultural and ecological integrity of the island's resources (Raynor, 1991).

Species common to these systems include in the upper main canopy coconuts *(Cocus nucifera)* and breadfruit *(Artocarpus altilis.* Ylang-ylang *(Cananga odorata)* and yams *(Dioscorea* spp.*)* are both common in between the main canopy and sub-canopy layers. Within the sub-canopy bananas and plantains (*Musa* spp.), hibiscus (*Hibiscus tiliaceus*), Indian Mulberry (*Morinda citrifolia*), yam vines (*Dioscorea* spp.), and soursop (*Annona muricata*) dominate planting activities. Below 2.5 meters, sakau *(Piper methysticum)* is very common in addition to root crops such as wild taro (*Alocasia macrorrhiza*), sweet taro, (*Colocasia esculenta*) and swamp taro (*Cyrtosperma chamissonis*) (Raynor and Fownes, 1991a,b).

Although homegarden practices are the most prominent land use on Pohnpei, they are not the only type of agroforests. Other lands located in the lowlands, that may or may not be in close proximity to homegardens, are also cultivated. Many of these lands are comprised of some or all of the crops produced in homegardens although they are often not as intensively farmed.

Additionally, households may cultivate crops in the highlands, or on lands that are owned, provided access to or that are found within the State's jurisdiction and are being cultivated illegally. In those lands being cultivated in the highlands or under the State's jurisdiction, the primary crop being produced is sakau. However, in some cases households are producing some of the same crops being produced in homegardens and other lowland agroforests in highlands as well.

Pohnpeaens recognize two major seasons based primarily on breadfruit and yams, traditionally the two most important staple foods. The breadfruit season most often falls between April and ends in the fall. The breadfruit season is recognized as being the "lazy time" because many of the tree crops used by humans for one use or another receive little care and attention other than just harvesting their fruits. In contrast, the yam season, coinciding with the ending of the breadfruit season is generally when bananas, taros and yams are harvested requiring more labor inputs. It is the traditional chiefs on Pohnpei that decide when a crop season begins and ends, signified by large feasts and driven in large part by the natural production of breadfruit (Raynor, 1991). Sakau is grown and harvested year round. Sakau combined with breadfruit and yams are considered the three most important crops for ceremonial purposes.

There is very limited production of crops more recently introduced for commercial purposes on Pohnpei. Of the more recently introduced cash crops, the most common are cucumbers (*Cucumis sativus*), cabbage (*Brassica* spp.), bell peppers (*Capsicum* spp.) and to a lesser extent black pepper (*Pepper nigrum*). Most commonly these crops are produced in small quantities in and around homegardens.

Within the traditional or prestige economy agricultural crops, yams (*Dioscorea* spp.), and sakau[2] (*Piper methysticum)* in particular, have played an important role in food security, maintenance of the availability of diverse cultivars and social status (Raynor, 1991; Barrau, 1961). However since the beginning of Compact funding, there has been increasing levels of imported food goods as Pohnpeaens have become increasingly accustomed to the convenience of cooking processed foods (dominated by imported rice), and more western appetites. Pohnpei remains a net importer of goods, dominated by importation of foods and beverages.

Reliable estimates of the annual economic value of all agricultural products produced on Pohnpei are few. Available estimates state that in 1996, the agricultural sector was responsible for approximately 9% of Pohnpei's gross domestic product while other sectors including wholesale and retail trade (30%), government services (30%) and transportation, storage and communications (9%) made up the majority of the remaining GDP during the same year (Pohnpei Statistical Office, 1998). One of the primary objectives of this study was to provide updated and reliable data pertaining to the production of crops being used for both commercial and subsistence activities within Pohnpei's agricultural sector.

[2] Sakau, is also known throughout the Pacific as kava, kava kava, and yogona. Sakau is in the Piperaceae family. Sakau is a mind altering beverage and its preparations has been and remains today, imbibed in a wide range of tropical Pacific societies (Lebot, 1992)

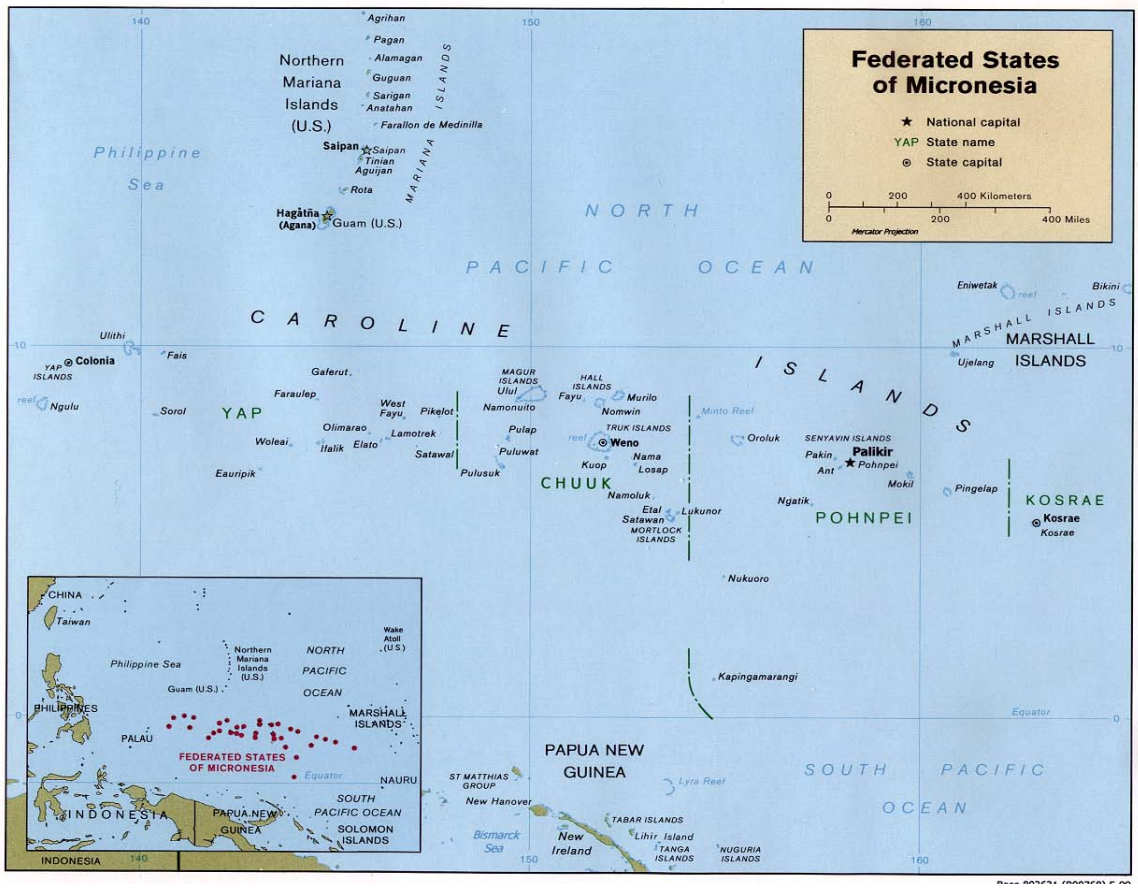

Figure 2-1. Location of Pohnpei, Federated States of Micronesia (Source: http://www.lib.utexas.edu/maps/islands_oceans_poles/micronesia_pol99.jpg)

Figure 2-2. Municipalities of Pohnpei, Federated States of Micronesia (Source: http://upload.wikimedia.org/wikipedia/commons/e/eb/Pohnpei_map.gif)

CHAPTER 3
RESEARCH DESIGN AND DATA COLLECTION

Research Design

The author had spent close to six months conducting research centered on resource use on Kosrae, another of the four main island states of the Federated States of Micronesia. As a result, prior to arriving on Pohnpei, the author had established working contacts with personnel from within the National and State governments, Pohnpei's Forestry and Agricultural Extension offices, The Nature Conservancy (TNC) and from the Ponape Agricultural & Trade School. Upon arrival on Pohnpei, the author met on several occasion with these established contacts to discuss the objectives of the proposed research. Consultations with residents on Pohnpei also provided relevant guidance on appropriate strategies to consider during the administration of a questionnaire and further data collection proposed over a 12 month period. Additional meetings were held with village members to communicate the purpose of the research and to informally measure the willingness of participants to participate in the research project.

Following multiple meetings and discussions with officials, TNC staff, and several community members, as well as informally spending significant time with members of different villages, a draft household questionnaire form was developed and tested (administered) among those who had participated in prior meetings. In response to feedback resulting from the administering of the first iteration of the questionnaire, two more versions were tested before a final household survey was considered acceptable by the author and those who might be participating in the research project. A parallel process was followed in order to establish forms needed for the collection of data relative to agricultural and fishing activities. The household questionnaire was created in English, however the agricultural and fishing activities forms, while

initially created in English, was converted to the Pohnpeaen language by TNC and Agricultural Extension staff.

Based on many discussions with established contacts, it was determined that having someone who lived and was respected in the municipality of Nett would be necessary to (1) have a local point of contact that served to appease any suspicions about the research being conducted, (2) bridge any cultural gap there might have been and (3) provide continued feedback into how the research was progressing and how best to work with and among household members in Nett. As a result, additional funding was pursued and granted by The Nature Conservancy to hire a part-time assistant who in turn was intimately involved with all aspects of data collection in Nett. This was less of a concern for Madolenhimw because this was where the author lived and had already established relationships with community members prior to or very early on during the initial field research activities.

The household questionnaire was structured into three main sections (Appendix A). The first section centered on demographics of each household. Demographic information was needed in order to determine household composition, age of participant etc. in order to more accurately characterize participating households. The second portion of the questionnaire centered on availability and use of resources other than labor, in order to determine the number of lands and area available for household use in addition to information relative to farming practices, e.g., use of fertilizers and/or other production inputs. The last section of the questionnaire centered on economic aspects of each household to document employment activities, amounts and sources of cash income and household expenses. Data from all three sections were used to quantitatively determine dependent and independent variable enabling regression analysis to be conducted. Additionally, data from the questionnaire were critical to determine unique livelihood systems

that in turn provided the basis for analysis of such systems using ethnographic linear programming. Approval of the final survey forms by the Internal Review Board at the University of Florida was sought and obtained.

To answer whether or not formal employment and access to markets were significant predictors of agricultural production, value, and income, a stratified random sample design was established with four strata: (1) households located close to market center (2) households located far from market center (3) households having at least one member formally employed and (4) households having no members formally employed. These strata along with other independent variables were used to conduct regression analysis to test the two hypotheses. To determine if market access was influencing agricultural activities, two municipalities, Nett and Madolenhimw, were chosen for this research[1]. Nett is located adjacent and very accessible to Kolonia, Pohnpei's (and that of the FSM) only urban center and where most of the island's commerce takes place (Figure 2-2). In contrast, Madolenhimw, separated by the municipality of U, is located to the SE of Nett at about an hour's driving distance from Nett.

To determine which households were selected to participate in this study, first of all, within each of the two municipalities, 19 villages were randomly selected. The next step was to meet with the chiefs from the selected villages to discuss the purpose of the research and to obtain permission to engage household members from their village in the research study. Once permission for a meeting was granted, the village chief provided a list of all the households, delineated by those having at least one member within each of the household earning a full-time

[1] Referring to Figure 2-2, it can be seen that there are only six municipalities comprising of Pohnpei with Nett containing Kolonia, the central urban area of the island. Both Kitti and Madolenhimw are furthest from Nett. In order to develop as much rapport with each of the participating households, the fact that the author was living in Madolenhimw and due to limited resources, Nett only one additional municipality (Madolenhimw) were chosen as the municipalities to include in this research.

wage (hereafter referred to as "formally employed") or not. These lists provided the basis to randomly select households, stratified by proximity to Pohnpei's market center of Kolonia and employment status (households within both Nett and Madolenhimw stratified by employment status). Households were then randomly selected and approached to ask if the families were interested and willing to participate in the research. Initially there were over 50 participating households; 33 were completed for the study (Table 3-1).

Methods of Data Collection

Each of the participating households was administered the questionnaire. After completing the questionnaire, participants were asked again if they would still be interested and willing to record information relative to their agricultural and fishery activities. For households interested in participating, a weight scale, clip board, pens and record forms, were provided to heads of households. Members from each household recorded the hours spent working on agriculture, what was harvested and how much, and how harvested crops were used (Appendix B contains the record form). The use categories included cash income, household consumption, ceremonial activities, and for extended family and friends. Cash income was determined based on how much of any given crop was sold either to markets, sold locally at family owned and run road side markets and/or directly to other village members. Consumption use was defined as the amount of a given crop consumed within the household and/or used to feed animals. Ceremonial use was considered to be the amount of crops used in both traditional celebrations such as seasonal feasts signifying the beginning or end of breadfruit and yam seasons, tribute to traditional leaders, the granting of traditional titles of prestige, religious ceremonies, funerals, weddings and childbirths as well as more contemporary celebrations such as school graduations and athletic events. Finally, use for extended family and friends was considered to be crops given to family members and friends residing in households other than the participating households themselves.

Agriculture production was recorded either by weight or by number depending on how it was transacted in the local markets and those received by farmers themselves. The size of lands used for agriculture was determined by responses of heads of households. In those instances when heads of households were not exactly sure of the size of lands, estimates were derived based on using known landmarks as proxies e.g., local soccer fields, meeting locations, churchs, etc. Fishing activity was also recorded but limited to the number of hours fished, total catch and total sold. To ensure record forms were being filled out correctly weekly visits to each of the households were carried out. Prices used to determine values of agricultural crops and fish harvested were based on the average prices observed in local markets. Data were collected over a period of 12 months during 2002-2003. Data collected during the field research were then transferred into a database to allow for descriptive statistics, regression analysis (Chapter 4) to be conducted and linear programming model simulations (Chapter 5) to be completed. Additionally, data incorporated into the database were used to conduct an analysis comparing private and social profitability's using the Policy Analysis Matrix methodology (Chapter 6).

Throughout the duration of the field research, there was a continued and conscious effort to spend as much time as possible visiting friends and families participating in the research itself with the aim of learning as much as possible about the various livelihoods of Pohnpeaens. Whether spending time helping to prepare for ceremonial activities such as seasonal feasts, attending funerals, church, or other activities, doing so provided a much more robust opportunity to observe first-hand life on Pohnpei. As importantly, it provided an opportunity to build rapport with household members that were involved with this research.

Table 3-1. Employment status of households participating in the survey in the two municipalities of FSM

Municipality	Employed	No Employment	Total
Nett	11	4	15
Madolenhimw	7	11	18
Total	18	15	33

CHAPTER 4
PRODUCTION, USE AND VALUE OF POHNPEI'S AGROFORESTS

Introduction

As Pohnpei moves forward and attempts to develop its agricultural sector, the efficient use of scarce resources will require that proscribed programs have the highest probability for success. Understanding current agricultural activities provides a baseline in which to measure against potential change. Moreover, determining the relative dependence on agriculture can help determine whether there are variations in current practices between different segments of a population and in doing so can help sharpen the focus on which types of programs might most effectively achieve success.

For over a century, researchers have been interested in determining the potential variation in agricultural systems and the driving forces behind any such variation. For example, Von Thu¨nen (1826) was interested in determining if spatial distances from agricultural markets had any significant influence on the intensity of agricultural systems. His theory was that intensity was inversely related to distance to market because the greater the distance, the lower the profits resulting from higher transportation costs for farmers living further from markets (Symons, 1978; Visser, 1980). Others have also drawn attention to the potential role that infrastructure and market access may play in the adoption of agricultural systems and the use of crops because they broaden the opportunities for the adoption of new technologies and crops leading to changes in agricultural systems themselves (Allan, 1986; Turkelboom *et al*., 1996; Reardon *et al*., 2001). In the case of Pohnpei and prior to this study, it had yet to be determined whether the relative proximity to markets has any influence on the types of crops being produced. Moreover it had yet to be determined whether market access influences the use of crops produced within agroforests are used for different purposes, and specifically for cash income.

Population density has also been identified as a major influencing factor on agricultural systems. Boserup (1965) theorized that as populations increased, land scarcity increased leading to gradual intensification and changes in the use of agricultural systems. An example of this trend is the shift from swidden agriculture having long fallow periods to annual cropping systems as population densities and land scarcity increase. A counter argument to Boserup might be that population density-as measured by the number of members per household-may actually result in increased amounts of available labor to farm and produce additional crops. Moreover, households having more land-less scarcity-provide greater opportunities to utilize larger areas for agricultural purposes, once again, providing the means to produce and use a greater quantity of crops. At what point does population density and land scarcity trigger transformation of agricultural practices is a question that is very likely site specific given available resources, local cultures and the relative dependence on agriculture to meet livelihood objectives. With increasing populations and with more and more families on Pohnpei needing land to farm, it has yet to be determined whether population densities and the scarcity of land are influencing agroforestry practices and the relative dependence on agroforests for their livelihoods. Of particular interest to this research is examining whether population density and land scarcity as measured by the number of members per household (density) and the amount of land available to a given household (scarcity) has any statistically significant influence on the relative dependence on agriculture for household income.

