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Valuing Invasives:

Understanding the *Merremia peltata* Invasion in Post-Colonial Samoa

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**Valuing Invasives:
Understanding the *Merremia peltata* Invasion in Post-Colonial Samoa**

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Dissertation

Presented to the Faculty of the Graduate School of

the University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

May 2005

For Amye

Acknowledgments

The author would like to express his gratitude to the following individuals, organizations and groups, without whom this research would not have been possible:

Foremost, I would like to thank the people of the village of Fa'ala and the *pulenu'u* Tui Lukini, Laulu Fa'aola, and Fuiava Toetau for allowing me to perform my research in the village. The family of Laulu Fouvale for letting me live with them, and especially Auva'a Laulu, Laufau Kirkham, Tausala Sefo and Pau Sefo for their assistance with fieldwork. A debt of gratitude is also extended toward all of the families that discussed their knowledge of plants with me, and allowed me to access their lands for vegetation sampling.

In the Forestry Division of the Ministry of Agriculture, Forestry, Fisheries and Meteorology, I humbly thank Sami Lemalu and Setoa of the Maota field office for generously providing housing, and to Tolusina Pouli of the Vailima field office for assistance with research questions and aerial photographs. In the Ministry of Natural Resources and the Environment, I graciously acknowledge the assistance and support of Seiuli Vainu'upo'o Jungblut of the Department of Natural Resources and Le'o'o of the Mapping Division for their support, but especially Tony Tipama'a and Talie Foliga of the Parks Department for their assistance with plant identifications. I would further like to thank Papali'itele Aukuso Leauvasa, Albert Peters, Clark Peteru,

Charles Martel, Dion Ale of O le Siosiomaga Society and Steve Brown of Ecotour Samoa for advice and informational resources, and to Arthur Whistler for advice and plant identifications.

I would also like to thank Dr. Mohammed Eaquad and soil science crew at the University of the South Pacific at Alafua, for their patience and understanding in analyzing my soil samples.

I am especially grateful for several former students of mine from my days as a volunteer teacher at St. Joseph's College in Alafua, who are now employed in the public service, for their assistance in my research.

A particular debt of gratitude is owed to my advisors, Dr. William E. Doolittle and Dr. Gregory Knapp, and to my committee, for the patience, understanding and copious advice that went into shaping my work, and to their constant support throughout this project.

I especially want to thank my family for standing by me and supporting me throughout this endeavor.

Finally, I would like to extend my gratitude to the National Science Foundation and Fulbright-Hays program for funding my research.

Valuing Invasives:
Understanding the *Merremia peltata* Invasion in Post-Colonial Samoa

Publication No. _____

William Stuart Kirkham, Ph.D.
The University of Texas at Austin, 2005

Supervisor: William Doolittle and Gregory Knapp

Merremia peltata has been identified as an invasive species of environmental concern in several Pacific Island countries, and several environmental agencies are seeking means of controlling it. The species is native to this region, and very little is known about it, scientifically. This study investigates some fundamental questions about the invasion from a biogeographic perspective, such as causes of the invasion, both natural and anthropogenic, and prospects for remediation. Given that biological invasions are acknowledged to be a human driven phenomenon, the study also examines cultural and political aspects of the invasion, including perspectives on the plant across several social scales and exploring the social context in which the problem has been identified and addressed. Methods thus employ both biogeographic and ethnographic approaches. Aerial photographs and GIS and field mapping (traditional and GPS) were employed to develop a stratified random sample of vegetation plots. Vegetation cover and environmental data were gathered. Cluster Analysis and Nonmetric Multidimensional Scaling (NMS) were used to analyze the vegetation data. Cultural immersion, progressive contextualization and Q-

methodology were employed in ethnographic analysis. Biogeographic results indicate that the dominance of *Merremia peltata* on the landscape is driven by fluctuating patterns of disturbance on the landscape. Disturbance is seen to be the driving force behind the changing character of floral biodiversity through its interaction with the reproductive and dispersal habits of the plant species. This disturbance arose from changes in patterns of land use as the regional economy shifted from colonial to post-colonial patterns contributed to *M. peltata*'s dominance. Village level planters and local ecologists are less concerned about this species dominance on the landscape than regional ecologists are. Lingering power inequalities from the colonial period between the core and peripheral countries in the region give more weight to the core perspectives becoming enacted, effectively intervening in these landscapes to protect their own. Recommendations for managing *Merremia peltata in situ* are given, including aiding successional processes.

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Chapter 1

Introduction

Problem Statement

Merremia peltata is a species that is well known but little understood. It has been identified both as an invasive species of environmental concern in several Pacific Island Countries (PICs, Meyer 2000, Space and Flynn 2002), and as being native to the Pacific in general and Samoa specifically (Whistler 2002, Space and Flynn 2002), a fact which runs contrary to the conventional wisdom that invasive species are typically alien to the ecosystem being invaded. This apparent contradiction in the standard concepts regarding invasive species provides an opportunity to refine theoretical knowledge, as well as to offer practical insights into plant management.

Merremia peltata has been a component of lowland Pacific Island ecosystems for several hundred years, probably thousands (assuming its nativity), yet it has only become identified as a dominant species on the landscape during the past decade. The question of why this species has apparently only recently exploded across the landscape merits examination. Accordingly, this research investigates a rural landscape in Samoa that has been invaded by *M. peltata* in order to gain an understanding of the relevant factors that have contributed to its invasion. It analyzes the dynamics of *M. peltata* in the vegetation communities in which it occurs across several regimes of disturbance, and scrutinizes the natural and anthropogenic causes

and patterns of disturbance across several scales. As such, this study draws upon and informs several disciplines, including invasion biology, island biogeography, and cultural and political ecology.

The Threat to Biodiversity

This research demonstrates that both the invasion of *Merremia peltata* and the threat to biodiversity are disturbance-driven processes. Disturbance creates the conditions on the landscape that allow *Merremia peltata* to spread and become dominant, but also drive the overall population dynamics of the local biodiversity. That is, disturbance contributes more to the mortality of native species and their removal from the soil seed bank than intraspecific competition with *M. peltata* does. Across the entire lowland rainforest ecosystem gradient (elevational, land use, disturbance and recovery) studied in this investigation, the same species are typically present in the earliest stages of recovery. These species are typically wind, bird, or fruit bat propagated, and are thus widely and rapidly dispersed. In later stages of succession, however, there is a significant difference in species composition relative to the pattern of disturbance to which that area has been subjected. Areas that have experienced prolonged and frequent disturbance, primarily coconut plantations, display a marked deficiency in less dispersible native and endemic species than areas that are subject to shorter, less frequent disturbances, such as areas under forest cover. It is these less dispersible natives and endemics that are of greatest concern to biodiversity conservation, and management efforts should be directed toward this

broader disturbance-based perspective rather than by confronting individual species, such as *M. peltata*, directly.

The sources of disturbance are both anthropogenic and natural. In the case of the latter, tropical cyclones are perhaps the most significant disturbance agent of the natural habitats, offering a disturbance of short duration and varying frequency, possibly increasing in frequency since the 1990s. These disturbances drive the population dynamics by increasing the mortality of extant trees on the landscape, but not by directly acting on the soil seed bank, except by reducing the replenishment of seeds through increased mortality. Cyclone disturbance is large in spatial scale, however, affecting the entire island and all of the ecosystems contained therein. Anthropogenic disturbance by contrast, is of greater duration and frequency, but focused primarily on lowland rainforest, littoral and near-shore lagoon and coral reef ecosystems. On the terrestrial systems, anthropogenic disturbance acts to drive mortality of extant species on the landscape and to disturb the soil seed bank through agricultural clearing and weeding. The anthropogenic pattern of disturbance is closely related to the ebb and flow of activity in the global economic networks to which Samoa belongs.

The differing patterns of vegetation and vectors of recovery on the landscape are closely tied to fluctuations in agricultural activity primarily and its integration into the overall developing economy secondarily. The species that are currently identified as being invasive non-native species and that are represented in both anthropogenically disturbed and more natural areas, are all recorded as having been in

the Pacific region for over one hundred years, and date to the colonial period. Furthermore, the lands under coconut plantations were developed in conjunction with the export of copra, coconut oil and other coconut products that were the mainstay of the colonial primary product export-led development model of the colonial period. The dominance of *Merremia peltata* on the landscape, however, is more closely associated with the post-colonial development model, that focuses on migration, earning two revenue streams for Samoa from remittances and export of taro to feed the growing Pacific Islander community overseas. This increasing demand for taro overseas created an expansion of swidden cultivation, which caused extensive deforestation but was ultimately short-lived due to a fungal blight that eliminated taro production and resulted in much land being put back into fallow. As such, *M. peltata* dominance is strongly associated with land that has experienced shorter and less frequent disturbance than the other agricultural areas, and is more ecologically similar to forested land than to the more highly disturbed coconut plantations. This invasion is better understood to be the earliest stages of rainforest recovery, with the extent of disturbance on the landscape causing the recolonization of the landscape by tree species to be proceeding at a much slower pace than *M. peltata* is capable of dominating it.

That this invasion should be described by regional environmental organizations in terms of this species being a non-native invasive species, despite the fact that it is well known to be native to the region, requires the invasion process to be examined from a socially self-reflective perspective. This perspective examines not

just the biogeographic aspects of the invasion, but the social aspects of how the phenomenon is perceived and reacted to by actors across the social spectrum. The findings suggest that lingering power inequalities from the colonial period between Pacific Island Countries and the cosmopolitan core countries allow biosecurity perspectives to shape biodiversity conservation efforts. Biosecurity is predominantly concerned with preventing the transportation of non-native species across national boundaries, whereas biodiversity conservation is about mutually maintaining the integrity of local ecosystems and preventing the extinction of native species. The topic of non-native invasive species is germane to both biosecurity and biodiversity conservation, and thus these efforts often overlap. Efforts to control invasive species in their extant locations in order to prevent their spread are based upon biosecurity concerns, and risk harming local ecosystems should the species be native to part of the region, as *Merremia peltata* is. Heavy dependence on foreign aid and expertise often mean that the perspectives from the cosmopolitan core win out over local experience, and voices that are less alarmist about *M. peltata* based on first hand knowledge are ignored. In practice, the only areas that are in the Pacific Region that do not already have *M. peltata* are the cosmopolitan core countries, and the social momentum is such that this species could be controlled in its native range to protect these countries, possibly resulting in a higher occurrence of non-native species in those islands. The international power inequalities are such that the biosecurity interests of the core countries are dominating discourse on invasive species control,

and preventing a more locally driven biodiversity conservation program from being implemented.