Pohnpei's dualistic economy provides a unique opportunity to examine how the process of monetization may be influencing agricultural activities. Throughout the pacific (Brookfield, 1972: Clarke and Thamen, 1993; Powell, 1997), and in Micronesia in particular (Barrau, 1961; Bascom, 1963), production of crops for ritual and ceremonial purposes has been noted as an

important component of livelihood activities. As a result of participating in these types of activities, islanders not only are able to receive tangible goods through reciprocity of agricultural crops, greater social status among communities may also be achieved. Yet there are opportunity costs associated with using products of economic value for one purpose versus another e.g., for prestige versus cash. Indeed, one can speculate that as cash income and material wealth become more highly valued relative to traditional gains, a greater emphasis on pursuing whatever means possible to achieve such wealth will come at the expense of traditional activities.

In addition to the ideas discussed above, another topic having relevance to this study deals with economic development itself and the theory of structural transformation. Structural transformation is a process by which the contribution of nonagricultural sectors to an overall economy rises as the agriculture sector's role declines in relative terms (Johnston, 1970). The inference at the household level is that as households become more actively engaged in activities outside of the agricultural sector for economic purposes, the relative dependence on agriculture declines. Whether at the household or larger economy-wide scale, in those areas that have not become entirely industrialized, agriculture remains an important contributor to economic activity but on a relative scale.

As Pohnpei continues its pursuit of economic development, in what capacity agriculture might contribute to such development is uncertain. Is Pohnpei in the midst of a structural transformation and if so, where along the process does Pohnpei stand vis a vis the relationship between agriculture and other economic activities and their relative contribution to household incomes?

Based on the discussed above, the objectives of this chapter is to (1) quantify the production, use and value of agroforests on Pohnpei at the household level and then scaling up

the analysis to determine these same values at the island-wide level and (2) to determine whether market access, number of household members, available land area, ceremonial use of crops and formal employment are statistically significant explanatory variables of the percentage of total household income derived from agriculture. What follows is first the methods used for this chapter's analyses followed by the results that include descriptive statistics of households involved in this study, the productivity and use of agricultural crops, and economic contribution of agriculture at the household and island-wide scales. The Results section also presents findings based on regression analysis of explanatory variables explaining the percentage of total household income from the sale of crops. The Chapter concludes with a section comprising of discussion of the results and their possible implications for the development of Pohnpei's agricultural sector.

Methods of Analysis

The data provided for the descriptive statistical analysis were derived from those data collected as described in Chapter 3. Descriptive statistics presented here include the mean values for household demographics, land ownership, crop production, crop value and crop use. These data provide the basis to determine the value of agroforestry products and their use, based on production levels and market prices observed during the duration of the field research activities. As described in Chapter 3, the research design was a stratified random sample to assess the potential influence of market access and income on the productivity, use and value of agroforests, using the variations in agricultural activities between households in the municipalities of Nett and Madolenhimw, and between households having at least one member formally employed as the indicators of these parameters to assess.

Correlation analysis was conducted to test for multicolinearity and to determine whether positive or negative relationships existed between explanatory variables. Additionally,

independent Sample T-tests were conducted to assess if significant differences existed between the four strata. Finally a linear regression model was developed in order to determine significant predictors of the contribution of agriculture to household incomes. Backward elimination regression method was used to determine the most significant model based on five explanatory variables. This method begins with fitting the regression model with all of the explanatory variables and eliminates variables one at a time until the best-fit is found.

Regression Model

To assess the influence of the various theories discussed above and the influence of the prestige economy on total cash income, the regression model comprised of the following variables. The dependent variable used was the percentage of total income derived from the sale of agricultural crops (PINCAG). This variable helps to explain the relative dependence on agriculture for cash income. Presumably, if other opportunities for income generation such as formal employment change so too would the relative dependence on other income earning activities e.g., commercial agriculture.

The explanatory variables used in this model include:

- Relative access to market (MKACES). A dummy variable was assigned to households in Nett (1) and for households situated in Madolenhimw (0). Nett is situated adjacent to Kolonia, Pohnpei's only urban center and where most commercial activity on the island is located. Therefore, it was expected that because of the advantage of having market(s) nearby, households in Nett would have a greater opportunity to sell crops and therefore, *ceteris paribus*, those households would derive a greater percentage of income from agriculture. Moreover, in addition to having to drive up to an hour to reach Kolonia, households in Madolenhimw have more limited information about market demands for crops and as a result, may be more risk averse, choosing not to go into Kolonia to sell crops.

- Total number of persons residing in the household (NHHMEM). Given already limited opportunities for formal employment, the increasing number of people to feed and financially support as well as the available agricultural labor, it was expected that there would be a positive relationship between NHHMEM and the dependence on agriculture for cash income.

- Total available land in hectares (TOTLND). With increasing land area available to farm, it would be expected that more crops could be produced and used for cash income purposes. Therefore, a positive relationship between TOTLND and PINCAG would be expected.

- Percent of crop value for ceremonial activities (PERCER). It was expected there would be an inverse relationship between the percentage of total crop value resulting from selling and ceremonial use of crops. With a greater percentage of crop value being used for ceremonial activities, there would be a declining percentage of crop value for cash earning purposes.

- Households having at least one member formally employed full-time (EMPLOY). A dummy variable was assigned to households having at least one member employed full-time (1) and for those that do not (0). Those households having at least one member formally employed will have a more steady and reliable source of income and therefore will not necessarily be as dependent on agriculture to meet cash income needs. It is expected that there would be a negative relationship between EMPLOY and the percentage of total income from agriculture.

The full equation to estimate the percentage of total income derived from agriculture is:

$$\text{PINCAG} = \alpha + B_1\,(\text{MKACES}) + B_2\,(\text{EMPLOY}) + B_3\,(\text{NHHMEM}) + B_4\,(\text{TOTLND}) + B_5\,(\text{PERCER})$$

Results

Household Characteristics

The average age of head of household was 47 years and the average age of households where homegardens were located was 29 years. The average household had 10 members, five adults and five children under the age of 18 years. Forty-six percent of the households had at least one member having graduated from high school. On Pohnpei, there is a community college providing opportunities for higher education. Nonetheless, only 21% of households had any member that had at least some university level education.

With the signing of Compact I, Micronesians were provided the freedom to travel and work in the U.S. and its territories. As a result, many of the households (64%) had at least one immediate family member residing off-island (an average of 1.6 persons per household), the majority of which were residing in Hawaii and the U.S. mainland. Forty-five percent of

households were receiving an average of $106 per month in remittances from family members residing outside of Pohnpei.

Households on Pohnpei employ diverse strategies for generating income. Sixty-four percent of all households generated at least some income from three or more different sources, 24% from only two sources and only 12% depended on only once income source. In addition to formal employment, some household members are involved in commercial agriculture (88%), fishing (42%) receive remittances (46%) or collect social security (20%) as a means to acquire cash income. Seventy-nine percent of households having at least one member formally employed considered employment as the most important source of income, primarily due to the insecurity of their employment status. Comparatively, for those households not having any formal employment, 59% noted agriculture, 12% noted fishing and 18% noted Social Security or other retirement pensions as their most important source of income.

Household Crop Production

All the households participating in this research had members that owned at least one parcel of land, with 40% owning only one, 37% owning two and 23% owning three or more. On Pohnpei, land may be granted for use by extended family members providing additional areas for crop cultivation. Thus, although only 23% of households owned three or more parcels, 48% had access to at least three land parcels. However, access doesn't necessarily reflect actual use. Only 21% of households were cultivating three land parcels compared to 64% cultivating two; 100% of the participating households were cultivating at least one land parcel, their homegarden.

One hundred percent of households were cultivating multiple crops within their homegardens including sakau (94%), yams (97%), breadfruit (94%), swamp taro (85%), coconuts (100%), betel nut (64%) and bananas (100%). There were no households that produced crops exclusively on lands other than their homegardens. Moreover, with the exception of sakau,

the majority of all crops are produced within homeagardens (Table 4-1). All participating households stated that their agroforests were currently producing enough food crops for household consumption needs.

Within the homegardens, bananas are produced in the greatest quantity by weight (689 kg yr^{-1}) followed by breadfruit (387 kg yr^{-1}) and swamp taro (196 kg yr^{-1}) being produced in the smallest amounts. However, when crops produced on all lands are combined, sakau is harvested in the greatest quantity (1106 kg yr^{-1}). In terms of absolute numbers, betel nut is produced in far greater quantity (but by fewer households), relative to coconuts, the only other crop sold by piece as opposed to weight. Households in Nett produced significantly more swamp taro ($P<0.1$) relative to households in Madolenhimw, most likely due to the prevalence of freshwater wetlands in Nett. There were no significant differences in production of any crops between households having and not having at least one member employed.

Household Crop Use

Each of the participating households was asked to record how each of the crops were being used, either by weight or number. The use categories were broken down by whether crops were used for cash income, traditional ceremonial purposes, provided to extended family and friends or used within the household (consumption by either household members or animals). Although 100% of participating households producing some or all crops used them for more than one activity, the percentage of households per activity varied based on the particular crop in question. For those households that produced a given crop, the majority of them utilized at least some the total harvest for ceremonial activities ranging from 90% of households producing sakau down to only 12% of households producing betel nut (Table 4-2). Eighty five percent of all households sold at least some of the crops harvested.

The majority of these households sold at least some bananas (64%) and sakau (58%). More than 90% of all households producing any crop consumed at least a portion of the total harvested. As a whole, the number of households that provided crops to friends and extended family members was low.

While the percentage of households using crops for a particular use is informative, the percentage of each crop produced by households used for each activity sheds light on relative importance of each activity to households on Pohnpei. The three main crops used for ceremonial purposes by quantity are yam (42%), sakau (24%) and breadfruit (18%) respectively. Although 90% of households use sakau for ceremonial purposes only 24% of the amount of sakau produced is used for ceremonial activities (Table 4-3). On the other hand, of the 81% of households using yams for ceremonial activities close to half of all yam production by the same households is used exclusively for this purpose.

Relatively little of each crop produced by a household is used for cash income, the exception being betel nut (61%) and sakau (39%). In contrast, the majority of crops are consumed within the household ranging from a high of 91% of coconuts, down to only 25% of betel nut. Although a relatively large percentage of households provides each of the crops produced to friends and extended family, the actual quantity is low relative to other uses (Table 4-3). Households in Nett were consuming significantly more swamp taro ($P<.05$) compared to those in Madolenhimw. Additionally, households having one member employed sold significantly more swamp taro ($P<.05$) than those that do not. But for these two exceptions, there were no significant differences in crop use between households in Nett and Madolenhimw or depending on employment status of the households.

Household Value of Crops

For homegarden-produced crops, the economic value varied from a high of \$575 yr^{-1} for sakau and a low of \$85 yr^{-1} for breadfruit per household in 2002 (Table 4-4).

Although the economic value is greatest for sakau, both yams and betel nuts have household values over \$500 yr^{-1} indicating that there was no dramatic difference between the values of these three crops produced in homegardens. Considering the economic value of crops produced on all lands, the order of crop values remained the same as crops produced solely in homegardens, yet the value of sakau (\$2,434 yr^{-1}) was four-fold more than that of any other crop .

Homegardens alone provided goods valued at just over \$2000 yr^{-1}. When the values for all crops being produced on all lands used were combined, the average value of agriculture per household was just over \$4,000 yr^{-1}. In 1999 at the time of the last census, annual median household income on Pohnpei was \$6,354. Thus, the estimated total value of agriculture based on the seven crops considered in this research was equivalent to 67% of median household income. Households engaged in selling agricultural crops generated almost \$1,600 in cash annually representing 24% of median household income (Table 4-5). Sakau and betel nut sales alone explain more than 90% of the source of cash income from commercial agriculture.

The total average household consumption value was very close to average cash income primarily due to the large contribution of income from selling sakau. With the exception of sakau and betel nut, all crops had a greater value associated with household consumption relative to other uses.

Island-wide Value of Crops Produced Within Pohnpei's Agroforests

Using household values determined in this research and multiplying them by the total number of households on Pohnpei it becomes possible to calculate the total economic importance

of Pohnpei's agricultural sector. Homegardens alone are valued at more than $8 million per year with sakau having the greatest total value of all crops considered (Table 4-6). When all lands are combined, the total value of agroforests almost doubled to nearly $16 million.

Island Wide Value by Use

In terms of the total value of crops and their use, sakau holds the highest value regardless of how it is used (Table 4-7). On the other hand, coconuts used for ceremonial purposes have the lowest value ($614). In terms of the largest value per use, household consumption of agricultural crops on Pohnpei was valued at just over $7 million per year. Based on a population of 34,000, the seven agricultural crops included in this study have a consumption value worth $208 per year per person on the island.

Second behind consumption value is cash income valued at just under $5 million yr $^{-1}$; ceremonial use was valued at close to $3 million yr $^{-1}$ and friends and extended family use at more than $1 million yr $^{-1}$. Combining all use values, production of the seven crops included in this study had a total annual approximating 8% of the GDP for all of the Federated States of Micronesia. This value equates to just below 18% of Pohnpei's GDP during 2001 when this research was conducted. Based on the census conducted in 2000, the total value of these seven crops on Pohnpei equates to approximately 50% of total annual household cash income.

Regression Results

Based on the correlation results (Table 4-8), there is not a concern for multicolinearity given that none of the explanatory variables were strongly correlated with each other (Table 4-8).

Results of the initial and final regression models are provided in Tables 4-9 and 4-10 respectively. The results confirm expected positive or negative relationships between the explanatory variables and the percentage of total income from agriculture. Households having greater market access, more members and more total land area available to them were positively

correlated to the percentage of income from agriculture. On the other hand, employment and the use of crops for ceremonial purpose both negatively affect the percentage of income from agriculture.

The final model consisted of only market access and employment as significant explanatory variables ($F = 8.285$; $df = 31$; $P < .001$). The number of household members and thus presumably available labor does not significantly influence the total proportion of income due to crop sales. Nor does having more or less land available for agriculture or the percentage of crops for ceremonial purposes significantly influence relative income levels. Thus of all of the explanatory variables only households having greater market access ($P < 0.05$) and those having at least one member employed ($P < 0.001$) are significant predictors of the total percentage of income derived from agriculture on Pohnpei ($N = 33$). The final model explains 36% of the percentage of total household income that is derived from agriculture.

Both of the significant explanatory variables (defined as $P < 0.05$ or $P < 0.001$) in the model are discrete. Because of this it is difficult extrapolating the model to predict percentage of total income from agriculture. Thus the model proves very useful in determining which of the explanatory variables are most significant, their positive or negative relationship to the dependent variable and the relative contribution of the explanatory variables in explaining the percentage of total income coming from agriculture. However, the model is not as useful as a means to predict the percentage of total income from agriculture.

Given the shortfall of using the model coefficients, a two by two contingency table was constructed to show the mean values of each of the four scenarios based on the two significant explanatory variables (Table 4-11). Regardless of relative proximity to markets, households having formal employment are deriving only between 7% and 12% of their income from

commercial agriculture. Households in Nett and particularly those not having formal means of employment (Table 4-11-Quad 2) are most heavily dependent on agriculture as their primary means for cash income.

Although not significantly different (at $P<.05$), households with more limited access to markets and without any formal means of employment (Table 4.11-Quad 1) depend on commercial agriculture for cash income more than households with formal employment regardless of proximity to markets (Table 4-11-Quads 3 & 4). Those households with formal employment and in more remote locales depend on commercial agriculture for cash income the least of all four groups (Table 4-11-Quad 4).

With the exception of households without formal employment and that are in close proximity to urban market, a relatively small percentage of total income is derived from commercial agriculture. For more remote households this may be primarily a function of high transaction costs and the market uncertainty. For those households in Nett having formal employment, the relatively small percentage of total income from agriculture might be explained simply by limited demand and/or household income levels meeting existing needs.

Discussion

Like other Small Island Developing States in remote locations and having limited domestic markets, few opportunities exist for economic development on Pohnpei. Pohnpeaens have developed diverse strategies to meet the needs for cash income, food security and cultural obligations. To meet many of these needs, one of the primary activities household members are engaged in is agriculture, employing traditional practices that have been in existence for centuries.

The results of this study, possibly the first of its kind on Pohnpei, indicate that all households involved with this research were producing multiple crops within Pohnpei's

agroforests. With the exception of sakau, the vast majority of the crops (and values) included in this study are derived from homegardens, an indication of the importance of these agroforestry systems to Pohnpeaens. With the exception of swamp taro which is produced in significantly greater quantities in Nett then Madolenhimw, the types and quantities of crops being produced were not significantly different among households having more or less market access or having members formally employed or not (Table 4-1). Given the similarities in the types and quantity of crops produced, this suggests there is a relatively high level of homogeneity of Pohnpei's agroforests. The level of homogeneity, however, is not the same when it comes to the particular use of crops. Whereas swamp taro, bananas and coconuts are used primarily for household consumption and for feeding animals, yams and sakau are particularly important for ceremonial activities. Sakau and betel nuts are the primary sources of income from the sale of crops (Table 4-7).

Agriculture is contributing substantial value in terms of household consumption needs, ceremonial goods and monetary worth to both Pohnpei's formal and informal economy. The sale of seven of the primary crops produced in Pohnpei's agroforests alone represents a large contribution to Pohnpei's local economy estimated at just under $5 million annually (Table 4-5). Moreover, agriculture is providing necessary sources of income in light of very limited formal employment opportunities. In addition to the formal economy, ceremonial use of the same crops is valued at almost $3 million per year, indicative of the relationship that Pohnpeaens have to their traditional culture. Beyond formal and cultural values, agriculture is providing just over $7 million annually in consumptive values and in doing so providing for nutritional needs in light of ever-increasing consumption of imported food goods. Combined with over a $1 million annually being used to provide extended family and friends with food sources, the results illustrate how

agriculture is truly embedded in most aspects of daily life on Pohnpei. Should the role of agriculture diminish whether in terms of its commercial value, cultural contribution or food security, it would be expected there would also be substantial societal changes, the implications of which should be evaluated when considering possible development strategies.

Comparing agriculture's contribution to Pohnpei's GDP with estimates of agriculture's contribution to GDP in other SIDS in the Pacific regions provides further indication of the relative importance of Pohnpei's agroforests to the local economy. It can be seen that almost 20% of Pohnpei's total GDP is derived from crops produced within agroforests (Figure 4-1). This value is relatively high compared to many other SIDS in the Pacific region, particularly if one considers the percentages for SIDS in Figure 4-1 other than Pohnpei include production and value added of agricultural, forestry and fishery products as opposed to only the seven crops comprising of the nearly 20% of Pohnpei's GDP[1].

While the commercial forestry sector on Pohnpei, and for all of the Federated States of Micronesia is limited, the fisheries sector in the FSM remains an important contributor to GDP having an estimated value of $36,900,000 in 1999 (Gillet and Lightfoot, 2001). Assuming that only a quarter of this value was attributed to Pohnpei (Pohnpei being one of four states within the FSM), the percentage of Pohnpei's GDP as defined for the other countries in Figure 4-1 would increase to close to 28% indicating the importance of natural resources to Pohnpei's (and the FSM) economy.

[1] Definition: Agriculture for all countries except Pohnpei includes production and value added figures for forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. Source: World Bank national accounts data, and OECD National Accounts data files.

Taking into consideration the total value of all agroforests it becomes very clear that sakau is driving both commercial agricultural activities, as well as the total value derived from these agroforests (Tables 4-5 & 4-6). However, the importance of sakau is proving to be a mixed blessing. On the one hand, sakau is clearly contributing to household incomes and the formal and prestige economies. On the other hand, because of the substantial local demand for sakau, farmers have cleared extensive areas of upland native forests to plant sakau where it grows more quickly to a harvestable size (Kostka and Raynor, 2000). The results of these actions are contributing to the loss of unique and very biologically diverse native forests. Moreover, clearing is causing negative impacts downstream due to erosion and according to local farmers sakau production in the uplands is not sustainable (Sakau in relation to the environment and economy of Pohnpei is explored further in Chapter 6).

Pohnpei has established a "grow-low" campaign to encourage the planting of sakau in the lowlands of Pohnpei which is proving to be somewhat successful (Kostka and Raynor, 2000, Raynor personal communication 2007). Unless an opportunity to market a greater assortment of crops becomes possible, the heavy dependence on sakau grown in the uplands will continue to cause detrimental impacts to Pohnpei's upland forests.

The heavy dependence on only two crops (Sakau and betel nut) for cash income presents another challenging situation. While these crops are being produced within agroforests comprising of many more crops, the reliance on only two crops for substantial income increases the economic vulnerability of farmers to significant events, be it a result of anthropogenic or natural causes. To reduce the potential vulnerability strategies to establish markets should focus on diversifying as well as increasing potential marketing opportunities.

The percentage of total income from agriculture is assumed to be a reasonable indicator of the dependence on agriculture for cash income. Contrary to what was expected, total number of people per household did not appear to influence the relative dependence on agriculture for cash income. Nor did household population have any statistically significant bearing on the contribution of crops to total income. One explanation for this could be that enough, if not surplus, labor exists to produce what is needed for household consumption, ceremonial obligations, and what the current market demand for crops calls for. It also would suggest that additional labor on Pohnpei is available for income earning activities if such opportunities existed. Moreover, available land per household has not proven to be a statistically significant predictor of the dependence on agriculture for household income.

At this juncture the results suggests that population density (measured by number of people per household) as well as lands available to each household (land scarcity) have not reached a point in which they are influencing agricultural activities as proposed by Boserup (1965) and specifically the dependence on agriculture for cash income. One may assume that in other SIDS having similar household population densities and available land areas agricultural activities are not determined by these metrics.

Although all households use a portion of their crops for ceremonial purposes it does not appear that doing so has any significant bearing on the percentage of total household income generated from crop sales; Pohnpeaens still believe in the importance of maintaining traditional cultural ties such that the desire to increase cash income has not yet taken full precedent over the desire to remain integrated into Pohnpei's prestige economy.

The regression model also suggests that those households without employment and having greater market access derive a larger percentage of total income, and are therefore more

dependent on agriculture for cash income relative to other households. It remains to be seen if farmers will modify their farming activities in response to increased market access (viz. Von Thu¨nen 1826). However based on the fact that households having greater market access and no formal employment generate almost 75% of their total income from agricultural sales strongly suggests that having greater market access will broaden the range of opportunities for Pohnpeaens as Allen (1986) and Reardon *et al.* (2001) suggest.

Households having members formally employed generate a significantly less amount of their total income from agriculture relative to households that do not have formal employment (Table 4-11). Assuming these same households represent a segment of Pohnpei's population that is reliant on nonagricultural activities for the majority of household income, the results point to Pohnpei being in the midst of a structural transformation. It would follow that assuming formal employment opportunities were to increase in the future fewer households would rely on agriculture for cash income. However based on the same results, it would be expected that if formal employment levels were to level off or even decline in light of an increasing population, households on Pohnpei would look to other opportunities for income generation. In doing so, the continued trend towards moving away from the agricultural sector to support economic development would pause, if not reverse in direction.

At the time this research was conducted, limited local demand was acknowledged by many farmers as being a major reason for not increasing the production of crops with the exception being for sakau. Given Pohnpei's relatively small size, the fact that all of the households that participated in this research were producing enough food for their own consumption and ceremonial needs, further research needs to be conducted to look at marketing opportunities off-island.

After spending more than 3 years living and working on Small-Island States in the Pacific and in particular, through direct observation of Pohnpeaens over the course of a 12 month-period, the author has determined that the *modus operandi* for many Pacific island farmers, is that they market their crops based on short-term, immediate needs. This is in part likely a function of limited markets although it is also likely that culturally, Pohnpeaens (and many other Pacific island cultures) are not accustomed to producing a consistent flow of high quality products to meet market expectations. There may be the means to produce sufficient quantities of agricultural products to supply off-island markets; however the current manner in which many farmers produce and sell their crops is problematic and risky to those willing to invest the time and finances necessary to establish viable production and marketing chains from the farmgate to markets themselves.

There is a need to develop a multi-pronged strategy aimed at developing both local marketing opportunities as well as devoting sufficient financial and human resources to train and enable potential farmers and buyers to develop and implement more agricultural commerce. Conducting marketing research to determine the potential for niche markets outside of the FSM combined with research on possible value-added activities should be implemented. Public sector efforts should also center on developing infrastructure including improving roads and public transportation opportunities, linking rural to urban areas reducing transaction costs that in turn improve potential profitability's for commercial agriculture. Providing financial incentives such as tax relief for capital investments in processing and market facilities, export subsidies to attract private investment, as well as establishing low-interest credit programs for farmers in support of interstate and international agricultural commerce should also be given consideration. Exploring all possible options that center on production and sales of as many traditional crops as possible

enabling Pohnpei's agroforests to remain a primary component of agricultural development should be pursued.

Throughout much of the world (and certainly among SIDS too) agricultural development policy has focused on promoting commercial agriculture via the intensification of land use and often through the introduction of monoculture practices. In such situations, intensification and changes in farming practices have most often taken the form of increased use of synthetic inputs and mechanization of labor. The process fundamentally altering traditional agricultural practices has in some instances been quite successful in achieving both economic and food security objectives. However, it has also led to increased dependence on production inputs and exposure to market fluctuations. For SIDS where such small economies have no influence on market supply and demand, the impacts of implementing such policies substantially increases the vulnerability of an island's economic well being as well as potential for significant deterioration of natural resources. Indeed, for those States and territories where agriculture remains an integral part of every day life, implementing such changes leads to fundamental changes not only to the agricultural sector, but potentially to all aspect of a given population.

As Figure 4-1 illustrates, of the countries included, agriculture's contribution to Pohnpei's GDP is second highest (17.8%), surpassed only by Tonga (28.6%) which derives the vast majority of its agricultural value from the production and export of squash using intensive monoculture practices. The promotion of Tonga's squash industry has been at the center of developing its economy and has been the backbone of the transformation of what, only 50 years ago, was a non-monetary economy based on subsistence agriculture to a fully-monetary economy today. In the process of developing Tonga's squash industry, the practices employed

have resulted in extensive deforestation and the loss of traditional agroforestry systems throughout Tonga during the last three decades (Wolff, 2001).

More recently, Tonga's squash industry has suffered due to increasing production costs and vulnerability to world demand fluctuations that remain out of the control of Tongan farmers. There are now ongoing efforts to reintroduce and promote traditional agroforestry practices on Tonga as a result of the loss of forests, unsustainable monoculture practices and the loss of ecosystem services once provided by such traditional practices. Tonga provides a useful example of how a Small Island Developing State has transitioned from traditional agroforestry practices that supported a country's population for centuries to more intensive monoculture producing a very narrow range of crops for the primary purpose of developing its economy. Other countries such as the Cook Islands have also experienced a boom and bust period of agricultural development but have been more able to respond to the collapse of its pineapple industry through effective development of a tourism sector. Pohnpei has yet to make a similar transition as experienced in Tonga, the Cook Islands as well as other developing states but it is well on its way.

As Pohnpei continues towards a more fully monetized economy whereby greater cash income is sought, the results of this research suggest that it could be expected, particularly given the limited employment opportunities, there would be an increasing trend toward selling as much agricultural products as possible. If this were to happen it is also very likely there would be a shift from the use of crops for ceremonial and extended family purposes to purely commercial purposes. Doing so would likely strain the existing cultural integrity of Pohnpeaens and would certainly test the social resiliency of Pohnpeaen society. It remains to be seen if Pohnpei will pursue similar development strategies as those pursued in other pacific islands such as Tonga.

Those in policy positions must address the potential tradeoffs between promoting more modern agricultural practices relative to the important role and value of existing practices. Based on the results of this study, economic comparisons of the traditional agricultural systems practiced on Pohnpei and more modern technologies used elsewhere needs to be conducted. Currently, it is unclear whether more modern practices, particularly given Pohnpei's remoteness and associated transaction high costs, would actually provide greater and lasting benefits.

Having a long tradition of being a subsistence economy, Pohnpei is now moving towards a more cash based society where tradition and prestige, based largely on production of traditional crops, is slowly giving way to western ideals and the desires of material wealth. The trajectory and pace of where agriculture on Pohnpei goes from here will largely depend on the availability of markets for those crops currently produced within Pohnpei's agroforests and possibly others that may be introduced. Critical to any analysis that may help shape Pohnpei's future course is the full appreciation and recognition of the total value of current agricultural practices as well as the contribution of agriculture to Pohnpei's culture and consumption patterns. The research reported here is one step in this direction.

Table 4-1. Role of homegarden agroforests in household production of crops in Pohnpei, FSM

Crop	Unit of Measure	Homegarden		Total		% from Homegarden
		Mean	S.E.	Mean	S.E.	
Yams	kg yr^{-1}	258	43.7	314	40.8	76.5
Breadfruit	kg yr^{-1}	387	60.7	480	94.7	80.7
Swamp taro	kg yr^{-1}	196	45.2	255*	55.3	85.9
Coconuts	Number yr^{-1}	1041	155.9	1335	180.4	81.2
Betel nut	Number yr^{-1}	10,130	4,114.4	10,850	4,181.2	92.4
Sakau	kg yr^{-1}	261	51.5	1106	271.6	53.0
Bananas	kg yr^{-1}	689	66.1	867	82.8	82.3

Nett vs. Madolenhimw: *= P<.10

Table 4-2. Average allocation of household production of crops for various uses (ceremonial, cash income, friends and household consumption) in Pohnpei, FSM

		% of households using the crop for			
Crop	% of households producing crop	Ceremonial	Cash income	Friends and extended family	Household consumption
Yam	97	81	30	42	97
Breadfruit	94	88	24	66	100
Swamp taro	85	48	18	48	93
Coconuts	100	27	36	48	100
Betel nuts	64	12	48	30	64
Sakau	94	90	58	60	94
Bananas	100	48	64	78	100

Table 4-3. Use of crops for ceremonial, cash income, friends, and household consumption on Pohnpei, FSM

	Percentage of total crop production per use				
Crop	Ceremonial	Cash income	Friends and extended family	Household consumption	Total
Yam	42	5	4	49	100
Breadfruit	18	3	9	70	100
Swamp taro	3	19+	14	64*	100
Coconuts	2	3	4	91	100
Betel nuts	1	61	13	25	100
Sakau	24	39	6	31	100
Bananas	7	3	9	81	100

Nett vs. Madolenhimw: *= P< .05
Employment vs. no-employment: += P< .05

Table 4-4. Average household value of crops produced in Pohnpei's agroforests, 2002

Crop	Homegarden Mean ($ yr $^{-1}$)	S.E. ($ yr $^{-1}$)	Total Mean ($ yr $^{-1}$)	S.E. ($ yr $^{-1}$)	% of value from Homegarden
Yams	551	94.0	690	89.8	80
Breadfruit	85	13.6	109	21.2	78
Swamp taro	151	34.8	254	55.4	59
Coconuts	104	15.5	133	18.0	78
Betel nut	506	205.5	542	209.0	98
Sakau	575	113.3	2,434	597.5	24
Bananas	379	36.4	477	45.5	79
Total*	2,089	234.7	4,242	612.9	

*Note that the total value per crop per use is not equal to the sum of individual crop values because not all households produce every crop. The total value reflects the sum of values for households producing a given crop.

Table 4.5. Value of crop used per household from Pohnpei's agroforests

	Value per crop activity ($ yr^{-1})			
Crop	Ceremonial	Cash income	Friends and extended family	Household consumption
Yam	412	95	56	296
Breadfruit	11	26	18	69
Swamp taro	20	57	46	142
Coconut	10	8	13	121
Betel nut	21	503	161	101
Sakau	606	1705	308	633
Banana	429	63	64	375
Total household value per use*	966	1,538	399	1,556

* Note that the total value per use does not equal to the sum of individual crop values because not all households produce every crop. Instead, the total value reflects the sum of the average total value for each household producing and using a crop for a specified use.