Understanding Merremia peltata

Merremia peltata (Linné) Merrill is a woody vine (liana) of the family Convolvulaceae. Synonyms include *Convolvulus peltatus* L., *C. bufalina* Lour., *C. crispatus* Wall., *Ipomoea nymphaefolia* Blume, *I. peltata* (L.) Choisy, *I. bufalina* Choisy, *I. petaloidea* Choisy, *Merremia borneensis* Merr., *M. bufalina* Merr. and Rendle, *M. distillatoria* (Blanco) Merr., *M. elmeri* Merr., *Operculina bufalina* Hall f., *O. petaloidea* Ooststr., and *Spiranthera peltata* (L.) Bojer (Roberty 1952, Deroin 2001). This species most prominent feature are its large peltate leaves (Figure 1.1) that give it the ability to blanket disturbed areas such as fallowed land, and, in conjunction with its twining and climbing stems, has the ability to smother small trees and secondary growth (Figure 1.2), and is common in native forests up to 300 m elevation (Whistler 1995). Whistler (ibid) cites its geographic range as extending from East Africa to Tahiti, with the Pacific Islands as its native area. Meyer (2000) uses a definition for invasive species that employs a criterion that a species must be non-native to be invasive; his inclusion of *Merremia peltata* as an invasive would thus seem to indicate that he considers it to be non-native to the Pacific. Space and Flynn (2002) note that the species may be an ancient Polynesian introduction, but consider it to be a native species behaving invasively. Research into this particular

Figure 1.1. Photograph of *Merremia peltata* leaves with 50mm lens cap for comparison.



Figure 1.2. Photograph of a landscape covered with *Merremia peltata*.



invasion should thus yield insight into ecology's and biogeography's understanding of the invasion process.

Little is known of the biology of this plant species. It reproduces both vegetatively and by seed, although one study indicated that seed viability rates were low (Bacon 1982), so vegetative spread may be its primary mechanism of proliferation, and thus its spread may be very sensitive to landscape structure (the presence of shading canopy that it would hinder its spread) and disturbance (that would remove this shading cover). Little is known of any species that act as pollinators or dispersers of this plant. During the course of this study ants were frequently observed in the corolla of the *Merremia peltata* flowers, but never bees or wasps that were frequently seen on flowers of other species. There is, however, a species in the same genus (*M. palmeri*) that is moth pollinated (Willmott and Burquez 1996); if this is the case for *M. peltata* is not clear, because no nocturnal observations were made by the author of this study. Without an animal disperser (especially amongst birds) and not being wind dispersed, the question of how the species reached the islands of the Pacific becomes an important one. *M. discoidesperma* has seeds that remain buoyant in seawater for up to three years and are dispersed on ocean currents (Gunn 1977). If *M. peltata* possessed these characteristics, then it would be expected to be a member of the littoral vegetation, but it is not. Questions of human dispersal become highly plausible under these considerations and are explored in greater detail in Chapter 8. Clearly more research needs to be done on the

reproductive biology of this species, but this research lies outside the scope of this study.

Merremia peltata has been identified as an invasive species of environmental concern in several PICs (Meyer 2000, Space and Flynn 2002). This species was cited as a pest of banana plantations in Fiji during the 1970s (Robinson and Singh 1973, cited in Bacon 1982). Its identification as an invasive species of environmental concern is more recent, however. Research into hurricane disturbance by cyclones Ofa and Val of the rainforest on the Tafua Peninsula only indicate *Mikania micrantha* and *Passiflora foetida* as the dominant vine invaders of disturbed patches (Elmqvist et al. 1994, Elmqvist et al. 2001). Savage (1992) studied forest regeneration under vine cover, noting only the vine species *Dioscorea bulbifera*, *D. pentaphylla* and *Passiflora foetida* and calls into question the assumption that vines suppress forest regeneration. Woods and Pouli (1995) describe forest regeneration trials in Samoa in an area of lowland forest recovering from logging where vines (primarily *Merremia peltata* and *Mikania micrantha*) were removed from saplings in some treatment plots and not removed from control plots; after ten months, the authors noted no significant change in trunk diameter between the treatment and control, but did note improved canopy development in the treatment. Whistler (1995) commented on *Merremia peltata*'s smothering abilities and by the early 21st century the alarms were being raised in Samoa and across the Pacific (Meyer 2000, Space and Flynn 2002, Whistler 2002). The predominance of *M. peltata* on the Samoan landscape appears to begin taking off in the mid-1990s, judging by its mention in the literature.

Lianas, in general, tend to have a bad reputation. This is a view that has arisen in forest management, where lianas are widely attributed with damaging trees and stunting their growth (Alvira et al. 2004), as well as increasing tree mortality and increasing the likelihood of multiple-tree falls due to linked canopies (Putz 1984), and are frequently seen to proliferate after disturbances (Putz and Chai 1987, Schnitzer et al. 2004). Experimental efforts have been directed toward reducing the prevalence of lianas in post-logging landscapes by cutting lianas prior to logging, so as to maximize growth of regenerating trees (Grauel and Putz 2004, Schnitzer et al. 2004). Tree plantations that have been managed for maximizing tree growth have been observed to suffer more damage from hurricanes than natural forests (Fu, Pedraza and Lugo 1996), and it is becoming increasingly clear that forests must be managed with the prospects of these kinds of disturbances in mind (Dale et al. 1998). What role lianas play in this frame of management is unclear. Indeed, the ecologically positive aspects of lianas are not clearly understood (Putz 2004).

Organization of the Text

The purpose of this study is to gain some insights into the *Merremia peltata* invasion. Chapter 2 reviews the literature on biological invasions and the cultural and political ecology of the Pacific. Chapter 3 presents the research site, rationale for its selection and a description of the setting, in terms of its natural, social, and political context. Chapter 4 describes the methods used in vegetation sampling and analysis, landscape analysis, and ethnographic analysis. Chapter 5 presents descriptive

findings of the research site and their implications for this project. Chapters 6 presents the results of the vegetation study. Chapter 7 examines the plurality of views over this species, and how management of the invasion is contested through power-laden social networks across several scales from the local to the global. Finally, Chapter 8 ties these threads together and discusses the implications of this research and gives some prospects for managing *Merremia peltata*.

Chapter 2

Rationale

Overview

The question of species invasions challenges modern academia because it is defined as being simultaneously natural and anthropogenic in origin. Adequately addressing the question involves engaging both the natural and social sciences. Each, on its own, cannot address the invasives question adequately. Although the natural sciences have acknowledged that the invasion process was a human driven problem from its inception, biological ecologists and biogeographers have only begun to address the human dominance of ecosystems in recent years and lack the necessary expertise that social scientists offer in this regard. Cultural ecologists in geography, on the other hand, have long acknowledged the human dominance of ecosystems, but recent trends in cultural and political ecology have de-emphasized the material base of societies, and disengaged from positivistic explanations and methods in general. As a result, cultural and political ecology have become less able to explain the impact of human activity on the natural environment. The invasives question has been nearly completely neglected in the social sciences, except for deconstructions of the language employed. A gap in the research thus exists, arising from disciplinary boundaries, which must be addressed in resolving the invasives problem.

The following review examines the development of invasion ecology. The current trends in invasion ecology research is firmly rooted in the equilibrium-oriented ecology that dominated ecological thought in the mid-twentieth century, and

despite recent research urging an examination of disturbance and human influence in the invasion process, these topics have remained largely unaddressed. The importance of studying the role of disturbance in the case of island invasions is another topic that has been raised in the literature but not studied. This research project addresses this gap in the knowledge by examining a biological invasion across a landscape in light of biological, environmental, anthropogenic and disturbance processes, simultaneously.

Foundations of Invasion Ecology

The current surge of concern over invasive species arose largely in the mid- to late- 1980s and was rooted in disquietude over the loss of global biodiversity, although health and economic concerns are often acknowledged if not followed upon (Mooney and Drake 1987). Indeed, invasive species are considered to be among the two main threats to biodiversity, second to, but on par with, habitat loss (Wilson 1992). Many of the ecologists from this period look toward Charles Elton as the herald of the invasives problem, whose declaration that “we must make no mistake: we are seeing one of the great historical convulsions in the world’s fauna and flora” (Elton 1958, 31) is still used to frame the debate over invasions (Mooney and Cleland 2001).

The invasives problem, as well as addressing a perceived ecological reality, highlights several issues inherent in early 20th century ecological thought. The concept of some species being foreign to particular ecosystems is a theoretical

construct borne out of the “Balance of Nature” school of ecological thought. One such aspect of this conceptual model of nature is the bounded character of ecosystems, in which all of the nutrients are in a finite supply, and constrained by the boundaries of the system. These models were based on studies of sharply bounded features such as lakes (Forbes 1887, Lindemann 1942), islands (culminating with MacArthur and Wilson 1967) and, for biological invasions specifically, continents, following the concepts of Wallace’s Realms (Elton 1958). Such studies were foundational to the formation of homeostatic system ideas such as the ecosystem and climax community (Tansley 1935, Clements 1936). Theorizing boundaries thus assumes an inside and an outside, with corresponding species membership, and boundary crossings thus become transgressive acts. It is not surprising then, that the idea of biological invaders has been around almost as long as ideas of homeostasis-seeking ecosystems (Elton cites an article he wrote in 1943 as the origin of his ideas; 1958, 13).