Table 4-6. Island-wide values for crops produced in Pohnpei's agroforests

Crop	Homegarden	Total
	Mean ($ yr $^{-1}$)	Mean ($ yr $^{-1}$)
Yam	2,083,188	2,524,760
Breadfruit	310,597	373,255
Swamp taro	482,793	625,660
Coconuts	396,516	461,650
Beetle nut	1,226,743	1,254,504
Sakau	2,126,520	8,711,975
Banana	1,443,420	1,816,321
TOTAL	8,069,777	15,768,125

Table 4-7. Island wide-value of agricultural crops produced and used for different purposes on Pohnpei, FSM

Crop	Ceremonial ($)	Cash income ($)	Friends and extended family ($)	Household consumption ($)
Yam	1,269,288	109,356	91,009	1,202,756
Breadfruit	85,297	9,995	46,368	310,597
Swamp taro	105,045	14,227	93,661	455,937
Coconuts	614	13,849	24,192	461,650
Betel nuts	24,094	928,875	184,608	942,046
Sakau	1,337,416	3,701,776	711,013	2,260,412
Bananas	49,876	154,188	182,514	1,428,755
TOTAL	2,871,630	4,932,266	1,333,365	7,062,153

Table 4-8. Correlation matrix of explanatory variables used in the model for determining percentage of total income derived from agroforests on Pohnpei, FSM

	Market access	Households having formal employment	# of household members	Total lands available	% of crop value used for ceremonial activities
Market access	1.000				
Households having formal employment	0.277	1.000			
# of household members	0.149	0.377	1.000		
Total lands available	-0.064	0.062	0.186	1.000	
% of crop value used for ceremonial activities	0.021	-0.015	0.104	0.198	1.000

Table 4-9. Results of the complete regression model predicting agriculture as a percentage of total income

	Descriptor	Coefficient	Standard Error	T-stat
Intercept		0.252	0.120	2.102
MKACES	Market access	0.278	0.095	2.940**
EMPLOY	Household with employed member	-0.347	0.100	-3.453***
NHHMEM	Number of household members	0.000	0.006	0.041
TOTLND	Total land area available (ha)	0.025	0.020	1.258
PERCER	Percent of total value for ceremonial activities	-.287	0.254	-1.130

* P< 0.10 ** P< 0.05 *** P< .001 R^2 = 0.40 Adjusted R^2 =.30

Table 4-10. Results of the final regression model predicting agriculture as a percentage of total income

	Descriptor	Coefficients	Standard Error	T-Stat
Intercept		0.277	0.073	3.934
MKACES	Market access	0.265	0.093	2.847**
EMPLOY	Household with employed member	-0.332	0.093	-3.583***

* P< 0.10 ** P< 0.05 *** P< 0.001 R^2 = 0.36 Adjusted R^2 =.31

Table 4-11. 2 X 2 contingency table showing percentage of total household income from agriculture for significant explanatory variables

No employment	72.0% (Quad 2 N=4)	19.8% (Quad 1 N=11)
Employment	12.3% (Quad 3 N=11)	6.8% (Quad 4 N=7)
	Nett	Madolenhimw

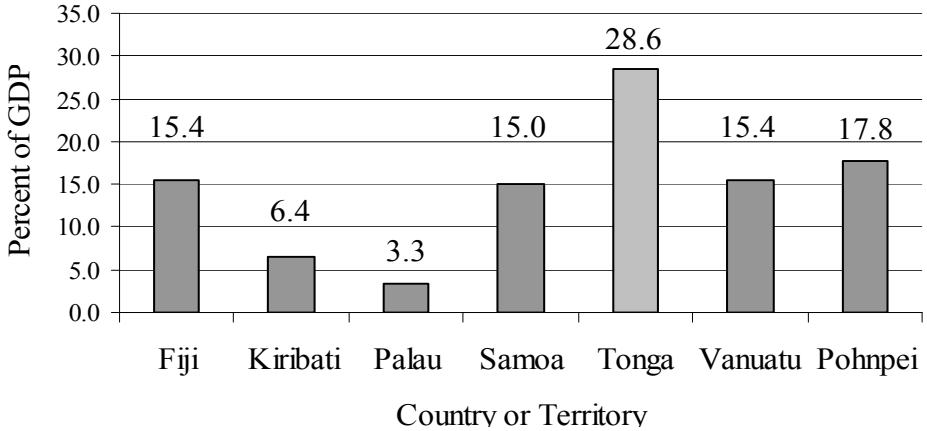

Figure 4-1. Comparison of the percent of GDP from agriculture in 2002 (World Bank, 2008)

CHAPTER 5
MODELING LIVELIHOODS ON POHNPEI USING ETHNOGRAPHIC LINEAR PROGRAMMING

Introduction

In contrast to traditional economic theory that associates the allocation of resources to maximizing profits, small scale, limited resource families often pursue diverse strategies to meet livelihood objectives (Hildebrand *et al*., 2008). Pacific islanders often manage their limited resources to meet multiple objectives both monetary and non-monetary in nature (Powell, 1998). For example where tradition and cultural norms remain strong, certain crops are often produced for reasons of prestige and acquisition of social status in addition to income generation. Additionally, households may emphasize production of goods and maintenance of ecosystem services to meet food security objectives. Over centuries, Pacific cultures have pursued several strategies to meet these multiple objectives, principal among these are the development of traditional agricultural systems (food security, social status gains, ceremonial and income earning objectives) fishing (food security and income earning objectives) and more recently the pursuit of formal employment for cash income objectives (Hazel, 1993; Peoples, 1995). As the process of globalization continues and subsequent increased desires for greater cash income occur, the order of importance of these multiple objectives may shift.

A livelihood system is defined broadly as the composite of all activities available to all households in the system from which to choose to secure their livelihoods (Hildebrand *et al.,* 2008). Within a livelihood system there are often subsets of households selecting diverse strategies based on composition, preferences, skills, location, and household objectives. The activities chosen by a given household from those comprising the livelihood system make up what is known as livelihood strategies (Hildebrand *et al.,* 2008). Modeling households within livelihood systems enables an ex ante assessment of possible development programs and is one

tool to help better understand the implications of such development scenarios. Having such information can not only help to ensure that appropriate development programs are established, it can also help to ensure the substantial and often very limited resources needed for development programs are used more efficiently.

In Chapter 4, descriptive statistics were presented and regression analysis was conducted providing values associated with agricultural productivity to determine whether there are significant predictors of agriculture's contribution to total household income. In this chapter, the scope of interest is broadened to examine livelihood strategies being employed to meet household objectives, including production activities other than agriculture. Understanding Pohnpei's agricultural sector is important and can provide useful insight into potential agricultural development programs. However, the efficacy of such programs may be less than desired without having a comprehensive understanding of the how resource availability and constraints facing various household groups influence the allocation of limited resources and for what purposes.

In the next section, a brief description of the method used to model households on Pohnpei is presented followed by a description of the model specifications, the livelihood systems being modeled and three scenarios that the model simulates. The remainder of the chapter consists of results of the simulations followed by a discussion based on the results of the simulations conducted.

Methods

Mathematical programming has been used in the agricultural sectors for decades. One such type of mathematical programming is linear programming. A linear program (LP) is a mathematical "optimizing" procedure that maximizes or minimizes an objective subject to constraints (See Appendix D for a mathematical explanation of linear programming).

Traditionally, LPs were developed and used in agriculture as a normative tool as opposed simulating what a farmer was actually doing and based on current actions, to estimate how might a desired objective (increasing cash income, minimize land or labor etc.) be achieved. In the early years of linear programming, modelers limited their analysis to those activities specific to agricultural productivity without incorporating other activities pursued by households or commercial firms

More recently ethnographic linear programming models (ELPs) have been developed as a means to more fully comprehend livelihood systems and strategies being employed by households and to assess potential impact resulting from a change in technologies, environmental conditions, policy or livelihood objectives themselves. Ethnographic linear programs are simply a decision support tool that enables decision makers to be more informed. The ELP models are developed (1) to help researchers or other decision makers understand the complexities and diversity of livelihood systems and the households that depend on them and ultimately (2) to simulate the livelihood systems and livelihood strategies of the diverse households within these systems.

At the household level, the process of developing ELPs consists of determining resources such as land, labor, and capital (usually cash but can include trading) used for a particular production activity, production outputs and the total amount of resources available to a household. This information is then used to create a matrix comprised of resources used (inputs) to produce a given amount of production outputs along with actual or potential uses of the outputs being produced. Once the ELPs are developed the models themselves can be validated. Validation is most readily done by direct interviews with participating households to see if the model's structure inputs and outputs closely reflect reality. When and where available, validation

may also be supported comparing model inputs and outputs with secondary literature and data collected by local agricultural extension offices. Once validated, the models can be used to simulate and assess potential impacts on different kinds of households of programs being considered prior to implementation in a given locale or within a particular recommendation domain.

To conduct the analysis of livelihoods on Pohnpei, ELP was used. Both descriptive and analytic in scope, ELP allows for relevant activities carried out by individual households along with production, market or other constraints to be incorporated into analyses to determine, ex ante, the potential changes resulting from a proposed action. While it is recognized that every household is engaged in both production and reproduction activities, the analysis conducted for this chapter centers only on production activities included in the ELP models as described below. However, in doing so, available adult labor was limited to eight hours per day, five days a week and children's available labor is limited based on whether or not they were enrolled in school. Additionally, while absolute values for time required to prepare food were not included in the model, time and resources required to grow food for household consumption was.

Model Specifications

Data used for the ELPs developed for this chapter were collected, during a one-year period, based on the methods described in Chapter 3. For all four scenarios discussed below, simulations were conducted for each of the participating households (n=33). Based on the primary source(s) of income, four livelihood systems were identified. Household models were then grouped per livelihood system and averages for households within each of the respective systems were calculated.

Production Activities

Several activities were incorporated into the ELPs developed for this analysis. Agricultural activities included production of the seven main crops found within Pohnpei's agroforests (yams, breadfruit, giant taro, coconuts, beetle nut, sakau and bananas). Agricultural activities were broken down based on whether they were conducted within homegardens or other lands (Land2, Land3) either owned by extended family or are considered public lands. Agricultural crops are used for multiple purposes on Pohnpei including for each of the "use options" of agricultural crops as identified in Chapter 4 (household consumption, given to friends and extended family, commercial sale, use in traditional activities) was incorporated into the ELPs to reflect actual uses by individual households.

Other activities in the models comprised of production of handicrafts, mangrove crab harvesting, fishing, full and part-time employment, receiving retirement/pension income and receiving remittances, either from local or from sources from outside of Pohnpei.

Coefficients for agricultural and fishing activities in the ELP models included production inputs, namely land and labor, broken down by adult male, adult female, male child, and female child[1]. For households with employed members, the standard number of hours worked in the public sector was used unless otherwise indicated by participants. Income generated from sales of handicrafts, crops, and fish were derived based on production levels multiplied by local market prices. Income from employment, retirement and remittances, was based on responses provided from household surveys (Appendix C).

[1] For this research a household member was considered an adult if s/he was 18 years of age or older.

Model Constraints

Constraints can be considered restrictions on activities, uses, and/or quantities of an input or output coefficient that often are used to capture realities of households in a given livelihood system. For example a constraint can be incorporated into a model to reflect minimum needs to produce and use a given crop for household food consumption or a maximum value for the amount of crops that can be sold based on market conditions. Relaxing or reducing constraints is one way to simulate potential effects on a given livelihoods system resulting from the introduction of policies, technological changes or otherwise.

For the base case scenario (Scenario 1 below), constraints imposed in the ELPs are based on available resources and how each of the households allocated harvested goods to various uses identified above. Thus, during the course of data collection, if a household had recorded 100 kg of yams being used for ceremonial purposes, the model had a constraint requiring at least 100 kg of yams be produced and allocated to ceremonial activities.

Additionally, constraints limiting the amount of crops or fish that can be sold commercially, demand constraints, were imposed based on what each household actually sold. The underlying assumption behind imposing a market constraint is based on the understanding that if local demand were greater, households would sell more of their crops and/or fish. Since not all households participated in every activity, if a particular household did not engage in a particular activity, a constraint was imposed restricting households from such activities. Employment constraints were imposed to limit the amount of time, and thus income that can be earned based on the actual number of household participants that held formal employment positions and the income generated from such activities. Finally, a constraint imposed for cash needs was based on what was identified as cash needs per household per month converted to an annual amount. Modification of these constraints, an assumed crop pricing policy and expanded

market opportunities provide the basis for three additional scenarios to be simulated as described below.

Objective Function

It is recognized that in settings such as Pohnpei, households manage their resources to meet multiple objectives. Among these are those associated with meeting cultural and extended family obligations and food security. However, more and more, acquiring cash income to support material wealth has become a primary goal of many households and maximizing cash income a primary objective to achieve this goal. Therefore the objective function for this model is maximizing end of year cash income.

Livelihood Strategies

Based on the results of the field research conducted, four household groups were identified (hereafter referred to as Employment households, Agriculture households, Fishing households and Remittance households). While many of the participating households were engaged in similar activities (Table 5-1) given the objective function to maximize cash income, households were grouped based on relative dependence on employment, agriculture, fishing or remittances as primary sources of income.

Description of Livelihood systems

- **Employment**: Households that generate the majority of their income from formal employment (N=18). Households in this group include those located in Nett (56%) and Madolenhimw (44%). Eighty nine percent of these households had at least one member employed full time while 11% had at least one member employed part time.

- **Commercial agriculture**: Households that generate the majority of their income from commercial agricultural activities (N=6). There were no households in this domain having members formally employed full time. Sixty seven percent and 33% of households in this domain are located in Nett and Madolenhimw respectively.

- **Commercial fishing**: Households that generate the majority of their income from commercial fishing activities (N=3). All households in this domain are located in one village

in the district of Madolenhimw. Two of the households had no members formally employed full time. One household had at least one member employed part-time.

- **Remittance**: This recommendation domain comprised of households that generated the majority of their income from sources other than formal employment, commercial agriculture or commercial fishing (N=6). Sixty seven percent and 33% of households derived the majority of their income from remittances and retirement sources respectively. All but one household was located in the more remote district of Madolenhimw and none of the households had any members formally employed full time. One household within this recommendation domain had at least one member employed part-time.

Scenarios Simulated

- **Scenario 1:** Simulates the base case and reflects what households were actually doing at the time and under market conditions that existed when the field research was conducted.
- **Scenario 2:** Simulates the effect of a crop pricing policy of 25% increase in crop prices while holding constant the amount of crops sold in domestic markets (demand constraint) to that of Scenario 1.
- **Scenario 3:** Simulates the effects of an increase of international market opportunities in light of declining uses of crops within the prestige economy. To do so, Scenario 3 simulates the assumption that Pohnpei's local markets for the crops and fish meet local demand and introduces an opportunity to sell crops internationally at 50% of actual local market prices[2]. This scenario also assumes productivity remains constant while ceremonial use of crops is constrained at only 50% of original values, providing surplus for sale to international markets.
- **Scenario 4:** Simulates an expansion of fish marketing opportunities by relaxing fish consumption constraints by 50% and assuming Pohnpei's domestic market could absorb additional fish sales at current prices. Scenario 4 only includes changes in marketing conditions specific to fishing activities as opposed to mangrove crab harvesting and fishing.

[2] A 50% decrease in crop price relative to actual local crop prices used in Scenario 1 simulations.

Results

Model Validation

Given this is the first known work on Pohnpei that documents productivity and use of crops over the course of a year's period there are very few secondary data available to validate the model. However, the model has been validated to the extent that results were shown and discussed with household members participating in this research. Based on their feedback the base model (Scenario 1) is an accurate representation of livelihoods on Pohnpei.

Scenario 1: Base Case

Scenario 1 represents the results of the simulations based on the actual data collected. Therefore the results of Scenario 1 most closely represent current strategies and associated incomes per livelihood system.

Households in all four livelihood systems rely on between three and seven different sources of income (Figure 5-1). There is a positive correlation between the number of income sources and actual income levels among the four livelihood systems. However although such a correlation exists, three out of the four systems derive between 65% and 77% of their total household income from only one source. Agriculture and Fishing households generate more than 70% of their total incomes from agriculture (77%) and fishing (72%) respectively. Households within both systems also depend on part-time employment and remittances as their only other sources of income.

Households reliant primarily on employment generate income from more sources (total seven) than households within the three other livelihood systems. Even so, these same households are reliant on employment for almost 70% of total annual income. Second in importance to employment is agriculture income providing 12% with the remaining sources of income ranging from between 1%-6% of total income (Figure 5-1).

In contrast to the other livelihood systems, households within the Remittance group have more balanced strategies to generate cash income. The two most important sources of income are remittances (39%) and retirement (36%) followed by agriculture (17%). The balance of income is generated from part-time employment (5%), handicrafts (2%) and fishing (1%). Fishing households is the only livelihood system that does not rely on commercial agriculture for cash income.

Household incomes for the four livelihood systems range between just over \$11,500 yr^{-1} and just under \$2,000 yr^{-1} (Figure 5-2). Employment households have significantly greater income ($P<.001$) relative to all other domains.

Households most reliant on fishing have the lowest cash incomes (\$1,966 yr^{-1}) followed by commercial agriculture (\$3,303 yr^{-1}) and remittance (\$4,536 yr^{-1}) livelihood systems.

For the remaining three scenarios, production inputs and quantity of crops harvested did not change relative to the base case. Instead, the use of crops and/or fish harvested and the value associated with their use changed based on the particular scenario simulated.

Scenario 2: 25% Crop Price Subsidy

In Scenario 2, prices for crops that were actually sold in Scenario 1 were increased by 25% to simulate how household incomes would change assuming such a pricing policy was established. Households most dependent on agriculture would realize the largest increase in incomes relative to households within the other livelihood systems. The benefit of such an increase in crop prices would contribute an additional \$643 yr^{-1} to Agriculture households, a value equivalent to almost 20% of their total existing incomes (Table 5-2). Income levels for Employment and Remittance households would increase by \$343 yr^{-1} and \$178 yr^{-1} respectively representing an increase of between 3-4% of total income. Fishing households are not currently

engaged in any commercial activities. As a result, their income would not change as a result in crop prices being increased by 25%.

Scenario 3: Relaxing Ceremonial Use Constraint

Table 5-3 summarizes the results of reducing the constraint imposed on ceremonial use of crops by 50% while simultaneously assuming international markets (at 50% of domestic crop prices) could absorb the surplus crops not used for ceremonial purposes. In this scenario, commercial agricultural households would realize the largest increase in income ($335 yr^{-1}), roughly half of the gain derived based on Scenario 2.

An increase in household income of $249 yr^{-1} would be realized by employment households representing a total increase of 2.0% relative to Scenario 1 results. Although Remittance households would realize a greater percentage of increased income relative to Employment households, in absolute terms the increase would only be $153 yr^{-1}. Fishing households would realize very little benefit from relaxing ceremonial constraints because of the small amount of agricultural products produced that are actually used for ceremonial purposes.

Scenario 4: Expansion of Fish Markets

In Scenario 4 simulations were conducted to determine the relative effects of increasing the sale of fish in local markets. Those households most reliant on fish for income are also the largest consumers of fish on a per household basis. As a result, and working under the assumption that maximizing household cash income was the objective, these same households would benefit the most from having an opportunity to sell as much as 50% of the fish currently being consumed (Table 5-4). The actual increase in income for fishing households is more than double ($477 yr^{-1}) of any other household groups representing an increase of 24% over the Base Case.

For both Employment and Remittance households, they would realize an increase of household income of approximately \$200 yr^{-1}. Agricultural households consuming the least amount of fish of the four groups would only realize a very small increase representing a difference of less than 1% of annual household income or \$24 yr^{-1}.

Discussion

The results of Scenario 1 (existing situation) illustrate how the major share of household income is derived from employment, particularly relative to the three other livelihood systems. Second to households within the Employment group, households most reliant on remittances and retirement have the second highest incomes albeit still less than 50% of formal employment households. Those households most reliant primarily on natural resources (Agriculture and Fishing households) generate the lowest cash income among the four groups. Moreover, in the case of households reliant on fishing their income is less than 20% of the income generated by Employment households illustrating the large income disparity between these two livelihood systems. Two main conclusions can be drawn from these findings. First, while the vast majority of all households on Pohnpei derive income from multiple sources, employment outside the home is by far the largest single source of income. With approximately 50% of households on Pohnpei having at least one member employed, formal employment is the driving stimulus of the economic activity on Pohnpei. Secondly, although income levels for households most reliant on Pohnpei's natural resources are far less than those having formal employment, commercial agriculture and fishing are providing indispensable incomes given the very limited opportunities for other income earning activities.

The differences in income earning strategies and amounts between the four livelihood systems also illustrate the potential vulnerabilities that households within each system must cope with. For Employment, Agriculture and Fishing households there is a significant reliance (at

least 65% of total income) on only one source of income. For households within the Employment system, and with the continued decline in Compact funding, public sector employment opportunities will continue to diminish. Given that close to 50% of formal employment is within the public sector, should a reduction in employment opportunities occur, these same households would loose the majority of their household income. In the case of Agricultural and/or Fishing households where more than 70% of incomes are generated from natural resources, they are particularly vulnerable to natural disasters, disease occurrence and/or introduced pest infestations[3]. Such vulnerabilities, both in terms of secure employment and exposure to natural disasters support much of what has been described as unique challenges facing Small Island Developing States.

Oddly enough, it may be households that are less reliant on existing domestic employment or markets that are positioned best to at least maintain their current levels of income. For this group of households their income is primarily generated from either retirement or remittances. It is highly unlikely that sources of retirement funds (Social Security, pensions) will be curtailed in the foreseeable future. Similarly, with the exception of a substantial downturn in the US mainland, Guam, or Hawaiian economies there is little reason to expect that remittance levels will decline.

The results also illustrate the value of ethnographic linear programming (ELP) as a means to examine, ex ante, the potential impacts of different policies or development strategies on different types of households. Moreover, this study demonstrates the importance of tailoring development strategies if the goal is to promote development and increase cash incomes for

[3] Such was the case with taro producers in Western Samoa that experienced a series of typhoons and then disease that repeatedly destroyed entire taro production during the 1990s (Paulson and Rogers, 1997)

different household types in a given locale, and particularly on Pohnpei. In the case of Scenario 2 where a cropping price subsidy was simulated, households most reliant on agriculture for cash income would realize almost a 20% increase in household income ($643 yr^{-1}) while the other three household groups would realize a much smaller proportional benefit if any at all. Likewise, as simulated in Scenario 4 where marketing opportunities of fish were expanded, with the exception of households most reliant on fish for income the other household groupings would realize only a marginal increase in household incomes.

Given the large discrepancy in income among the four livelihood systems, it seems reasonable that policies aimed at improving household income should focus on improving economic opportunities for those households that currently do not have access to formal employment. More specifically, policies aimed at improving cash income through enhanced market opportunities for both fish and agricultural products would benefit those households that do not have formal employment or that are currently receiving remittances and/or retirement income. Doing so may also help to offset the loss of income from the potential reduction in public sector employment that may result from declining Compact funds.

Pohnpei's economy mirrors the MIRAB (Migration, Remittances/Aid and Bureaucracy) model first discussed by Bertram and Watters (1985). The underlying premise of the MIRAB model is that Pacific islanders have been involved in a global economy for decades, and have responded to the unique characterization of SIDS via emigration of islanders to metropolitan markets as (factors of production), the transfer of remittances back to home islands as (financial transfers) and procurement of substantial aid to fund large bureaucracies resulting in inflated public employment (production of non-tradables).

With almost two thirds of households on Pohnpei having immediate family residing off-island (emigration), all four livelihood systems are deriving at least some income from remittances (financial transfers). In particular, Remittance households are receiving almost 40% of total income is from remittances. This suggests not only the importance of remittance income to support livelihoods on Pohnpei, but also the importance of the ability of Micronesians to study and work freely in the United States and its territories as a condition of the Compact negotiations.

Compact funds are also providing essential aid responsible for supporting formal employment on Pohnpei (production of non-tradables). With substantial overseas aid, Compact funds are the primary source supporting the public employment sector estimated to comprise close to 50% of all formal employment positions. Funds supporting the public employment sector are also providing indirect funding to Pohnpei's local economy through purchases of goods and services derived from salaries as well as other government expenditures necessary for everyday operations.

Outside the bounds of the MIRAB model, Compact funds are also indirectly linked to the health and viability of Pohnpei's natural resources. The results of this study show an inverse relationship between formal employment and dependence on natural resources for total household income. As noted above, the conditions of the Compact are providing both direct and indirect funding supporting livelihoods on Pohnpei via the support of public sector employment and through the provision of remittance providing opportunities. Without such opportunities, and unless private sector opportunities are it is very likely there would be a trend towards the over-exploitation of Pohnpei's natural resources.

Given the narrow band of opportunities for the development of Small Island Developing States, a strategy for expanding marketing opportunities for agricultural and fishery products on Pohnpei will have limitations. To complement such a strategy, developing a portfolio of additional possible opportunities needs to be pursued. One such opportunity may be to research the potential for eco-cultural tourism highlighting the unique culture, resources and traditional agricultural practices on Pohnpei. Doing so has the potential to support economic development through establishing private sector opportunities for such activities as “home stays” where visitors are exposed to Pohneaen life while also potentially increasing the demand for locally produced goods. Another strategy is to ensure, if not promote through policy incentives the freedom to travel and work abroad enabling employment and in turn remittance income on Pohnpei. Such strategies would serve as an example for other Small Island Developing States pursuing development that complements their existing livelihoods as opposed to fundamentally changing their way of life.

Table 5-1. Percentage of households per livelihood system involved in various activities on Pohnpei, FSM

Activity	Livelihood System			
	Employment	Agriculture	Fishing	Remittance
Employment-full time	89	0	33	0
Employment-part time	11	17	33	17
Commercial agriculture	94	100	0	86
Subsistence agriculture	100	100	100	100
Commercial fishing	44	17	100	50
Subsistence fishing	44	17	100	100
Remittances	44	33	33	100
Retirement	17	0	0	50
Handicrafts	6	0	0	17

Table 5-2. Impacts of a 25% increase in crop prices per livelihood system on Pohnpei, FSM

Livelihood system	Base case	25% crop price subsidy	Income difference	% change
Employment	$11,537	$11,880	$343	+2.9
Commercial agriculture	$3,303	$3,946	$643	+19.4
Commercial fishing	$1,966	$1,966	$0	0.0
Remittance	$4,536	$4,714	$178	+3.9

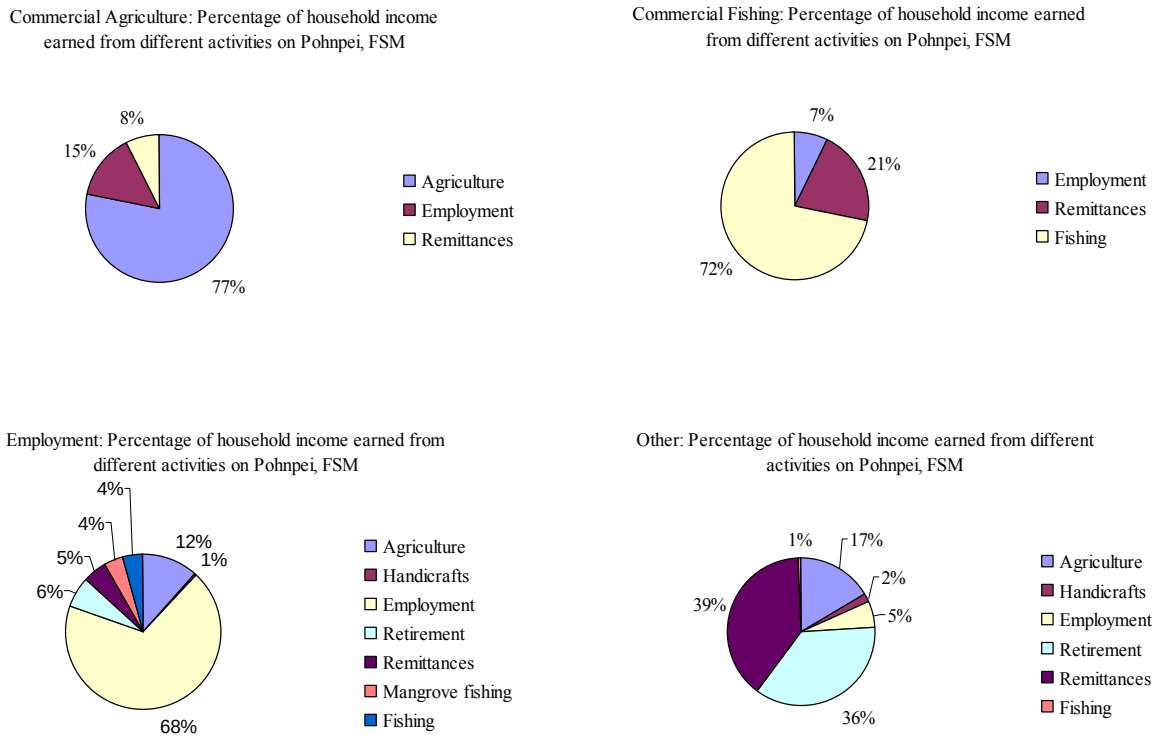

Figure 5-1.Percentage of cash income from different sources per recommendation domain on Pohnpei, FSM

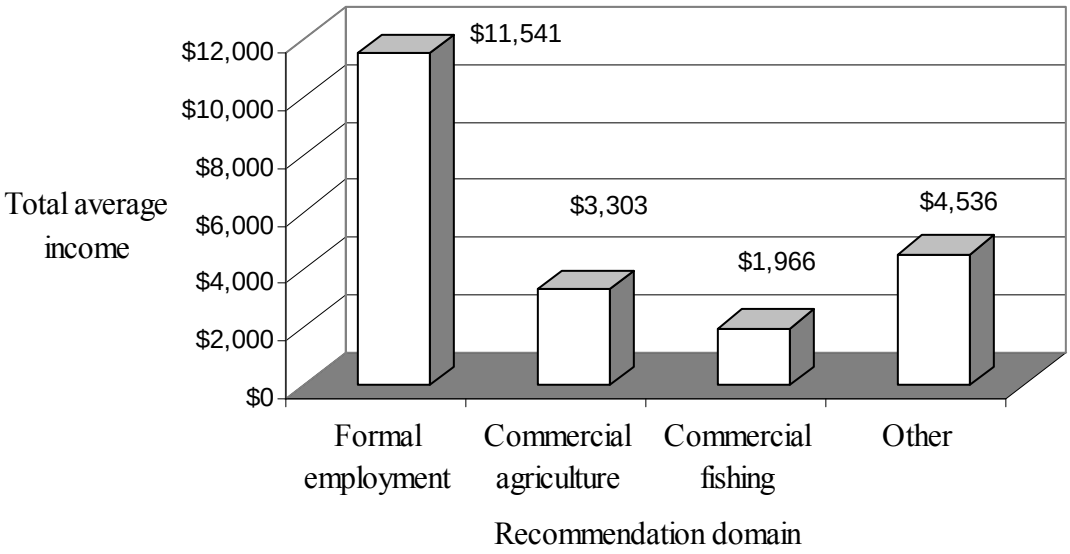

Figure 5-2. Scenario 1-Total annual cash income per livelihood system on Pohnpei, FSM

Table 5-3. Impacts of reducing ceremonial crop constraints by 50% and assuming an international market exists for surplus crops per livelihood system on Pohnpei, FSM

Livelihood system	Base case	International market/50% reduction in ceremonial use	Income difference	Percent change
Employment	$11,537	$11,786	$249	+2.1
Commercial agriculture	$3,303	$3,638	$335	+10.1
Commercial fishing	$1,966	$1,993	$27	+1.3
Remittance	$4,536	$4,714	$153	+3.3

Table 5-4. Impacts of reducing fish consumption constraint by 50% and establishing domestic markets to sell surplus fish per livelihood system on Pohnpei, FSM

Livelihood system	Base case	50% of fish consumption sold in domestic markets	Income difference	% change
Employment	$11,537	$11,733	$196	+1.7
Commercial agriculture	$3,303	$3,327	$ 24	<+1.0
Commercial fishing	$1,966	$2,443	$477	+24.2
Remittance	$4,536	$4,746	$210	+4.6

CHAPTER 6
DETERMINING AGROFORESTRY PROFITABILITY USING THE POLICY ANALYSIS MATRIX

Introduction

In recent times, there has been a push to expand sakau production into the upland areas that have cooler temperatures and greater rainfall than in the lowlands; in the uplands, cultivation time before harvests is generally longer than in the uplands. However, the drive to maximize sakau production in the uplands has led to clearing large areas that in turn are exposed to heavy rains and significant soil erosion. Indeed, based on recent evidence (Kostka and Raynor, 2000), commercial production of sakau in Pohnpei's upland forests is not sustainable, with an estimated 5% to 10% decline in production annually. In contrast, sakau production has been practiced in Pohnpei's homegardens for decades suggesting ecological sustainability of the practice (Raynor and Fownes, 1991a,b).

Non-governmental organizations on Pohnpei are attempting to promote lowland sakau production within homegarden agroforests but continued upland clearing remains a problem. The government of Pohnpei now recognizes the negative impacts associated with upland sakau farming while also recognizing the need on the farmers' part to generate income. Comparing private and social profits for these three systems will provide a building block to develop appropriate strategies for the future use of Pohnpei's resources.

The primary objective of this chapter is to examine the profitability of three different agroforestry systems on Pohnpei, FSM using the Policy Analysis Matrix methodology and to assess how policy may influence their profitability. The three systems are: two homegarden systems differentiated by the presence or not of freshwater swampland and a third upland system cultivated primarily for a single cash crop-sakau. The Policy Analysis Matrix (PAM) methodology is used to assess two different measures of profits: private profitability (PP), or

those profits that are actually realized by practicing farmers; and social profitability (SP), or those profits that in theory would be realized in the absence of policy distortion and/or market failure. This will provide a means to quantify the impacts of current public sector policies and market failures (or lack thereof) for dominant agroforestry systems on Pohnpei. In addition, essential information will also be provided to better understand the current motives of farmers and how potential government strategies may impact the agricultural sector. Moreover, the comparison of profits reveals the underlying comparative advantage of different commodities/systems in question. A secondary objective of this chapter is to provide a framework to expand the traditional PAM allowing for the internalization of non-market values.