A second salient feature inherent in early ecological thought that resurfaces frequently in the debate over invasives is the conceptual separation of the social and natural worlds. Ecologists have often ascribed human intervention to the failure of ecosystems to behave as their equilibrium-seeking models suggest (Hengeveld 1987). Indeed, ecologists considered human activity to be the primary cause for the establishment of non-native species in an area, even including human-assisted establishment as a defining criteria of an invasive species (Elton 1958, Hengeveld 1987, MacDonald et al. 1989). Given it was argued that trophic food chains formed

by competing species within a bounded ecosystem were stable, a species from outside this system would not be able to establish, hence an additional external element, people, are necessary to transform complex, stable systems into simplified, invulnerable ones. That is, people were seen to create disturbed, simplified, invulnerable environmental conditions in which non-native species, introduced to the area by people, either directly or indirectly, establish, only to later break into stable ecosystems (unaided by people) due to hybridization or mutation. Similarly, where disturbance was seen to occur, ecologists often distinguish between exogenous (human induced) and endogenous (natural) disturbance (Di Castri 1989).

The SCOPE Project

Although conventional wisdom at the time held that intact native ecosystems were resistant to invasion, it had been observed during the 1980s that invasives were making inroads into these intact native ecosystems, and the Scientific Committee on Problems of the Environment (SCOPE) resolved to investigate the problem in depth (Drake et al. 1989). The SCOPE project sought to understand the invasion problem according to three broad research questions, namely identifying the factors that determine plant invasiveness, ecosystem invulnerability, and how these lessons should shape management (Usher et al. 1988). This group performed research across the globe, with projects in North America and Hawaii (Mooney and Drake 1986), Australia (Groves and Burdon 1986), South Africa (MacDonald et al. 1986), the United Kingdom (Kornberg and Williamson 1987) and the Netherlands (Joenje et al.

1987), and in nature reserves (representing intact but invaded ecosystems) across several biomes, including the tropics (MacDonald and Frame 1988), arid lands (Loope et al. 1988), Mediterranean climates (MacDonald et al. 1988) and islands (Brockie et al 1988). Taking a comprehensive approach to ecological praxis, researchers engaged population and community ecology (Bazzaz 1986, Breytenbach 1986, Kruger et al. 1986, Rejmánek 1989), landscape ecology (Hobbs 1989), population genetics (Bazzaz 1986, Dean et al. 1986, Ehrlich 1986), epidemiology (Dobson and May 1986, Gibbs 1986, von Broembsen 1989), biogeography (Simberloff 1986, Mack 1986, Ewel 1986, Moulton and Pimm 1986, Mooney et al. 1986) and quantitative modeling (Roughgarden 1986, Kornberg and Williamson 1987, Williamson 1989) to understand the invasion phenomenon.

Within this comprehensive framework, some SCOPE scientists reexamined the theoretical foundations underwriting the invasion problem. Some researchers focused on the differences between community (equilibrium-seeking) and individualistic (non-equilibrium) views on ecology. While the invasiveness of an ecosystem was related to its relative degree of being “open” or “closed,” this openness was tautologically defined relative to its invasiveness, rendering the concept of boundedness neither meaningful, applicable, nor measurable (Hengeveld 1989). Indeed, the division between community and individualistic approaches to ecology highlights a rift between deductive and inductive approaches, respectively, to ecology, with many assumptions of the former remaining untested or reified and falling away in the face of empirical data (Hengeveld 1989, Golley 1993, Slobodkin

2001). Additionally, whereas Balance of Nature ecology views interspecific competition as the main regulatory mechanism controlling community structure, research from this period indicates that intraspecific competition was only apparent in a few instances of biological invasions, and that the ability of individual species to influence ecosystem properties more likely accounts for fluctuating species composition (Oriens 1986, Vitousek 1986, Hengeveld 1987). Every species can change its range and distribution in response to fluctuating environmental conditions, and each species responds to a particular environmental change differently, emphasizing the naturalness of species entering new communities and illustrating that every species is an invader to some degree (Hengeveld 1989). Indeed, although most contemporary studies focus on invasions that have occurred in the past 150 years, the members of these invaded communities can be seen to be invaders themselves when viewed on a longer time frame; that is, the distinction between native and invading species can be lost after several hundred years (Oriens 1986, Weeda 1987, Brockie et al. 1988). These long-term changes are often associated with changes in climate, a variable that the equilibrium-seeking view of ecology treats as static, but one that the SCOPE program identified as important in understanding the changing conditions that influence invasions (Fox and Fox 1986, Oriens 1986, Hengeveld 1988, Di Castri 1989). In other words, the traditional view of the ecosystem overlooked the influence of external factors in influencing internal functions, treating ecosystem function as a single scale phenomenon.

SCOPE scientists also examined the role of disturbance, perhaps the most conspicuous point of departure between equilibrium and non-equilibrium approaches to ecology, in contributing to ecological invasions. Although Elton (1958) viewed disturbance as creating the preconditions for invasion by essentially creating the simplified ecosystems necessary for non-native colonization, an observation generally supported by subsequent research (Orians 1986) and by experimentation (Hobbs 1989), other research indicates a broader role in creating the conditions necessary for the invasions of intact ecosystems. Orians (1986) explains that both perceptions of ecosystem and disturbance are scale sensitive, with the traditional conception of ecosystem and disturbance based on the viewpoint of large mammals, as opposed for instance to small insects responding to changes in chemical output from the plant they live on being under stress. Additionally, Fox and Fox (1986) assert that invasions do not occur without disturbance and that all communities are susceptible to disturbance and invasion, since even endogenous disturbance regimes are subject to change. In teasing out the differences between these two differing theoretical perspectives, researchers present a view of invasions that is simultaneously hopeful, based on the naturalness of the phenomenon (a view espoused by a minority of contemporary researchers; Botkin 2001, Slobodkin 2001) and perturbing, due to the susceptibility of all communities to disturbance and invasion and the ability of any species to be an invader, creating the perception of imminent risk and frustrating unpredictability.

Aside from theory, the SCOPE project sought to find generalizations regarding invasive species and their invaded ecosystems in order to better inform

management strategies, a task that proved to be daunting in the myriad ways that invasions occur. In general, the project found that the difficulties in predicting invasions lay in the fact that a successful invasion is a product of the interplay between both plant characteristics and site characteristics; it is difficult to predict an invasion on the basis of either aspect alone. There are no trends as to the functional role in a community to which an invasive species has infiltrated, for instance, because the functional role of a species only matters depending on whether the absence (or presence) of certain taxonomic groups in those roles inhibits or aids the invader in question (Mooney and Drake 1989). Although many of the world's invasive plants are (originally) agricultural weeds with high reproductive rates, short life histories and wide dispersal capabilities of the families Asteraceae, Poaceae, and Fabaceae (Bazzaz 1986, Heywood 1989), these families represent the highest number of species in general, invasive or native, and other plants with similar reproductive and dispersal habits do not become successful invaders (and other species without these traits have); these characteristics of the plants alone do not account for their invasive success (Orians 1986, Mooney and Drake 1989). As for the impacts that species have on ecosystems, observed effects include accelerated soil erosion rates, preventing native species recruitment, and alteration of biogeochemical cycling, geomorphological processes, hydrologic cycles, and fire regimes with successful invasions likely in simplified communities with few predators or herbivores (Mooney and Drake 1989). Additionally, the project scientists observed that not every introduced species becomes a threatening invader. Some simply add to the species

richness of an area (Mooney and Drake 1989). Williamson and Brown (1987), in constructing predictive models, present their “rule of 10,” which states that in general, 10% of introduced species become established in an area, and 10% of established species become invasive (actual numbers can vary anywhere from 5-20%). The authors acknowledge that while this can help predict numbers of species that could become invasive, it cannot directly predict which species will become invasive in which environments. The main generalization to come from the research is that predictive generalizations are difficult and more research on specific invasions needed to be done.

The various authors address areas of inadequate knowledge of the invasion process. These include the lack of information on failures of introductions (Moulton and Pimm 1986, Mooney and Drake 1989), a lack of emphasis on species-environment interaction (Orians 1986, Vitousek 1986, Mack 1989), a lack of experimentation (Di Castri 1989, Hobbs 1989, Mooney and Drake 1989), and a need for more study of tropical invasions (Ramakrishnan 1991). From the lessons learned from this project, the SCOPE team reformulated its inquiry into an examination of “ecosystem function of biodiversity” with an emphasis on understanding how species affect ecosystem function and stability, inaugurated by a study of islands (Vitousek, Loope and Adersen 1995).