During the past few decades, the PAM has been used to quantify profitability and the impacts of policy interventions on dairy systems in Kenya (Staal, 1996), rice in Thailand (Yao, 1997), and rice and sugar in Indonesia (Nelson and Panggabean, 1991; Pearson, *et al*., 1991). Whereas the PAM methodology has been used to measure a single crop produced within an agroforestry system (Adesina and Coulibaly, 1998), to the best of the author's knowledge, the PAM approach has not been used to quantify profitability of multiple crops cultivated within complex agroforestry systems anywhere in the world, let alone within the Pacific region. What follows is first, a brief description of the farming systems being analyzed, as a means to further distinguish them from the "homegarden" and "other" lands discussed in Chapter 3. This is followed by a discussion on the PAM methodology itself. Next, sources of data and the policy scenarios used within our analysis are presented followed by our results and a discussion on the respective findings. The chapter concludes with a few final thoughts regarding the Policy Analysis Matrix as a tool for profitability analyses.

Background and Methodology

Description of Three Farming Systems Being Analyzed

Chapter 2 described general characteristics of the homegardens found on Pohnpei. However, in Pohnpei, like in many other island locales, people have established homes in areas where wetlands exist, combining wetland food production practices with those resembling other homegarden systems. Data collected for this research indicated that homegardens on Pohnpei could be further differentiated by the presence of wetland areas that have been converted into taro patches. Together, these two homegarden systems, homegardens (HG) and homegardens with wetlands (HGW), dominate the agricultural landscape on Pohnpei and therefore both are examined in this study. A third system of interest is centered on the cultivation of sakau, primarily in the uplands of Pohnpei.

The significance of sakau to Pohnpei's economy is growing in response to increasing demand, primarily from the domestic market. At one time used almost exclusively for traditional ceremonial activities, sakau is now more widely used for both social and ceremonial purposes and therefore its economic importance has increased, which has become a mixed blessing. On the one hand, increasing sakau production is contributing both directly and indirectly to economic activity on Pohnpei. On the other hand, recent research has shown that production of sakau has led to the conversion of a significant amount of Pohnpei's remaining intact-upland forests to the upland sakau system (UPS) (ADB, 1996; Kostka and Raynor, 2000). The UPS is best characterized as being less biologically diverse relative to the other two homegardens systems and having much more emphasis on cultivating sakau for ceremonial and commercial needs. While all of the participating households had homegardens 15 of the households had HGW and 18 households had HG systems. Eleven of the participating households were actively cultivating sakau in the uplands using UPS.

Policy Analysis Matrix Methodology

Monke and Pearson (1989) developed the Policy Analysis Matrix methodology in the late 1970s primarily for use in the profitability analysis of single crops within specific cropping systems. The PAM has proven to be an effective tool for analyzing the influence of policy distortions on farmer profits and the willingness of farmers to modify existing practices. For example, trade, domestic factor market, as well as exchange rate policies can be analyzed in relation to their impacts on farm profits (Pearson *et al*., 1991). Additionally, the PAM allows for in-depth analysis of the domestic or international "production chain," i.e., activities involved in the movement of products between the farmgate and markets. As a result, the macro-micro linkages can be clearly illustrated, helping to inform policy makers about the potential tradeoffs and impacts of alternative technologies, as well as revealing the underlying comparative advantage of different commodity systems.

According to Monke and Pearson (1989), the mechanics of the PAM consists of two accounting identities (Table 6-1). The first measures profits based on total revenues less the costs of tradable inputs and domestic factors. The top row of the PAM represents private costs and returns, where profitability (D) is defined as revenue (A) less total costs (B+C). The prices used for calculating private profitability are based on observations, inclusive of any current policy interventions and/or market failures. The second row of the PAM measures social profitability based on the difference between social revenue (E) less social costs (F+G).

In contrast to private prices, social prices are "efficiency prices" or those that would be observed without any policy distortions or market failures. It follows that social revenues and costs reflect the underlying scarcity values and if used in actual decision-making would reflect the optimal allocation of resources from an economic efficiency standpoint. While relevant

values for the calculation of private profitability are derived directly from actual observed prices at the farm and markets, determining social values is more complex.

Social prices for those commodities traded in the international market, both inputs and outputs, are derived using world market prices; CIF (cost, insurance, freight) price for imports and/or the FOB (freight on board) for exports. Both CIF and FOB prices provide the basis for calculating the import and export parity prices needed for determining farm level revenues and costs. For example, the "social" farmgate cost of imported fertilizer used within a farming system is its CIF price plus the marketing and distribution costs of moving the goods from the dock to the farmgate. In contrast, farmers exporting their goods would expect to realize the FOB price less the costs of processing, marketing, and transporting their goods to the dock in a distortion free setting. Calculating parity prices allows a policy analyst to identify the impacts of policy intervention(s) at all stages of production. Social prices for domestic factors are based on social opportunity costs reflecting underlying domestic factor market conditions. For example, in the case of labor, assuming a functioning labor market freedom of movement among laborers, the social price would be equivalent to the going market wage rate.

The second accounting identity (third row of the PAM) allows for the calculation of divergences between private and social revenues, costs, and profits resulting from policy impact(s) and/or market failures. The third row of the PAM also allows for determination of the direction of transfers between producers, government budgets, and consumers. The signs of each of the variables in the third row facilitate determining whether producers are being "taxed" or "subsidized." To quantify costs and benefits resulting specifically from externalities, these costs and benefits can be disaggregated from policy distortions and labor, land, and credit market failures by incorporating an additional private and social prices row (Table 6-2). For example, in

the case of an environmental tax on outputs being assessed to mitigate the costs of soil erosion, the farmer would realize these costs, thereby internalizing them and, as such, the outcome would be reflected in the private prices$_2$ row within "A_2". On the other hand, where externalities are generated from, for example, carbon sequestration, yet the farmer is not internalizing benefits derived from this additional output of the farming system, the values of these, externalities would be included in the social prices$_2$ row within "E_2". The net effects of both policy distortions and market failures are still found within the second accounting row, but in this case, "I" would be equal to the $\Sigma(A_1+A_2) - \Sigma(E_1+E_2)$. Likewise, the net transfers for each of the remaining costs and in turn profits would be calculated accordingly.

The PAM also allows for the determining policy parameters for measuring the impact of policies on single-commodities, whole farm production systems, and comparing multiple systems. Most notably among these parameters are the nominal protection coefficient (NPC), effective protection coefficient (EPC), the private cost ratio (PCR), the domestic resource cost (DRC) and the profitability coefficient (PC). Each of these parameters is briefly described in Table 6-3.

Data Specifications and Policy Scenarios

Data used for this analysis were collected from randomly selected households as described in Chapter 3. In each of the homegardens, all of these crops are being cultivated albeit in different quantities as a function of the presence/absence of the wetlands. In contrast, in most areas where the UPS are located, sakau is the primary, if not the only crop being cultivated. Land area per household was based on either owner documents or using local landmarks as proxies to estimate land area used/owned by each household. Data for all three systems were derived from "mature" agroforests in which the perennial components had attained fruit-bearing age.

Averages for labor inputs and crop outputs per hectare were determined for each of the three respective systems providing the basis for cost and revenue estimates. Prices used to determine values for the crops harvested were based on those observed by farmers throughout the same one-year time period. The price of labor was based on Pohnpei's minimum wage rate[1]. All farm operations were manual; no form of mechanized farming was used. Only 5% of households indicated that they used any production inputs other than labor (the purchase of planting materials is almost nonexistent on Pohnpei where farmers obtain needed planting materials from their own farm plots). Farm profits were derived using the total value of outputs less costs of labor.

There is no current trade or pricing policies contributing to divergences between private and social prices involving the HG and the HGW systems. Yet, these systems are providing a positive externality in the form of carbon sequestration. Farmers practicing either the HG or the HGW systems are not currently receiving payments for carbon being sequestered within these systems, and therefore, payments for carbon are not considered within the private profitability calculation. Instead, assuming a functioning carbon market in Pohnpei (correcting for a market failure), farmers would receive payment and, thus, values for sequestration are to be included in the social profit calculation. More specifically, given carbon sequestration is produced within a specified system, in the PAM it is accounted for in "E_2" or in the social "output" calculation. For complex tropical agroforests, average values for carbon sequestration rates have recently been estimated to range between 1.5 to 4 Mg ha^{-1} yr^{-1} (Palm *et al*., 2000; Montagnini and Nair, 2004). For carbon sequestration value determination in the HG system, an average of these values (2.75

[1] Pohnpei's minimum wage in 2001 was US$1.35 hr -1. Given the significant unemployment rate, the actual opportunity cost of labor is likely to be closer to US$0.00. Regardless, there is essentially no hiring of labor for farming purposes on Pohnpei; instead, the immediate household members, friends, or extended family provide the labor.

Mg ha^{-1} yr^{-1}) was used. Research conducted on another island in Federated States of Micronesia (Kosrae) has shown that wetland-based agroforests similar to those in Pohnpei have carbon sequestration rates approximating 2.3 Mg ha^{-1} yr^{-1} (Chimmer and Ewel, 2002), which is used for the HGW system in this analysis. Prices for carbon sequestration are generally between US$10 and US$30 Mg $^{-1}$ (Niles *et al.,* 2001).

In contrast to the two homegarden systems, carbon values were not included for the PAMs derived from the UPS system. The process of clearing much of the existing vegetation from the land, removing sakau roots and the process of harvesting sakau resulting in substantial soil loss and disturbance, may actually lead to a net carbon loss in these systems. Moreover, cultivating sakau in the uplands has increased downstream erosion, negatively affecting the coral and fishery resources in local lagoons. Thus, the amount of potential carbon sequestered is compromised resulting from extensive soil disturbance and negative externalities stemming from erosion generate costs not currently internalized by those farming in the uplands.

The "external" cost(s) of erosion resulting from the UPS are incurred by Pohnpeaens yet are not being paid for by the farmers responsible for them. As such, profits realized by the farmers actually reflect greater values than if they were paying the full cost of their cultivation activities (i.e., private profits are greater than social profits by an amount equivalent to the costs of the erosion impacts). While exact costs of erosion stemming from upland sakau production has not been determined, for our analysis, we have assumed a difference of 10% between the private and social output price of sakau for the UPS to reflect these costs. This assumption is based on the premise that if farmers in the uplands were to be assessed a 10% "environmental" tax (reflected in the "A_2" calculation) on the production of sakau the receipts from such a tax would be sufficient to pay for the "downstream" impacts associated with upland farming. Profits

for these three systems are therefore not only affected by the composition and quantity of the different products being produced, but also the effects of the presence of two externalities, one positive (carbon sequestration) and one negative (erosion).

Based on numerous discussions with local farmers and extension agents on Pohnpei, evidence to date suggests that each of the two homegarden systems (HG and HMW) are producing a consistent quantity of outputs from year to year using the same level of labor inputs. As such, we assume that the annual data collected for this study represent inputs and outputs that remain constant from one year to another for both of the homegarden systems. On the other hand, Pohnpei farmers reported an unsustainable 10% annual decline in sakau cultivated in the UPS.

It is valuable to examine how changes in crop productivity as well as any proposed policies may influence farmer profits, and in turn, how these influences are likely to factor into farming decisions over time. Given the consequences of upland sakau production, policy makers on Pohnpei are interested in determining what strategies may keep farmers from further expanding into the uplands. From an economic policy standpoint, pricing policies in the form of taxes and/or subsidies are often used as incentives (or disincentives) to achieve a desired outcome. Here, in addition to examining how a 10% per annum decline in sakau yields in the UPS influences farmer profits, we also explore how two such policies, a subsidy on outputs from the two homegarden systems and an "environmental" tax on sakau from the UPS are likely to influence future farming activities on Pohnpei.

Within the context of the PAM methodology, it is necessary to calculate net present values (whereby future values are discounted into today's currency terms) for revenues, tradable and non-tradable inputs, and domestic factors to measure divergences that may exist over time and

how they influence profitability outcomes. In theory, if elasticities of supply and demand were known for Pohnpei's economy, one could examine the dynamic effects associated with price and production changes over time. However, such data are nonexistent in Pohnpei. As a result, we assume constant output prices for all three systems, constant input and output coefficients for the HG and HGW systems, and annual sakau yields declining by 10% for the UPS. In the Federated States of Micronesia, the currency used is the US dollar; therefore all financial and economic values are in US dollar denominations.

Results

Table 6-4 provides the profitability results for a single year's outcome under the current and potential policy scenarios of Pohnpei. For all three systems, under existing policies (first column of results), both private and social profits are positive, indicating that farmers on Pohnpei have financial incentives to continue farming all three systems.

Profits are greatest for the UPS (\$1,412 ha^{-1} yr^{-1}) followed by the HG (\$954 ha^{-1} yr^{-1}) and HGW (\$906 ha^{-1} yr^{-1}), explaining why farmers continue to move into the upland areas to farm. Comparing the second column of results, even if a carbon market was established and farmers in the uplands were taxed 10% for their erosion impacts, the social profit values generated from the UPS are still greater than the HG and HGW indicating that even with a 10% erosion tax, further expansion into the uplands is likely to continue.

Since policy makers are interested in minimizing impacts of sakau planting in the uplands and profits are currently far greater for the UPS than for either the HG or HGW, policy intervention in the form of economic incentive/disincentives may be necessary. The last three columns in Table 6-4 present how a range of subsidies on outputs from the two homegarden systems and erosion taxes on sakau in the upland system, are likely to influence both potential profits and farmer motivation for land use decisions.

First, consider a subsidy of HG and HGW in the absence of sakau erosion taxes. The subsidy rate necessary to persuade farmers to abandon upland activities would need to be at least 31%. At a rate of 31%, profits from all three systems would be essentially the same ($1,407 ha^{-1} yr^{-1}, $1,417 ha^{-1} yr^{-1}, and $1,412 ha^{-1} yr^{-1} for the HG, HGW, and UPS respectively). Under this policy, the government would also incur a budgetary cost of between $398 ha^{-1} yr^{-1} for the HG farmers to $464 ha^{-1} yr^{-1} for the HGW farmers. Given the existing limitations on the government budget on Pohnpei, combined with increasing demands to minimize government spending as a result of the new Compact agreement, this scenario is highly unlikely to be feasible without the provision of overseas grants.

A more practical alternative from a government budgetary perspective would be to assess a tax on sakau produced in the uplands. Under this scenario, the tax rate required to persuade farmers to abandon their upland activities is 27.5%, a value equivalent to a profit reduction of $507 ha^{-1} yr^{-1} for upland farmers (Table 6-4). Any tax rates less than 27.5% would result in greater profits for the UPS relative to the HG and HGW while a rate higher than 27.5% would, in theory, provide enough of an incentive to persuade farmers to adopt either of the two homegarden systems. If farmers still wanted to maintain activities at or near the margin in the uplands, the government could generate revenues from this policy that are above and beyond what is likely to be required to mitigate erosion impacts from these activities. The results presented above are based on profits for a 1-year time period. We now turn to how these profits are influenced for two longer time periods, (1) a 5- year time horizon and (2) a 10-year time horizon, testing the sustainability of these three production systems. We noted earlier that anecdotal evidence suggests that while both of the homegarden systems produce a sustainable flow of outputs, sakau yields in the uplands decline by about 10 % annually.

For the HG and HGW, a sustainable stream of private profits of $954 and $906 for 5 years respectively would produce a net present value of $3,616 ha $^{-1}$and $3,436 ha^{-1} if discounted at 10% (Table 6-5). The net present value of profits for the UPS is $4,213 ha $^{-1}$ using the same discount rate and time period but with production declining 10% annually[2]. Even taking into account the declining productivity of upland sakau over a five-year period, under the existing setting on Pohnpei, farmers in the uplands would still generate greater profits relative to the mother systems and therefore will continue to farm in these areas.

Although during the one-year period, establishing a carbon market and accounting for erosion costs does not change the order of profits for each of the three systems, these policy interventions combined with the declining sakau production in the UPS results in the HG generating the greatest profits with the HGW and UPS profits differing by only $20 ha $^{-1}$ (Table 6-5). Thus, in trying to achieve the government's objective of persuading upland farmers to move down to the lowlands, correcting for the existing market failures considered here would result in profits for all three systems being almost equal if farmers operate under a 5 year time horizon and a 10% discount rate.

If, alternatively, the government preferred a pricing policy in the form of a subsidy on homegarden outputs, the sustained output of crops in the two homegarden systems combined with a decline of sakau production would result in a subsidy rate far below that of the one-year period. Table 6-4 shows that a price subsidy on outputs from the HG and HGW systems of 10% would not provide a sufficient financial incentive for upland farmers to halt their activities.

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[2] For a comparison, the private real present value of $954 ha –1 yr –1, $906 ha –1 yr –1, and $1,412 ha –1 yr –1 incomes for the HG, HGW and UPS systems respectively discounted at 15% would be $3,197 ha –1, $3,038 ha –1, and $3,771 ha –1: discounted at 5.0% private real present values would be $4,130 ha –1, $3,924 ha –1, and $4,748 ha –1 for the HG, HGW, and UPS systems respectively.

However a subsidy rate of 12.5% or more would result in greater profits for the two homegarden systems relative to the upland system and in doing so, provide a financial justification for upland farmers to adopt either of the two homegarden systems.

Under the subsidy policy discussed in Table 6-5, and in order to attract upland farmers to adopt either of the two homegarden systems, the government would incur costs in the amount of between \$485 ha $^{-1}$and \$602 ha $^{-1}$over five years. While for a one-year period, the subsidy approach appears unlikely, payments based on a 12.5% subsidy over a five-year period may be more feasible. Indeed, on average, annual payments per hectare would range between \$97 for the HG and \$120 for the HGW.

Considering a tax on sakau produced in the UPS, a rate of 10% would equate to private and social profits being equal at \$3,634 ha $^{-1}$ (Table 6.5). Moreover, with a tax of only 10%, the UPS still generates greater profits than either the HG or HGW (in the absence of lowland subsidies). The impact of a 12.5% tax on sakau would result in the HG being more profitable than the UPS by a margin of \$126 ha $^{-1}$. At the same time, the UPS would still generate greater profits relative to the HGW by a margin of \$54 ha $^{-1}$. Thus in order to generate profits for both the HG and the HGW greater than the UPS, and thereby inducing upland farmers to adopt either the HG or HGW a tax of 15% would be necessary equating to a reduction in UPS profits by \$289 ha $^{-1}$.

As more time is taken into consideration, the ecological sustainability of these systems becomes much more pronounced. Table 6-6 shows that as a result of declining sakau yields in the UPS under the current policy setting, the net present values for both the HG and the HGW

systems becomes greater than for the UPS ($5,861 ha^{-1}, $5,569 ha^{-1}, and $5,358 ha^{-1} respectively)[3].

For those farmers and policy makers interested in generating greater profits over the long-term, the fact that sakau yields decline at such a rate in the UPS would, in theory, provide enough of an impetus to convince more farmers to forgo planting in the upland areas. However, given the limited opportunities to generate income, both in the short and long-term time period, farmers may still be inclined to continue farming the uplands as a means to generate greater income in the immediate time frame. In order to further persuade farmers to leave the upland areas, it may be necessary for the government to provide additional incentives.

Thus far we have examined profitability of three agroforestry systems based on actual dollar values. When comparing systems having identical commodities being produced, both the private and social profits are suitable indicators of relative competitiveness. When considering systems producing different outputs, or similar commodities using differing technologies or in different ecological settings, it is useful to examine the ratios (defined in Table 6-3) to ascertain the relative competitiveness of systems and the extent of policy divergences. Three such coefficients, the profitability coefficient (PC), the private cost ratio (PCR), and the domestic resource cost ratio (DECRY), derived from the PAMs under the current policy setting (ten-year time period) are shown in Table 6-7. For the profitability coefficient, an indicator of the net transfer effects, it is evident that the UPS system, having a value > 1 indicates that farmers are receiving an implicit subsidy whereas farmers engaged in the two homegarden systems are

[3] Once again for comparison, the private real present value of $954 ha –1 yr –1, $906 ha –1 yr –1, and $1,412 ha –1 yr –incomes for the HG, HGW and UPS systems respectively discounted at 15% would be $4,787 ha –1, $4,549 ha –1, and $4,596 ha –1: discounted at 5.0% private real present values would be $7,365 ha –1, $6,998 ha –1, and $6,370 ha –1 for the HG, HGW, and UPS systems respectively.

implicitly being taxed due to the nonexistent carbon market. Moreover, the relative value of the impacts is greatest for the upland system, inferring that correcting for the lack of a carbon market would have less of an impact on the two homegarden systems than correcting for the external costs associated with erosion. There is less of a relative difference when considering the private cost ratio and domestic resource cost ratio for these three systems.

Indeed, even though the UPS system has the lowest PCR and DRC ratios implying that for each unit of domestic resources used to produce sakau in the uplands greater profits are realized, both of these ratios infer that domestic resources are being used to generate positive profits both in private and social terms[4].

Discussion

The Policy Analysis Matrix methodology has been applied here to determine the relative profits and use of domestic resources associated with three agroforestry systems on Pohnpei. In Pohnpei, agroforestry systems have traditionally played an important role, primarily as the main source of food security, and to a lesser degree for commercial purposes. As the local economy continues to become more integrated into the global economy, so have preferences for western goods and subsequently the desire to increase household incomes for their purchase.

To develop Pohnpei's economy, one such strategy that historically has been promoted by government officials involves taking advantage of Compact funds from the United States to inflate the public sector work force, thereby providing employment to local citizens. The renegotiated Compact (Compact II) remains the primary source of funding supporting formal employment on Pohnpei, however, the amount of funding for this purpose will decline as

[4] A PCR or DRC value of 1 indicates that a marginal increase in domestic resource use generate the exact same amount in value-added. Similarly, a PCR/DRC < 1 reflects a relative efficiency value for the use of domestic resources. A smaller value indicates greater value-added per unit of domestic resources.

Compact II comes to a close in 2023. Nonetheless, the opportunities that Compact funds have provided, combined with relatively high wages paid for public sector jobs has led to a declining interest in agriculture on the part of the private sector, particularly for cash income needs.

The United States mandated a smaller public sector as a condition of the newly negotiated Compact, which directly impacts the government's role as the largest employer on the island. With already very limited private sector opportunities, local families are turning to the upland areas of Pohnpei establishing unsustainable agricultural systems to increase income levels and/or replace prior income sources due to the loss of public sector jobs. To date these actions are generating income for local families. Yet, they are also negatively impacting the local environment, and in turn other natural resources heavily depended upon by much of Pohnpei's population. In such situations where limited economic opportunities exist, private individuals often place a greater value on achieving short-term needs, even if it entails forgoing personal potential future benefits, or those that may be accrued by other members of society. In contrast, policy makers are often more concerned with potential benefits that may be accrued to all of society. In this sense, a policy maker is often more inclined to promote agricultural systems that use available resources in economically efficient manner.

Results presented here illustrate a dilemma often faced by policy makers, and now facing those on Pohnpei. On the one hand, a stated goal of the government is to promote increasing income by developing the agricultural sector. Based on our results, the upland system is most apt to do so in the short-term. On the other hand, the government is interested in economically efficient and ecologically sustainable use of limited local resources. If this last objective is to be realized, it is critical to consider the profitability over a longer time, particularly if a known unsustainable system is currently expanding.

When considering the results of a one-year and a five-year period under the current situation on Pohnpei, profits remain greater for the UPS than either of the two homegarden systems. Assuming the government intends to promote agricultural development farmers practicing the UPS interested in maximizing short-term profits will likely require policy intervention to adopt either of the two homegarden systems. In this chapter we have presented how different policy strategies may contribute to achieving this objective, namely (1) correcting for the current market failures, (2) establishing a subsidy for outputs derived from both homegarden systems, and (3) levying a tax on sakau produced in the upland system. On the other hand, for those farmers interested in maintaining a steady income over a longer time period, maintaining, or adopting either of the homegarden systems is likely to ensure such an outcome. In either case, policy makers can now be more informed about why farmers are engaged in their respective systems and what might be done to influence the future of Pohnpei's agricultural sector.

Concluding Comments on the Policy Analysis Matrix Methodology

The Policy Analysis Matrix provides a means by which the impacts of policy and market failures can be quantified. In doing so, it allows not only for the quantification of individual policies, but also the quantification of the aggregate impacts of all policies affecting farmers currently engaged in different agricultural practices. Having the ability to analyze individual as well as the total impacts of policies can provide an important function in settings where different public institutions have established policies in an uncoordinated fashion, all of which have a common objective, but that ultimately work against one another. In this regard, the PAM can aid in untangling policies unsuccessful in their symbiotic goal. Another useful aspect of the PAM is its utility in analyzing the potential of agricultural technologies under consideration. Once developed, sensitivity analysis can easily be carried out allowing for the impacts of new or

modified policies to be explored. In addition, the PAM, while somewhat complicated "behind the scenes" provides a fairly simple means to examine dynamics taking place at all levels of the production chain. This can be particularly important to policy planners when attempting to identify where and how policy intervention is most likely to result in the desired outcome. The case study presented here provided a unique opportunity to apply the PAM methodology within the context of agroforests over a multi-year time frame. This chapter also illustrated how the traditional PAM model could be expanded upon to include benefits derived from an ecological service even when a market for them is absent (i.e., correcting for the absence of a carbon market). In our case, carbon sequestration represents a benefit realized by society at large but results from an individual's actions. Other externalities, be they positive or negative, could also be incorporated into the PAM framework. The difficulty does not necessarily lie in determining how or where to include the cost or benefit of an externality within the PAM framework, but instead ascertaining relevant and accurate values to be used.

One limitation of the PAM methodology stems from the frequent use of fixed input-output coefficients making it more difficult to determine the dynamic effects attributable to policy shifts. As noted above, one means to address this dilemma is to determine price elasticities of supply and demand, as well as cross price elasticities of demand allowing for estimates of how farmers may respond to various policy interventions. Although this may be the case, in settings such as Pohnpei where the cash-economy is still developing, commodity choices are limited and motives of farmers are influenced by traditional norms, reliable estimates of elasticities are often difficult to obtain and thereby may limit the utility of PAMs under dynamic scenarios. This is not to say that certain assumptions pertaining to various elasticities could not be made and the robustness of the results tested through sensitivity analysis. Yet the PAM methodology was not

developed as an ultimate means to derive perfect results under all circumstances. Instead, it is a tool to empirically determine how public intervention(s), or lack thereof, may influence the decisions of those participating in the agricultural sector and in turn, how those decisions may affect government resources.

Table 6-1.Policy Analysis Matrix (PAM) framework

	Revenues	Costs		
	Output	Tradable inputs	Domestic factors	Profits
Private prices	A	B	C	D
Social prices	E	F	G	H
Effects of policy distortions and divergences	I	J	K	L

Private profits "D" = (A-B-C)
Output transfers "I" = (A-E)
Factor transfers "K" = (C-G)
Social profits "H" = (E-F-G)
Tradable input transfers "J = (B-F)
Net transfers "L" = (I-J-K) or (D-H)

Table 6-2.Policy Analysis Matrix expanded to incorporate externalities

	Revenues	Costs		
	Output	Tradable inputs	Domestic factors	Profits
Private prices$_1$	A_1	B_1	C_1	D_1
Private prices$_2$	A_2	B_2	C_2	D_2
Social prices$_1$	E_1	F_1	G_1	H_1
Social prices	E_2	F_2	G_2	H_2
Effects of policy distortions and divergences	I	J	K	L

Table 6-3. Coefficients derived from the Policy Analysis Matrix used to measure the relative impact(s) of policies or market failures

NPC = A/E: a ratio that contrasts private and social output values. A NPC > 1 is indicative of private prices of output being greater than social prices reflecting that producers are positively protected.
EPC = (A-B)/(E-F): the ratio of value added measured at private vs. social prices. Unlike the NPC and the NPI that measure the effect of divergences for output and tradable input prices respectively, the EPC measures the total effects of intervention in both markets. The implication of EPC > 1 is that there is an overall artificial incentive to produce a commodity due to the presence or absence of policies.
PCR = C/(A-B): the ratio of domestic factor prices to value added at private prices. It identifies the cost of domestic resources in private prices necessary to produce a unit of value added. A PCR between 0 and 1 indicates that in private terms, domestic resources generate more than their value in value added.
DRC = G/(E-F): the ratio of domestic factor prices to value added at social prices. It shows the cost of domestic resources in social prices needed to produce a unit of value added. If the DRC > 1 the commodity system is not desirable from an economic efficiency standpoint.
PC = D/H: measures the incentive effect of all policies and provides a ratio to determine the relative net policy transfers. A PC = 1 indicates no net transfers

Source: Monke and Pearson (1989)

Table 6-4. Estimates of private and social profitability calculated using the Policy Analysis Matrix (PAM) methodology, for a one-year period over the three dominant agroforestry land-use systems in Pohnpei, Federated States of Micronesia

	Policy scenarios			
Farming system	Existing: no carbon market (US \$ ha^{-1} yr^{-1})	10.0% output price subsidy (US \$ ha^{-1} yr^{-1})	15.0% output price subsidy (US \$ ha^{-1} yr^{-1})	31.0% output price subsidy (US \$ ha^{-1} yr^{-1})
Home Garden				
Private	\$954	\$1,100	\$1,173	\$1,407
Social	\$1,009	\$1,009	\$1,009	\$1,009
Divergence	-\$55	\$91	\$164	\$398
Home Garden Wetland				
Private	\$906	\$1,071	\$1,153	\$1,417
Social	\$953	\$953	\$953	\$953
Divergence	-\$47	\$118	\$200	\$464
Upland System				
Private	\$1,412	\$1,229	\$1,138	\$906
Social	\$1,229	\$1,229	\$1,229	\$1,229
Divergence	\$183	\$0.0	-\$91	-\$324

Table 6-5. Estimates of five-year net present values based on a 10% discount rate for private and social profitability calculated using the Policy Analysis Matrix (PAM) methodology, for the three dominant agroforestry land-use systems in Pohnpei, FSM

	Policy scenarios			
Farming system	Existing: no carbon market (US \$ ha^{-1} yr^{-1})	10.0% output price subsidy (US \$ ha^{-1} yr^{-1})	12.5 % output price subsidy (US \$ ha^{-1} yr^{-1})	15.0% output price subsidy (US \$ ha^{-1} yr^{-1})
Home Garden				
Private	\$3,616	\$4,170	\$4,309	\$4,448
Social	\$3,824	\$3,824	\$3,824	\$3,824
Divergence	-\$208	\$346	\$485	\$623
Home Garden Wetland				
Private	\$3,436	\$4,060	\$4,216	\$4,372
Social	\$3,614	\$3,614	\$3,614	\$3,614
Divergence	-\$178	\$446	\$602	\$759
Upland System				
Private	\$4,213	\$3,634	\$3,490	\$3,345
Social	\$3,634	\$3,634	\$3,634	\$3,634
Divergence	\$578	\$0.0	-\$145	-\$289

Table 6.6 Estimates of ten-year net present values based on a 10% discount rate for private and social profitability calculated using the Policy Analysis Matrix methodology, for the three dominant agroforestry land-use systems in Pohnpei, FSM

Farming system	Policy scenarios: Existing: no carbon market (US $ ha^{-1} yr^{-1})	Existing: with erosion costs not internalized (US $ ha^{-1})
Home Garden		
Private	$5,861	
Social	$6,199	
Divergence	-$338	
Home Garden Wetland		
Private	$5,569	
Social	$5,852	
Divergence	-$283	
Upland System		
Private		$5,358
Social		$4,567
Divergence		$791

Table 6-7. Ratio indicators derived from Policy Analyses Matrices for three dominant agroforestry land-use systems for a ten-year period discounted at 10%, in Pohnpei, FSM

Ratio Indicators	Homegarden	Homegarden Wetland	Upland Sakau
Profitability coefficient (PC)	0.96	0.97	1.11
Private cost ratio (PCR)	0.35	0.45	0.35
Domestic resource cost ratio (DRC)	0.34	0.44	0.38

CHAPTER 7
DISSERTATION SUMMARY

The populations of many Small Island Developing States (SIDS) have a long history of reliance on natural resources, particularly agriculture and fisheries, for their survival. An in-depth understanding of SIDS' continued reliance on agriculture and other natural resources is important for formulating development strategies. The research conducted for this dissertation illustrated how traditional agriculture is fundamentally intertwined in the lives of people living on Pohnpei, an island state within the Federated States of Micronesia (FSM).

This research centered on quantifying the productivity, value, and use of Pohnpei's agroforests at the household level. Through the extrapolation of household-level data, the total productivity and value of Pohnpei's agroforests to the island's economy were determined. In turn, these same data were used to assess the influence of market access and employment on household income from agriculture.