Invasion Biology in the Post-SCOPE Era

Since the original SCOPE program of the 1980s, research on the invasives problem has blossomed, with thousands of research articles and books being written in the fifteen year period following the publication of *Biological Invasions: A Global Perspective* (Drake et al. 1989). A combined search of the Science Citation Index, Social Science Citation Index, and Arts and Humanities Citation index using the keywords biological invasions, invasive species, non-native species, non-indigenous species, exotic species and invaders produced 2,953 documents published between 1975 and 2003, which when winnowed down based on topics relevant to this research project (plant invasions, ecosystems or environmental context, disturbance, human-environment interaction, theory, methods and critiques), resulted in a pool of 1,121 papers. Figure 2.1 depicts the trajectories of this latter pool. Of note is the small spike during the 1980s that is the exclusive work of the SCOPE program, and the steep surge in research in the late 1990s, undoubtedly the byproduct in the United States of the Invasive Species Act of 1996 and Executive Order 13112 (1998) which authorized tremendous amounts of funding to address the invasives problem. Table 2.1 summarizes the topical breakdown of 1024 of these papers from 1990 through 2003. The vast majority of the research (89%) has addressed the processes of specific invasions with the intent of informing prediction and management of invasions and ultimately upon discussion of management practices themselves. Research covers descriptions of invaded assemblages, interactions between invasive and native species, interactions between individual species (or assemblages of species) with the

Figure 2.1. Selected journal articles published on invasive species, 1975-2003

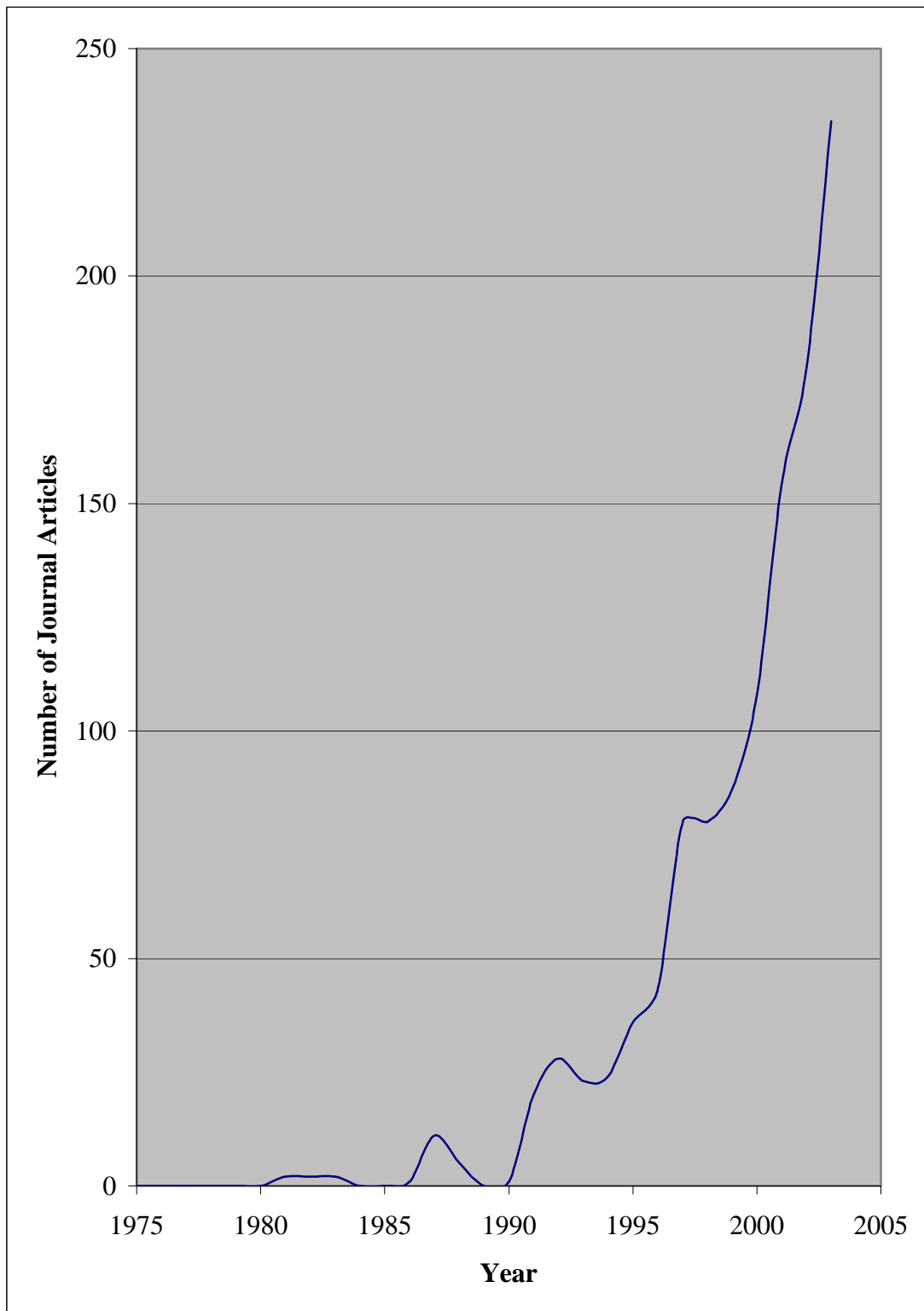


Table 2.1. Percentage breakdown of invasives research topics, 1990-2003.

| Topic | Percent |
|---|---------|
| Community and Floristic Description | 18.2 |
| Species (assemblage) and Environment Interaction (including climate change) | 16.5 |
| Plant Traits | 14.3 |
| Management | 12.3 |
| Species-to-species Interaction | 8.7 |
| Disturbance | 8.0 |
| Experimentation | 5.2 |
| Theory and Methodology | 4.9 |
| Human influences (other than disturbance) | 4.0 |
| Modelling | 3.2 |
| Landscape Ecology approaches | 1.9 |
| Global Change (excluding climate change) | 1.5 |
| Assessing whether an introduced species poses a threat | 0.7 |
| Philosophical Issues | 0.6 |
| Benefits of invasives | 0.2 |

biogeochemical environment, interactions of species (or assemblages) with disturbance and disturbance regimes, interactions with landscape structure, experimentation on these various interactions, and analysis of individual plant traits (genetics, morphological plasticity, hybridization, reproductive capacity, dispersal, etc.). Although the invasion problem is conceived as human-driven, little attention has been paid to the human dimension of the problem, except to attribute dispersal and disturbances to people's activities. Considerably less emphasis is placed on the advancement of theory, philosophical issues or the complexity of social interaction that results in the various activities on the landscape. As such, this emerging field of "invasion biology" or "invasion ecology" as it has come to be called (Reichard and White 2003) can thus be viewed as a highly practical field that applies ecological knowledge of which it itself is a subset.

Alternatively, the lack of emphasis on certain topical areas, such as ecological theory and the incorporation of social science perspectives of the human dimension of the invasives problem, and a reluctance to engage a critique of the epistemology of invasion ecology by those who practice it, hinders this field of study from becoming the driving force behind cutting-edge ecological research, which it has the promise to be. This is not to say that cutting-edge research is not being done within invasion ecology (it is), but rather the dialog between theory informing fieldwork and experimentation and the subsequent reformation of theory from these results has been heavily weighted toward its applications. The discussion of theory has largely taken the form of testing the assumptions behind both equilibrium and disequilibrium

ecologies, with the momentum shifting away from both these approaches and towards new emergent hypotheses, but a conservatism remains in that the scope of the invasives problem remains firmly rooted and defined by the same ideas originally laid down by Elton (1958), namely that there is a direct causal relationship between species invasion and biodiversity loss and extinctions.

Recent findings suggest that this traditional theoretical approach to ecology needs modification. For one, there appears to be no direct link between biodiversity and invasions. Both positive and negative correlations between diversity and invasibility have been observed, and are often associated with differences in scale, with positive correlations seen at larger spatial scales and negative relationships at smaller scales (Levine and D'Antonio 1999, Tilman 1999, Brown and Peet 2003, Byers and Noonburg 2003, Dunstan and Johnson 2004). The negative correlation is often attributed to population dynamics: having more species in a small area creates smaller populations of each species that are less stable and more vulnerable to mortality (Tilman 1999, Dunstan and Johnson 2004). The positive correlation at larger scales has been attributed to the greater heterogeneity of habitat and variation in resource availability and disturbance that allow for a more diverse array of species, with resulting pockets of stability and instability (Levine and D'Antonio 1999, Tilman 1999, Byers and Noonburg 2003). The causal relationship between diversity and invasibility is thus diluted. Indeed causation becomes difficult to pin down, since invasion is seen to be influenced by changing spatial patterns of resource availability

that must coincide with the kinds of opportunities the present species can exploit (Davis et al. 2000).

In addition to the diversity-invasibility hypothesis, the axiom that competition from invasive species causes extinctions of indigenous species has only limited support. Although competition is often assumed but rarely tested (Levine et al. 2002), competition-driven extinction can only be demonstrated on short time scales in cases of herbivory or predation (intertrophic competition) but not in cases of intratrophic competition (Davis 2003). Conversely, intratrophic competition may reduce invasiveness. The presence of a dominant competitive native species can prevent the establishment of introduced species, and the presence of these competitive dominants are more frequent as species diversity increases; in this case, the causal factor in preventing invasions lies in intratrophic competition, not in diversity itself (Wardle 2001). Although not undermining the urgency of the invasives issue, these case studies outline some of the fundamental flaws in the overall theoretical constructs employed to define the problem.

Although the empirical evidence suggests otherwise, the notion of “Balance of Nature” still pervades much of invasion ecology. It has, however, come under scrutiny in the past few years. Hengeveld (1986) indicated early on that equilibrium and non-equilibrium approaches differ in that the former is a largely deductivist approach while the latter is more inductive. Mikkelsen (2001) amplifies this theme by noting that more simplistic theories of complex systems are more accurate than complex theories when data are limited, while complexity of explanation strikes

closer to the truth as more data accrues. Although this would seem to suggest that equilibrium-ecology should give way to non-equilibrium ecology, evidence suggests that both of these approaches are conceptually tied together, and both must give way to new theories. Sterelny (2001) argues that while the fluctuating community membership observed in contemporary assemblages (as evidence of instability) can be observed in the fossil record, that a tendency toward stasis is apparent in the persistence of assemblages over long periods of time; that is, both equilibrium and non-equilibrium are apparent. Walker and Wilson (2002) demonstrate that vegetation often possess characteristics predicted by both perspectives, and that ecological reality lies somewhere between these two conceptual poles. Indeed, the difference between these two perspectives can be seen to be simply a matter of which environmental variables researchers hold constant in analyzing causal relationships, with equilibrium ecologists holding the environment constant to study changing species and non-equilibrium ecologists keeping species constant while studying changing environments. The two approaches are complementary, since the study of fluctuating species in coordination with fluctuating environments would likely only yield correlations (not causal relationships) and thus lack the rigor of causation that reductionist science requires. Invasion ecologists thus often switch between the two perspectives based on the relative explanatory power of each (Sax and Brown 2000). Indeed, whereas these two perspectives are often placed in opposition to each other, they are actually complementary. For example, Chapin et al. (1996, 1017) define a sustainable ecosystem as one in which “over the normal cycle of disturbance events

[non-equilibrium], maintains its characteristic diversity of major functional groups [i.e., avoids taxonomic disharmony, an equilibrium-based concept], productivity, soil fertility, and rates of biogeochemical cycling [non-equilibrium]” (bracketed statements added). This perspective draws upon the findings of invasion ecologists, drawing from both equilibrium and non-equilibrium perspectives, and utilizes the factors that were found to contribute to invasion success. As such, however, the stability of ecosystems is still defined in terms of its invasibility, and the original tautology of the Balance of Nature perspective is thus reproduced in another form. Within invasion ecology, theory is modified within the confines defined by the original phrasing of the invasion problem, but the problem itself remains unmodified. Given that invasion ecology is practiced as a subset of general ecology, it is perhaps not surprising to note that this problem whereby overall theory remains unmodified in the face of empirical evidence is endemic to biological ecology more broadly (Cooper 2001).

The Island Perspective

As a final note to the SCOPE project of the 1980s that is relevant to this research, the subject of islands received a considerable amount of attention. At that time, the typical understanding of islands suggested that with greater distance between islands or continents (that is, with greater isolation), the biota present were subjects of long-distance dispersal, and species richness was largely the product of adaptive radiation and endemism, reducing the overall number of families that species

were derived from and contributing to missing taxonomic functional groups (“disharmony;” Moulton and Pimm 1986, Brockie et al 1988, Loope and Mueller-Dombois 1989). Project researchers suggested that the same processes that contribute to endemism and disharmony (i.e., isolation) also render islands more susceptible to invasions. Rats (*Rattus spp.*), accidentally introduced by humans, have been implicated in the extinction of several island bird species that have evolved in isolation from predators, for instance, while island bird species that have evolved in conjunction with the presence of large predatory land crabs have found an equilibrium with introduced rats (Brockie et al. 1988, MacDonald et al. 1989). Table 2.2 uses data from Hawaii showing the percentage of successful introductions of species in higher order taxa (birds, reptiles and mammals) compared to the relative number of endemic, non-endemic natives, and introduced species in those classes, revealing a greater tendency for introductions to be successful in taxa without much representation from native species at all. Table 2.3, using data from island nature reserves, shows a trend toward greater numbers of introduced species with greater endemism, although the trend becomes less apparent at lower rates of endemism, and the relationship implied in Table 2.2 for Hawaii does not necessarily hold true in all cases, such as the Galapagos. Endemism, disharmony, and invasion success may not be directly causally linked, but may instead be reflections instead of a particular island’s relative isolation. Furthermore, the disharmony argument is based on evolutionary ecology models, and is biased toward Balance of Nature explanations where species adapt to static ecosystems. For example, New Zealand has an

Table 2.2. Data relating successful introductions to endemism and taxonomic disharmony.

| Species | Birds | Mammals | Reptiles | Source |
|---------------------|--------------|----------------|-----------------|------------------------------|
| Endemic | 44 | 0 | 0 | Loope & Mueller-Dombois 1989 |
| Other Native | 13 | 1 | 0 | Loope & Mueller-Dombois 1989 |
| Introduced | 38 | 18 | 13 | Loope & Mueller-Dombois 1989 |
| % Successful Int. | 60 | 90 | 93 | Moulton & Pimm 1986 |
| % Unsuccessful Int. | 40 | 10 | 7 | Moulton & Pimm 1986 |

Table 2.3. Endemism, disharmony, and introduced species for selected island nature reserves.

| Reserve | % IB | %IMR | % End | % Int |
|--------------------------------------|-------------|-------------|--------------|--------------|
| Haleakala National Park | 44.7 | 92.3 | 61 | 34.8 |
| Galapagos Islads National Park | 5 | 21.1 | 46.5 | 28.4 |
| Campbell Island Reserve, New Zealand | 25.6 | 0 | 33.5 | 5.3 |
| Aldabra Island, Seychelles | 4.5 | 66.7 | 21.6 | 7.11 |
| Salvage Islands, Portugal | 0 | 66.7 | 7.3 | 14.8 |
| Isle of Rhum National Nature Reserve | 0 | 33.3 | 0.1 | 3.6 |

Source: Brockie et al. 1988

Key: %IB = Introduced bird species as a percentage of all bird species; % IMR = Introduced mammal and reptile species as a percentage of all mammals and reptiles; % Endemic = endemic species as a percentage of total native species; % Introduced = introduced species as a percentage of total number of species

extremely large percentage of introduced species (47%; Heywood 1989), but these are limited largely to agricultural lands and rarely invade into the native forests unless they are disturbed; likewise with Haleakala National Park, the majority of the introduced species are limited to the former sugar plantations below 600m elevation, and the rainforest above 1200m “remain in near pristine condition “ (Brockie et al. 1988). The invasives appear to be limited to areas of disturbance, and the intact island ecosystems appear resilient from this perspective, a point that brings the question of disturbance’s role in the invasion process to the forefront of the discussion.

Although disturbance is often noted on islands, almost exclusively in regard to human activity, the *susceptibility* of islands to disturbance is not considered as contributing to the apparent vulnerability of island ecosystems to invasion, a point that is later considered in the SCOPE project (D’Antonio and Dudley 1995). Loope and Mueller-Dombois (1989) point out, however, that Hawaiian ecosystems are not adapted well to fire disturbance, and the introduction of burning in Polynesian agricultural practices dramatically transformed the biota of the islands.

Island ecosystems have long been viewed as being especially susceptible to invasion by non-native species (Loope and Mueller-Dombois 1989). With oceans providing formidable barriers to species spread, the total number of species present on islands tends to be lower than continental areas, with the number of species generally decreasing with increased distance from neighboring islands or continents (MacArthur and Wilson 1967). Evolutionary ecologists cite isolation as being a

driving force behind the susceptibility to invasion, leading to high rates of speciation and endemism through adaptive radiation (Usher et al. 1988, Whittaker 1998), with loss of dispersability being one aspect important to this study (Adersen 1995). These traits are believed to contribute to increased vulnerability of islands to invasions through the absence of key taxa, such as predators or herbivores, a situation described as taxonomic disharmony or vacant niches, or due to poor competitive ability of the species resulting from evolving with so few other species that are highly specialized and thus not coming into direct competition as often (Loope and Mueller-Dombois 1989, Whittaker 1998). An example of these relationships can be seen with bird populations on islands; bird populations that evolved with predation (land crabs) found an equilibrium with the introduction of rats, whereas those populations that evolved in the absence of predators often became extinct through predation by rats (Usher et al. 1988). Island invasibility arises, it is argued, as a result of isolation, endemism and specialization, because these conditions have created species that are poor competitors. These evolutionary arguments, focusing on taxonomic disharmony, tend to emphasize intertrophic interactions, which historically have produced a plethora of extinctions of island species. This study is concerned with intratrophic competition among plant species, however, and the remainder of this discussion focuses on this topic.

This view that the biota of island ecosystems are inherently poor competitors has come under dispute, however. D'Antonio and Dudley (1995) note that the view that islands are susceptible to invasion arises from the higher percentage of successful

introductions of non-native species to islands than continents, but note that there are no figures available for the number of failed introductions. The authors further suggest that the high specialization of island species to their niches should make them more competitive for those niches, and suggest that the alteration of nutrient pathways through disturbance makes these niches more generally available to a wider range of species. Indeed, many examples exist that demonstrate the resistance of native island forest ecosystems to invasion. Usher et al. (1988) and Kanehiro and Mueller-Dombois (1995) observe that invasive species are largely limited to areas of former human disturbance on Mt. Haleakala, Hawai'i, whereas forests that were not human disturbed remain relatively intact. Lepš et al. (2002) similarly note the dominance of *Piper aduncum* in early secondary forest succession and its absence from intact primary forest in Papua New Guinea, and Lavergne et al. (1999) note similar patterns of disturbance-associated establishment for *Ligustrum robustum* on La Réunion, which then forms dense monocultural stands that exclude native species and inhibit forest recovery. These examples contrast intact, native forests with invaded disturbed (especially by people) areas; indeed Steadman et al. (1999) observes that the greatest variation in the composition of vegetation communities on Tonga is closely tied to the degree of anthropogenic disturbance. These studies suggest that island plant species can be resistant to non-natives, and that the invasion process may be disturbance-driven.

Some researchers have investigated disturbance as a significant component of the invasion process. As evidence of the importance of disturbance, MacDonald and

Cooper (1995) note that changes in disturbance regime (as a regularly repeated pattern of disturbance) favor non-native species, although Mueller-Dombois (1995) notes no correlation between biodiversity and disturbance regime itself. That is, for a particular vegetation community to be formed in conjunction with a particular disturbance regime appears to have no effect on its invasibility or overall number of species, but when the pattern of disturbance changes, change in community structure, including invasion, become possible. Indeed, D'Antonio et al. (2000) explain how the exotic species that become established after disturbance can alter the disturbance regime, for instance by being susceptible to burning in a native vegetation that is not fire adapted. Further insights into the role that disturbance plays in altering environmental conditions are given by Rogers and Parker (2003), who indicate that although human disturbance of habitat fosters vegetation communities with higher representation of non-native species, the native vegetation can show resilience to change if the disturbance does not mitigate harsh environmental factors as salt spray or wave action, as in the case of littoral zones. Although disturbance has received some attention, it is rarely treated more than simply creating opportunities for non-natives, with more attention then being paid to specific plant traits.