Household-level data also provided the basis for understanding the role of agriculture within Pohnpeaen livelihoods. Utilizing ethnographic linear programming, livelihood systems were analyzed to establish how different livelihood strategies employing an array of activities can be employed to achieve cash incomes for each of the livelihood systems. The analysis was extended to simulate the effects of different crop-pricing policies and of market expansion on incomes for a broader group of households.

Household data were also used to quantify the productivity per unit area of different agroforestry systems on Pohnpei. Using the Policy Analysis Matrix methodology, production values were then used to calculate profits per unit area for the different systems. More specifically, profits for farmers in the presence of market failures (private profitability) and in the absence of market failures (social profits) were determined. This analysis not only allows one to

measure the tradeoffs of using different agroforestry systems, it also provides insight into how farmer behavior might change in response to an introduction of a new technology and/or a changing policy environment. Such an analysis can be extended to assess private and social profits at a state or national scale and to assess the tradeoffs associated with policies.

Pohnpeaen households derived benefits from their agroforests equal to nearly half the island's median household income. The majority of these values were derived from homegardens and were based on consumptive values signifying both the importance of homegarden agroforests and their contribution to food security. Moreover, in 2002 agroforests provided between 6%and 72% of total household cash income, depending on whether households have access to off-farm employment, and the extent to which they are involved with fishing and/or receiving remittance and retirement payments. During the same period, the value of Pohnpei's agroforests at the island-wide scale was more than $16 million or nearly 20% of Pohnpei's annual GDP. Greater market access could increase cash income for some segments of the population but would have only limited impacts on those livelihood systems reliant primarily on fish and/or remittances for cash income. While increased market access could expand opportunities for commercial agriculture, off-farm employment significantly reduces reliance on agriculture for cash income.

Given the long history of agroforestry on Pohnpei and the fact that agroforestry is still a dominant component of the island's livelihoods, it is logical that agroforestry should remain at the forefront of future development strategies. Although there are geographic, cultural, and economic differences among the other three states constituting the Federated States of Micronesia (Yap, Chuuk and Kosrae), livelihood strategies and the contribution that agroforests make to the populations of these islands are similar to those found on Pohnpei. As such,

development strategies, whether infrastructural improvement, expansion of off-farm employment, market expansion or changes in a crop-pricing policy, would will have similar ramifications on the livelihoods throughout the FSM.

Livelihoods in Pohnpei and that of the FSM – which, in terms of per capita GDP, lies midway along the continuum of SIDS worldwide – center around agriculture and the public sector. However, this is not necessarily the case for all other SIDS. Indeed, in many other regions of the world, SIDS that are economically advanced may pursue different development strategies. In general, agriculture plays only a minor part in the livelihoods in SIDS that are at the upper end of the development continuum (e.g., the British Virgin Islands). On the other end of the development continuum, other SIDS remain highly dependent on other sources of income (e.g., Kiribati). Although all SIDS must pursue an integrated approach for achieving sustainable development, each one has a unique pattern of traditional resource use and contemporary livelihood systems. Once such an understanding of distinct livelihood systems are realized, future development will be more informed and apt to focus on programs more appropriate for the local setting.

The approach employed for this research was based on the need to meet specific research goals as they related to SIDS in the western Pacific. The approach builds on the foundation of household data to analyze livelihood system and strategies and to serve as a basis for profitability analysis, and it has applicability to SIDS world-wide. Critical to the success of implementing such an approach elsewhere is the recognition that in all settings there will be unique – and, often challenging – circumstances that require flexibility and an adaptive approach in order to achieve research objectives.

Future research needs: This study quantified the value and use of agroforestry products on Pohnpei based on seven of the most commonly cultivated crops. However, past research conducted throughout the Pacific has documented the cultivation and use of many more agroforestry products throughout the region. The estimation of the total value of agroforests on Pohnpei can therefore be considered conservative. Building on this study and relevant past research could be a first step in fully accounting for the total value of Pohnpei's agroforests.

The simulations conducted using ethnographic linear programming provided insight into the impacts of household income relative to changing policy and market conditions. However additional insight could be gained by simulating technological changes such as the introduction of new crops and/or increasing production of existing crops through the use of either improved crop varieties or the use of synthetic inputs such as fertilizers. Before doing so, research to determine potential marketing opportunities would need to gauge additional demand for existing and/or new crops. Furthermore, research conducted in consultation with farmers and extension agents to determine which crops might be appropriate, given the biophysical and cultural setting, would be necessary. Once potential technological changes have been identified, using the ethnographic linear programming models developed for this research along with the Policy Analysis Matrix methodology, further analyses could be conducted to determine the potential for profitability and adoption of those technologies.

Further research is needed on identifying to what extent, if any overseas aid aimed primarily at economic development is contributing to the conservation of Small Island Developing State's natural resources. Within the FSM, overseas aid in the form of Compact II funding is largely responsible for maintaining formal employment. The present study has shown that households having members formally employed derive the vast majority of their income

from employment earnings. Additionally, these same households have shown less of a dependence on agricultural and fishery resources relative to other livelihood systems. Therefore it could be inferred that Compact II funding is helping to reduce pressure on Pohnpei's limited and fragile resource base for economic gain. As Compact II funding continues to decline in the coming years, it will be important to determine if similar trends associated with the relative dependence on employment and natural resources change, and, if so, in what direction. Understanding how overseas aid contributes to local economies and the relative dependence on natural resources is necessary to evaluate the potential tradeoffs of reducing aid packages and the need to ensure the health and viability of an island's natural resources.

APPENDIX A
HOUSEHOLD SURVEY

Household name: Kousapw:
Interviewee age: Age of house:

Number of adults (18 yrs. or older): Male: 1 2 3 4 5 6 7 8 9 10
Female: 1 2 3 4 5 6 7 8 9 10

Education grade completed for each adult:

	Grade for each male and female									
Males										
Females										

Number of children between ages 8-18 years: Male: 0 1 2 3 4 5 6 7 8 9 10
Female: 0 1 2 3 4 5 6 7 8 9 10

Number of children younger than 8 yrs: Male: 0 1 2 3 4 5 6 7 8 9 10
Female: 0 1 2 3 4 5 6 7 8 9 10

Number of children attending school Monday –Friday: 0 1 2 3 4 5 6 7 8 9 10

Number of land parcels owned by members of households: 0 1 2 3 4 5

Name of land parcel where house is located: _____

Name of each parcel owned by a member of the household not including where house is located:

Parcel name	Kousapw	Municipality	Agroforests? Y or N
1.			
2.			
3.			

Number of agroforests used by family members but not owned? 0 1 2 3 4 5

Parcel name	Kousapw	Municipality
1.		
2.		

Are there any crops that you plant only in the home garden plot and not in other agroforests? Y N

Plant name	Reason/Why
1.	
2.	

Number of Livestock:

Livestock type	Number per household	Sell ? Y or N
Chickens		
Pigs		
Dogs		
Other		

How much time do you spend feeding pigs each day?

Who in the family feeds the pigs most often? Adult male Adult female Male child Female child

Do you purchase any items that you use for your farm?

Input name	Type purchased	Estimated weekly use (quantity)
Fertilizer		
Seedlings		
Pig feed		
Other		

What is the main method of cooking? Fire Kerosene Electric stove Um
If fire, where do you obtain most of your fuel wood from?

Purchase	Home garden	Agroforests	Mangroves	Other

Do your agroforests lands produce enough food for your household needs? Y N
If no, what more would you like to be able to produce in your agroforest?

Plant name/type	Purpose	Reason why not currently producing crop/plant
1.		
2.		

How important is your home garden to your household? 1 2 3 4 NA
For what reason(s)?

Food	Prestige	Income	Other

How important are your other agroforests to your household? 1 2 3 4 NA
For what reason(s)?

Food	Prestige	Income	Other

What is your future plan for your land (s)?

What are the biggest constraints to farming for your family?
Labor Money Land Soil fertility Markets Transportation

Does anyone in this household own a business? Y N

Food shop	Gas station	Sakau bar	Other

Do you hire employees outside of family? Y N

Number employed	Hours per week	Hourly wage

Number of adults employed or retired: 0 1 2 3 4 5 6

	Gov't	Private	Family business	Retired
Male				
Female				

Number employed part time: 0 1 2 3 4 5

Gov't	Private	Family business

Approximate total monthly income from employment or retirement: Employment: $ Retirement:$

Do any family members fish? Y N Sell? Y N Estimated number of pounds sold per month:

Sell agriculture or livestock products? Y N Estimated monthly income from selling ag. products? $

Sell handicrafts? Y N Type: Estimated monthly income from selling handicrafts? $

Number of immediate family members living off island: 0 1 2 3 4 5 6 7 8 9 10

FSM	Guam	Hawaii	Mainland	Other

Estimated amount of remittances received per month: $

What are the five most important sources of cash income?
1. 2. 3. 4. 5.

Rank your family's top five monthly expenses?
1. 2. 3. 4. 5.

What is the approximate monthly cost for each of the top five expenses?
1. 2. 3. 4. 5.

What, if any, are your family's major credit sources (shops, banks, private etc.)?

APPENDIX B
RECORD FORM

Household name Kousapw

Mark Drew's home phone: 320-7539

Land parcel name

Date:	Hours spent on farm	Number of adults working on farm(18 yrs+)		Number of children working on farm		Planting activities			Total hours spent for:		
		Male	Female	Male	Female	Plant name	Variety	Number planted	Sakau	Bananas	Yams

Date:	Products harvested		Amount harvested		Amount of pounds or number of each crop used for each purpose							If sold	
	Name	Variety	Pounds	Number	Household consumption	Give to other family/friends	Funeral	Sell to market	Traditional ceremony	Animal feed	Trade	Market name	Selling price per product or pound

APPENDIX C
ETHNOGRAPHIC LINEAR PROGRAM MODEL

	Activities>	AF-Homegarden	LAND2	Sell Yams	Yam Ceremonial	Yam famfriends	Yam trn.	Sell brdfruit	brdfruit Ceremonial	brdfruit famfriends	brdfruit trn.	Sell GTaro	GTaro Ceremonial	GTaro famfriends	GTaro trn	Sell Coconuts	Coconuts famfriends	Coconuts trn	Sell Brud	Brud Ceremonial	Brud famfriends	Brud trn	Sell Sakau	Sakau Ceremonial	Sakau famfriends	AF-Sakau trn	Sell Banana	Banana Ceremonial	Banana famfriends	Banana trn	M-FT employment	M-PT employment	F-FT employment	F-PT employment	remittances	Fish	Sell Fish	Fish trn	Cash trn.		
Variables>		3.0000	2.9864	8.755	236.000	10.000	115.0000	0.2795	50.0000	0.0000	384.0000	0.0000	0.0000	0.0000	6.0000	0.0000	36.0000	2044.0000	0.0000	20.0000	0.0000	245.0000	0.0000	81.0000	0.0000	416.0000	0.0000	10.0000	16.0000	735.0000	0.0000	0.0000	0.0000	7.5264		0.0000	0.0000	0.0000	0.00	Resource Use	
Constraint	Unit	hectare	hectare	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	kg	#	#	#	#	#	#	#	kg	kg	kg	kg	kg	kg	kg	kg	month	month	month	month	$/month	day	kg	kg	$	RHS	Constraint
HG-land	Hectares	1																																						3.00 <=	3 HG-land
Land2	Hectares		1																																					2.99 <=	3 Land2
Adult male labor	m-hours	69	55	0			0																								134	80				7			0	374.43 <=	**6240** Adult male labor
Adult female labor	F-hours	4	1	0			0																										154	60					0	467.12 <=	**4160** Adult female labor
Child male labor	CM-hours	92	119																																					601.73 <=	**1664** Child male labor
Child female labor	CF-hours	2	1	0			0																																0	8.99 <=	**1664** Child female labor
Yam acct.	kg	-87	-23	1	1		1																																0	0.00 <=	0 Yam acct.
Yam consumption	kg	0		0			-1																																0	-1.15.00 <=	-115 Yam consumption
Yam Ceremonial	kg				-1																																			-236.00 <=	-236 Yam Ceremonial
Yam famfriends	kg					-1																																		-10.00 <=	-10 Yam famfriends
brdfruit acct	kg	-77	-69					1	1		1																													0.00 <=	brdfruit acct
brdfruit consumption	kg										-1																													-384.00 <=	-384 brdfruit consumption
brdfruit Ceremonial	kg								-1																															-50.00 <=	-50 brdfruit Ceremonial
brdfruit famfriends	kg									-1																														0.00 <=	0 brdfruit famfriends
GTaro acct	kg	-2	0									1	1		1																									0.00 <=	GTaro acct
GTaro consumption	kg														-1																									-6.00 <=	-6 GTaro consumption
GTaro Ceremonial	kg												-1																											0.00 <=	GTaro Ceremonial
GTaro famfriends	kg													-1																										0.00 <=	GTaro famfriends
Coconuts acct	#	-477	-378													1		1																						-228.04 <=	Coconuts acct
Coconuts consumption	#																	-1																						-2044.00 <=	-2044 Coconuts consumption
Coconuts famfriends	#																-1																							-36.00 <=	-36 Coconuts famfriends
Brud acct	#	-1498	-1408																1	1		1																		-8426.04 <=	Brud acct
Brud consumption	#																					-1																		-245.00 <=	-245 Brud consumption
Brud Ceremonial	#																			-1																				-20.00 <=	-20 Brud Ceremonial
Brud famfriends	#																				-1																			0.00 <=	Brud famfriends
Sakau acct	kg	-72	-94																				1	1		1														0.00 <=	Sakau acct
Sakau consumption	kg																									-1														-416.00 <=	-416 Sakau consumption
Sakau Ceremonial	kg																							-1																-81.00 <=	-81 Sakau Ceremonial
Sakau famfriends	kg																								-1															0.00 <=	Sakau famfriends
Banana acct	kg	-119	-128																								1	1		1										-21.53 <=	Banana acct
Banana consumption	kg																													-1										-735.00 <=	-735 Banana consumption
Banana Ceremonial	kg																											-1												-10.00 <=	-10 Banana Ceremonial
Banana famfriend	kg																												-1											-16.00 <=	-16 Banana famfriend
Fish acct	kg																																			-13	1	1		0.00 <=	Fish acct
Fish consumption	kg																																					-1		0.00 <=	Fish consumption
Fishing constraint	kg																																				-1			0.00 <=	Fishing constraint
cash beg. Season	$US	0		0			0																																1	0.00 <=	**100** cash beg. Season
Total cash end of season	$US	0		2			0	0.22			0	0.77			0	0.1		0	0.05				2.2			0	0.55				250	240	360	300	85	-5	1.98		1	2280.00 >=	**2280** Total cash end of season

APPENDIX D
MATHEMATICAL EXPLANATION OF LINEAR PROGRAMMING

Linear programming can be stated mathematically as (taken from Hildebrand *et al.,* 2008):

Max (or Min): $\Pi = \Sigma_j C_j X_j$ (j = 1 . . . n)
Subject to: $\Sigma_i A_{ij} X_j <= R_i$ (i = 1 . . . m)
and $X_i >= 0$

Π is the variable objective to be minimized or maximized, C_j is the cost (debit) or returns (credit) of each of the n activities X_j, A_{ij} is the set of input or output coefficients for each activity j and resource or constraint i, and R_i is the set of m minimum or maximum constraints or restrictions. The program is set up in a matrix (such as Excel® and solved with the add-in solver). The resources in this simple matrix are land, labor and beginning cash. The activities are the production of maize, hay and goats. Inside the matrix are the input or output coefficient, and the objective to be maximized, Π, is cash income.

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BIOGRAPHICAL SKETCH

Mark Drew currently serves as California Trout's Eastern Sierra program manager. Before joining California Trout, Mark worked as The Nature Conservancy's (TNC's) Southeastern Caribbean Program's protected areas specialist. As the protected areas specialist, Mark managed TNC's conservation programs in the US and British Virgin Islands. Before working for The Nature Conservancy, Mark spent almost 15 years involved, both academically and professionally, in resource conservation in the US mainland, Oceania, and the Asia region. Mark holds a B.S. degree in forestry and natural resources management from California Polytechnic State University and a M.A. degree in international development policy from Stanford University. Mark is now in the final stages of obtaining his Ph.D. at the University of Florida (in forest resources and conservation) with an emphasis on developing conservation strategies in Micronesia. Mark spent 3 years as a Peace Corps volunteer in the Cook Islands and Nepal where he implemented extensive conservation programs, aided in the development of resource management plans, and conducted numerous community-based projects. After completing his M.A. degree at Stanford, Mark worked for Stanford's Institute for International Studies for 3 years, designing and conducting research on the socioeconomic and ecological importance of mangrove and freshwater wetlands in Micronesia. He has conducted additional research centered on the economic and ecological dynamics of coastal aquaculture systems in Indonesia, Thailand, and Vietnam.