These studies fall short of presenting a theoretical view in which disturbance is a full, active, interactive agent in the invasion process. As the above examples illustrate, approaches to disturbance tend to represent a vacillation between non-equilibrium and equilibrium approaches. That is, disturbance is largely understood as first resetting environmental conditions, allowing for different species to establish in

an area (a non-equilibrium perspective since it asserts that the environmental conditions determine community composition, Hengeveld 1987), after which individual plant traits drive the invasion process (the equilibrium perspective, because it views competition between species as the determinant of community composition, *ibid*). This falls conceptually short of incorporating disturbance into an understanding of the invasibility of island communities. Whittaker (1995) asserted that investigating the interaction between disturbance and the specific life history and reproductive traits of the plant species was crucial to understanding the process of species turnover on islands, but little research has been done in this vein. More recent work in island ecology has been to reassess the assumptions that underwrite MacArthur and Wilson's (1967) Equilibrium Theory of Island Biogeography (ETIB), by addressing the wide variety of equilibrium or non-equilibrium conditions that persist, by clarifying spatial and temporal scales that various processes operate at, by abandoning emphases on concepts that are difficult to demonstrate such as competition, by clarifying distinctions between islands and continents and near-shore and remote islands, and by stressing the conditions that make each island or archipelago unique (Whittaker 2000, Walter 2004). Other island scholars have applied an improved ETIB model in regression analyses of factors contributing to deforestation, in an attempt to link the collapse of various Polynesian societies to the erosion of their ecological base (Rolett and Diamond 2004). Indeed, island scholars acknowledge that current conservation theory inadequately considers the pervasive anthropogenic character of most of the world's ecosystems (Whittaker et al. 2005).

A Human Driven Problem

Throughout the discussions of the SCOPE team members, the theme of human agency frequently surfaced but was not studied in depth. According to the definitions of this period, the classification of a particular species as invasive was contingent on humans as agents of introduction, either deliberately or accidentally (Usher et al. 1988, MacDonald et al. 1989). There was no further discussion of the topic, although Mooney and Drake (1989) generalize this agency to mean transportation networks and commerce without further elaboration, as well as citing population growth as a persistent and ever continuing threat to natural systems. Exceptionally, Di Castri (1989) discusses three periods of human agency in biological invasions, an early phase including all activity before A.D. 1500 (positive feedback between human activity and environmental change), a second phase commensurate with the onset of European colonization and exploration that broke down the biogeographic barriers between continents, and the third (current) phase in which human activity impacts the global system. If the last two phases are viewed on the same temporal scale as the first, then these two phases might be understood as being a single phenomenon. These are seen as two separate phases, however, because the natural environment is taken as the object of study, and the breaking down of biogeographic barriers and the commencement of global change are seen as two separate phenomena, whereas if these events are studied from a social science perspective, they can both be seen as a product of the capitalist world system (as per Wallerstein 1974). The lack of

attention given to human agency in the invasion process by the SCOPE project stems from the simple fact that this group of scientists did not study human society.

This division of subject matter between the social and natural sciences continues to cause the question of human influences to be largely neglected by invasion ecologists (Table 2.1), despite the unanimous concession that the phenomenon in question is a matter of human interaction with the environment. Where invasion ecologists have engaged human influences, people are depicted as remaining outside nature, lobbing sabots into the delicate machinery of ecosystem processes. Contemporary research on the problems often focus on global change, through the fostering of climate change (Kapelle et al. 1999, Walther 2002), alteration of biogeochemical cycles (Vitousek et al. 1997), or the extension of anthropogenically disturbed areas (changes in land-use) that create habitat for invasives (Mooney and Hobbs 2000, Jenkins and Pimm 2003), and deliberate introductions (Kowarik 2003). These arguments analyze the same aspects of the invasion problem as previous studies, only with an expanded scale. They do not add any new concepts, nor do they expand inquiry of processes into the social domain.

A few studies attempt to find statistical correlations between indigenous and non-indigenous species diversity and various quantified aspects of society, with some interesting results, and more telling responses by the researchers in question. Using the density of alien plants as the dependent variable compared to a variety of socioeconomic and land-use data in a step-wise regression analysis, Vilà and Pujadas (2001) found the strongest overall positive correlation of alien density with volume of

imports and the Human Development Index (HDI), but when land-use variables alone were used, the strongest *positive* relationship was with the area of protected land. The authors note that although imports and area of protected lands are independent, both are strongly positively correlated to the HDI. The use of HDI as a variable in regression analysis is highly questionable, since regression requires at least interval- or ratio-level data, and the HDI as an ordinal system, was never meant to be more than a comparative indicator. It is a composite of economic, social and demographic indicators, such that the composite indicator obscures the differences between these component values. That is, two countries may have similar composite HDI scores, but one's score may be the result of economic strength while another may be on social or demographic factors; the meaning of the results is thus obscured. Interestingly, in relation to the positive correlation between density of alien species and protected lands area, the authors have little to say other than to register their surprise and focus their attention instead on the possibility that improved living standards would foster more imports and thus increase the introduction of alien species.

A similar study by McKinney (2002) notes that diversity of both non-native and native species increases with park area. In his discussion, he notes that his study confirms previous assertions that native species diversity is positively correlated with large park area (the traditional, equilibrium, perspective), while he attributes the increased non-native diversity to a correlation with native diversity by way of heterogeneous landscapes and resource niches (only secondarily correlated with area,

and related to the scale-dependent effects on diversity, which is not traditional ecology). Oscillating between equilibrium and non-equilibrium explanations fails to advance our knowledge of the invasion process. It could be argued, for instance, that the scale-dependent effects on landscape heterogeneity that increases the diversity of non-natives is the same mechanism that creates diversity of natives as well. As a result, the question of why the parks are invisable remains unanswered, and the question of whether a separate, conserved nature is adequate to preserve biodiversity is avoided.

Invasion ecology is uniquely situated to bridge the intellectual gap between the physical and social sciences by addressing an inherently human-driven problem that engages all aspects of ecological science, both biological and social, but suffers from the traditional boundaries separating the social and natural sciences. That is, although invasion ecology is well situated to bridge this gap, natural scientists in invasion ecology have been more focused on maintaining the integrity of native ecosystems than expanding their view to be inclusive of human-driven disturbance and the social forces that contribute to it.

Deconstructing Nativity and Its Opposites

The social sciences have been reluctant to engage the invasive species issue in a way that would be viewed as constructive by invasion ecologists, largely because of the implications of the language that is used in describing this phenomenon. For instance, theoretical inertia within ecology has been attributed to ecological thought

being embedded in, and colored by value-laden ideas. Botkin (1990) demonstrates that these values are rooted most proximally in the deist belief from the Enlightenment in a mechanical, clockwork universe and are ultimately rooted in Christian religious beliefs giving Man [sic] dominion over Nature. Although prevalent in scientific thought in some form, the Balance of Nature idea was formally tied to Darwin, thus entering into ecology, by Herbert Spencer who used it to explain the preservation of races (Cuddington 2001), and therefore is tied into the notion of environmental determinism as well, the legacy of which continues to be a rift between the social and biological sciences in general and between physical and human geography in particular. Similarly, the concept of nativism is linked to nationalist, xenophobic, and racist discourse (Peretti 1998, Comaroff and Comaroff 2001). Simberloff (2003) objects to these criticisms, however, stating that these motives cannot be clearly linked to invasives research, that these criticisms ignore the damage that invasive species do, and that criticisms that management targets all invasives, not just harmful ones, or ignores the benefits are unfounded. However, a statement such as

The species *Homo sapiens* itself is without question the super invader of all time. In spite of numerous local genotypes gathered into the ancient races, the human line of evolution has not speciated and does not promise to, at least in the near future, in part because of constant hybridization and introgression (Wagner 1993).

begs to be deconstructed, but it is not representative of the whole of the literature, and Simberloff's (2003) point is well taken.

However, the paucity of articles (Table 2.1) that address benefits of non-indigenous species or even attempt to assess whether a particular species actually

poses a threat make such efforts appear to be little more than token contributions, and this part of his rebuttal is not entirely convincing, as certain biases appear evident. His concern lies in the fear that opponents to the control of exotic species will use these claims of racism and xenophobia to discredit invasives control efforts, and he cites an example whereby interests in the horticulture industry have attempted to do so. There is a tendency then to cling to the “Balance of Nature” idea because this theoretical perspective provides ethical values that conservationists can use in the political arena. Indeed, if ecology becomes seen as autecology only (as empirical evidence suggests), then generalizations become well nigh impossible (Woods and Moriarty 2001), and can no longer provide ethical guidance or political leverage to the ecologist. All values are strictly social constructs however, but adherents to the Balance of Nature approach expect their values to actually be realized in Nature (Botkin 2001), whereas preserving naturalness is but one of a plurality of ways to value the environment (Woods and Moriarty 2001). Although the Balance of Nature idea provides values that can be used to take a stance in the political arena, maintaining this position preserves a political vulnerability through nativism. Inasmuch as nativist discourse represents the politics of belonging (Comaroff and Comaroff 2001) and that being associated with people is typical grounds for excluding a particular species from native membership (Woods and Moriarty 2001), it is clear that to many invasion biologists it is people in general that do not belong (to nature). This division of society from nature underwrites these values and hinders the

“creativity and ingenuity [required] to protect nature in this troubling milieu” (Peretti 1998).

Current Contributions of Biogeography

Geographers have long been participants in the ecological debates described above, and biographers have made notable contributions to the themes relevant to this paper, including species invasions and island ecology. Indeed, island biogeography and the broad concerns over biodiversity loss and invasive species have been the foundational concerns of biodiversity conservation, such that biogeography has been playing an increasingly prominent role in this domain (Whittaker et al. 2005). The adequacy of current conservation theory has been called into question, with a reliance on MacArthur and Wilson’s (1967) Equilibrium Theory of Island Biogeography and a reluctance to accept the majority of landscapes as anthropogenic being the main targets of critique, and with biogeography’s emphases on disequilibrium, disturbance and studying the unique character of any given place providing alternative perspectives that are lacking in non-geographical ecology (Walter 2004, Whittaker et al. 2005). Biogeographers are making important contributions in the areas of invasive species, island ecology, and, increasingly, human-environment interaction.

In terms of invasive species, biogeographers contributed to the discussion from the beginning and continue to contribute in novel ways. Veblen and Stewart (1982) were examining the impact of introduced mammals on the forests of New Zealand in the years prior to the initiation of the SCOPE project on invasive species.

More currently, Relva and Veblen (1998) have performed similar studies of introduced herbivore impacts on forests in northern Patagonia, as well as developing methods to analyze invasions through the use of historical aerial photographs and GIS (Mast et al. 1997). Kupfer and Miller (2005) studied the interactions between species composition (emphasizing native and non-native differences), grazing, and fire disturbance in contributing to mesquite invasion in southern Arizona. Wolf et al. (2004) examine the interaction between invasive leguminous plants and the ways that they change soil conditions in promoting biological invasions. Some unconventional research in invasion ecology has been performed by biogeographers as well. Harrington and Ewel (1997) the invasion of monocropped tree plantations by both native and non-native species, identifying one of these commercial species as being concomitant with indigenous species, while others seem to exclude them. Other researchers have examined the risks and benefits from species introductions, and set down a research agenda for making these assessments (Ewel et al. 1999). The benefits of alien species, such as acting as nurse plants for natives or for filling empty niches, replacing extinct native species, providing resources for native species, controlling other non-natives or through their socioeconomic value, have been examined as well (Ewel and Putz 2004).

In terms of island ecology, biogeographers have been at the forefront of shaping theory in general and in studying Pacific Islands in particular. Some scholars have extended the Equilibrium Theory of Island Biogeography (ETIB; MacArthur and Wilson 1967) into questions of human-environment interaction (Rolett and

Diamond 2004). Others have pushed theory beyond ETIB by assessing its shortcomings and asking new research questions (Whittaker 2000, Walter 2004). Given that conservation theory is largely based upon ETIB, it is not surprising then that these new lines of inquiry have been reshaping conservation biogeography as well (Whittaker et al. 2005).

Other biogeographers have been performing fieldwork in the South Pacific islands. Variation in forest composition and structure in relation to environmental variables has long been a subject of Pacific Island biogeography, such as Franklin and Merlin's (1992) study forest variation in the Cook Islands or, more recently, along forest-shrubland gradients in New Caledonia (Enright, Rigg and Jaffre 2001). Other studies have investigated the distribution of birds throughout different forest types in Tonga and Fiji (Steadman et al. 1999, Steadman and Franklin 2000).

Biogeographers have also studied the interaction of people and the environment in recent years. Some researchers have studied the interaction between human induced fire disturbances and tropical rainforest recovery in response (Kellman and Tackaberry 1993, 1997; Kellman, Tackaberry and Rigg 1998). Voeks (2004) has examined the influence of people in proliferating plant species with medicinal properties in disturbed landscapes, as well as examined the role of forced African migrants in contributing to changes in the vegetation on the landscape (Carney and Voeks 2003). Other biogeographers have studied the effect of human activity on landscape structure and processes (Medley et al. 1995, Medley et al. 2003, Wang and Medley 2004). Biogeographers have been contributing to the study of

human-environment interaction, an area that has long been the domain of cultural and political ecologists, and, indeed, these geographers also have a contribution to make to the study of invasive species.

Cultural Ecology and Political Ecology Perspectives

Cultural and political ecology also has much to offer invasive species research, in that this geographical subdiscipline has a long history of engaging questions of human-environment interaction and participating in the development of ecological thought. Indeed, the early cultural ecology of the 1960s and 1970s were largely Pacific island-based studies that questioned some of the fundamental assumptions of the ecology of the day and laid the groundwork for the rise of political ecology in the 1980s (Geertz 1963, Rappaport 1968, Clarke 1971, Waddell 1972, Brookfield 1973).

Although the debate between equilibrium-based and non-equilibrium-based ecologies was a source of contention between invasion ecologists during the 1980s (Hengeveld 1987), cultural ecologists have been critical and suspicious of equilibrium-oriented ecologies for many decades prior to this time. Although the ecosystem and systems-ecology have been adopted by several early cultural ecologists (for example, Fosberg 1963, Rappaport 1968), non-equilibrium views of ecology have long been part of the cultural ecology tradition in geography, originally advocated by Sauer (1952) and developed further into ideas of adaptive strategies (Bennett 1976, Denevan 1983) and adaptive dynamics (Knapp 1984, 1991).

Where cultural ecologists did adopt equilibrium-oriented ecological perspectives, it was not done uncritically. For instance, Clarke (1971) revises the notion of a static carrying capacity of the land, and reconceives the idea in terms of dynamic interaction between the environment and knowledgeable, active human actors, such that change is open-ended and not cyclical or homeostatic. Waddell (1972) notes that the New Guinean society of his study was not a closed and bounded system, but was open to change from a broader political economy. Lea (1973) demonstrated a disjunction between perceived and actual ecological stress, and thus illustrated that no homeostatic mechanism connecting society to nature existed. Indeed, Brookfield (1973) refuted the central theorem of Rappaport's model by demonstrating that the social system of Highland New Guinean societies was not driven by porcine demography, but that people actively controlled the pig population until such a time as a feast was determined to be necessary. By the time that biological invasions were garnering attention by biological ecologists, cultural ecologists had already relegated its equilibrium-ecology underpinnings to being merely a heuristically useful concept (Knapp 1991). Given that equilibrium-ecology is a largely deductivist approach, it is not surprising that the geographers of this period, engaged in a program of intense fieldwork, rejected these ideas.

Although cultural ecologists have been critical of equilibrium-ecology for several decades on the grounds of its explanatory power, political ecologists have been critical of this mode of ecological thought for the values that it espouses, and the resultant ways in which implementation of these environmental ideas affect people

living in those environments. In terms of environmental conservation, much of the literature has focused on the coercive aspects of this discourse (Peluso 1993). For instance, researchers have questioned the systems-oriented, climax-vegetation model of ecology itself as inevitably blaming local level actors for environmental change (Leach and Mearns 1996). The use of environmentalist discourse has been identified as a means of justifying the removal of people from the land and forcing them to change their habits (Zimmerer 2000, Davis 2000). Single-scale approaches, such as approaching conservation through establishing bounded, large-area reserves that are constantly land hungry since the only way to bolster the threatened “naturalness” of these areas is to establish “buffers” and thus constantly expand, an issue of high relevance to the invasives debate, have been identified as one such means that removal of people is accomplished (Zimmerer 2000). Furthermore, such conservation policies rarely work unless they involve and work in the interest of the people in the surrounding area (Young and Zimmerer 1998). These critiques of equilibrium-oriented ecology are largely centered in poststructuralist political ecology, which is a perspective that centers on studying expert claims to knowledge and authority and relying on deconstructive methodology.

The poststructuralist approach has its limits in applicability, however. The poststructuralist critique in political ecology is an outgrowth of the early cultural ecology studies of the late 1960s and early 1970s, and arose largely out of the call by Blaikie and Brookfield (1987) to find a common theoretical currency from the plentiful supply of case studies (Peet and Watts 1996), which itself was a program of

research laid down by Brookfield (1973) that called for field studies to essentially build a political economy theory from the individual agents upwards, and avoiding the structural *a priori* assumptions inherent in much structuralist thought.

Poststructuralist research, however, rapidly disengaged from realist examination of environments, failed to explain environmental processes, and generally lost touch with its ecological foundations (Grossman 1998, Vayda and Walters 1999). While poststructural political ecology sought to deconstruct conservation theory and practice, it only managed to further reproduce the divisions between the social sciences and natural sciences, a feature of the postmodern condition (Latour 1993) that social ecologists suffer from as well as the invasion ecologists.

Geographers have made some movement toward bridging this gap. Non-equilibrium ecological approaches have been prescribed as a means avoiding the social excesses of the past (Zimmerer 1994, 2000). Robbins (2001), however, indicates that while landscapes have never behaved in the ways that modernist theories have predicted, that the “new ecologies” may not offer a viable alternative since their implementation requires the same knowledge-power relations as equilibrium ecologies. That is, biological ecologists in the “New Ecology” scenario still hold the knowledge and thus the answers to ecological problems, and thus the poststructural critique remains. Indeed, given the discussion above concerning the complementarity of equilibrium and non-equilibrium approaches, this critique is well founded. Cultural and political ecologists also need an infusion of new ecological theory (although lying in wait to simply pounce upon and deconstruct it is

no longer a desirable or constructive pursuit, Latour 1993), or need to formulate it themselves.

Geography thus stands uniquely poised to enter the fray over invasive species. Cultural and political ecology have a long tradition of engaging questions of human-environment interaction, and the invasives species issue clearly falls into this category, although the subdiscipline has been reluctant to enter this debate (Robbins 2001 being an exception). The role of ecological theory has a large role to play in this reluctance; the invasives problem falls under a theoretical heading that cultural and political ecologists have long considered questionable. A unique situation thus exists across the academic disciplines: invasion ecologists fail to fully explore the scope of the invasives problem because of the values they subscribe to, and cultural and political ecologists are slow to engage the topic because of these same values that define the problem. With these values strongly rooted in the division between the social and natural sciences, ecological research (more generally) can only move forward if this conceptual barrier is removed. Given that this problem is primarily defined as being human in origin, geography thus is in a favorable position to move ecology into the 21st century.

Summary

Invasion ecology presents both social and biological ecologists with the opportunity to advance multidisciplinary ecology by engaging the social processes that create disturbance or alter disturbance regimes on the landscape and contribute to

change in the vegetation. This study contributes to bridging this gap by studying an identified invasion, that of *Merremia peltata* in Samoa, across a landscape that possesses elements that are both natural and anthropogenic, and that are subject to a wide variety of disturbances of varying origin, duration and frequency.

Biogeographic analysis examines *M. peltata* in the context of vegetation communities across the landscape, so comparisons of other native and non-native species are made. A socially self-reflective analysis of this invasion as a perceived problem is presented, examining the conceptual constructs that define the problem as well as exploring the international power inequalities that influence how the varying perceptions play out on the landscape. It will be shown that traditional discourses over invasive species are applied to *M. peltata*, although it is a native species and appears to be spreading out of forested areas rather than into them, because international power inequalities cause biosecurity concerns to direct biodiversity conservation. That is, management over invasive species in the region focuses on preventing their spread from one location into another. In the case of *M. peltata*, which is spread throughout the Pacific Islands, the only countries at risk from its spread are Australia, New Zealand and the United States (Hawaii). These countries, through the considerable influence in the region that they wield through the disbursement of development aid, have tremendous influence in shaping local biodiversity management. The risk in Samoa is that by surreptitiously lumping *M. peltata* with non-native invasive species, that international efforts will misidentify the

root causes (and solutions) for the problem, and act in an interventionist manner to the detriment of local ecosystems for the sake of protecting their own.

Chapter 3

Background

Study Site

Research was conducted in the village of Fa'ala, on the island of Savai'i in the Independent State of Samoa (commonly referred to as Samoa and formerly called Western Samoa), from November 2002 until November 2003. Samoa is a Pacific Island Country (PIC) that comprises the western portion of the Samoa Archipelago (Figure 3.1) and contains the two largest islands of the chain, 'Upolu (containing the capital and seaport Apia) and Savai'i, as well as two smaller inhabited islands, Manono and Apolima. The eastern portion of the island chain is a United States Territory commonly referred to as American Samoa and consists of the inhabited islands of Tutuila (including the capital and seaport Pago Pago) with the small populated island of Aunu'u and the Manu'a group of islands that include Ofu, Olosega and Ta'u. The chain lies roughly between 13 and 14 degrees South latitude and 171 and 172 degrees West longitude, where it lies at a considerable distance from any of the cosmopolitan centers of the Pacific Rim, with New Zealand and Australia having the greatest political and economic influence on the independent state. Samoa is a developing country that has recently been upgraded by the World Bank from "least developed nation" status, its lowest ranking, into the next higher category, and is considered to be economically on par with, rumored to perhaps even to have surpassed, Fiji, which has long been the economic leader of the PICs. Development

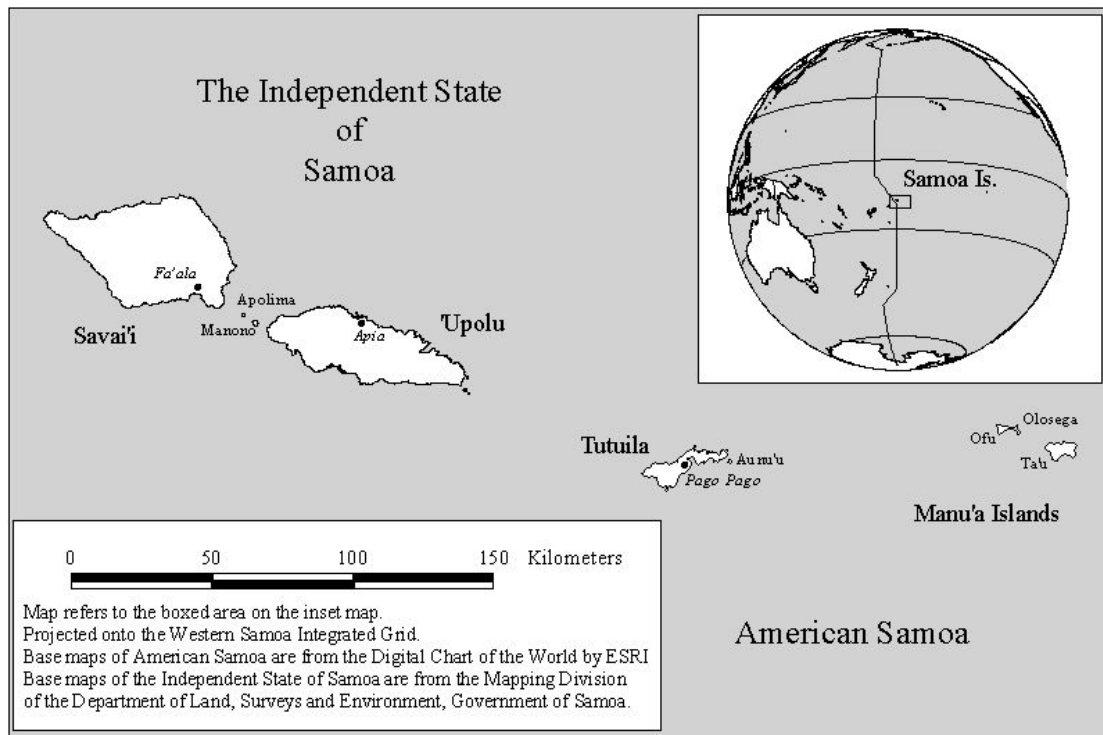


Figure 3.2. Map of the main islands of the Samoa chain.

has mostly been concentrated in Apia, however, and life in the rural villages has changed little over the past decade since the author first became involved with the country. The infrastructural improvements enjoyed by the urban populace are only very slowly being extended into the rural areas, and Savai'i last of all, a fact which has spawned an expression, "what is good for 'Upolu is good for Savai'i," that is often invoked in rhetoric to emphasize disparity in development opportunities.

Fa'ala was selected as the primary study site because the village maintains a large expanse of lowland rainforest, part of the Tafua Peninsula Rainforest Preserve, which is one of the few, large, extant expanses of lowland forest left in Samoa. Village lands extend upslope and include areas of montane forest as well. Figure 3.2 shows forest cover for Samoa circa 1989, and depicts the study area as well as indicating the 300 meter elevation contour, which serves as a rough boundary between lowland and upland ecosystems. This map demonstrates that Samoa's lowland ecosystem is extensively disturbed, and indeed, virtually all of Samoa's economic activity is concentrated in this zone. This lowland area also marks the elevational range for *Merremia peltata*. Fa'ala thus provides an excellent opportunity for studying this invasion across a landscape that expresses a wide range of natural and anthropogenic expression, and provides insight into the question of whether islands are inherently more susceptible to invasion or more susceptible to disturbance (D'Antonio and Dudley 1995). Indeed, the Fa'ala landscape is being written by the cooperation and contention of a variety of actors cutting across several spatial scales, from the local to the global.

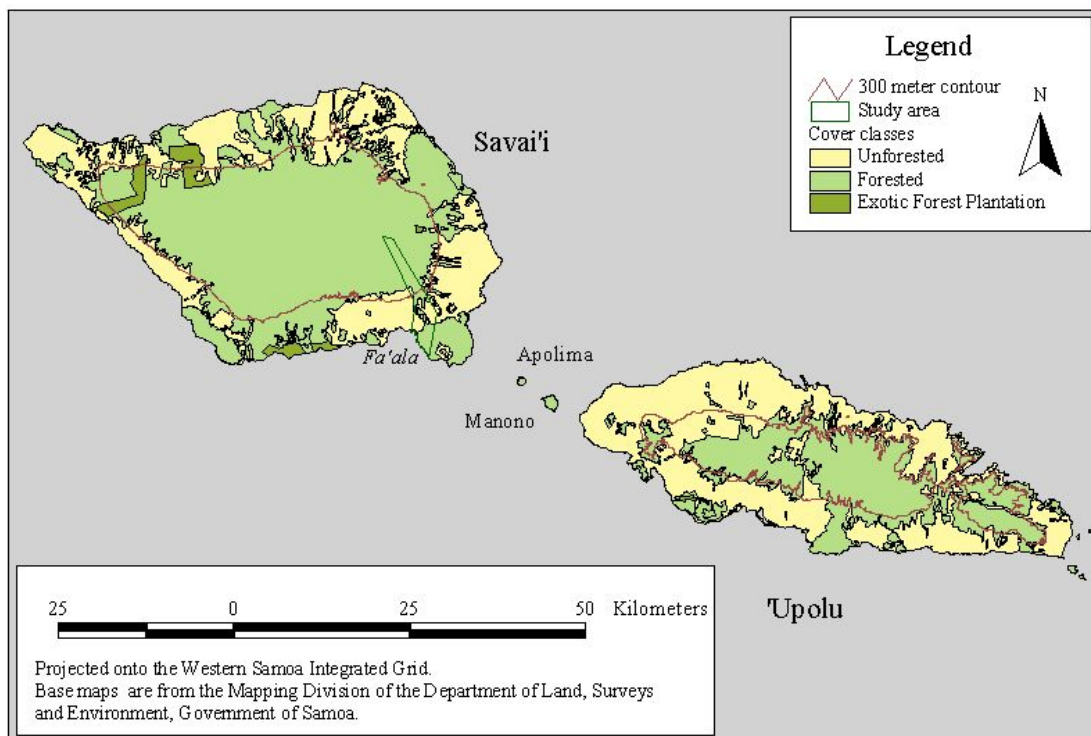


Figure 3.2. Map comparing lowland and upland forest cover

The Landscape

This study uses the “landscape” as its primary scale of analysis, since at this spatial scale, the simultaneity of both the natural and the social are apparent. The landscape is here defined as being the entire village lands held by Fa’ala. By custom, a village is entitled to the lands extending from the edge of its reefs to the crests of the mountains running along the center of the islands’ length (O’Meara 1990). With an environmental gradient running from the coastal marine to littoral, lowland rainforest and montane rainforest, with varying degrees of boundedness, use, and gradual abandonment to fallow, a village’s land holdings represent a sample of the entire island environment in addition to its aforementioned nature/society synchronicity. Although the landscape represents a particular scale of analysis, Swyngedeow (1997) indicates that “scale” is produced through contention between social actors, and such is the case with the village as landscape, and is intimately tied into ideas of land ownership, land use and naturalness.

Customary land ownership in Samoa is strongly tied to land use, the vegetation on the land and to a distinction between economic and natural species. First, access to land occurs through an investment of labor that transforms the vegetation (or that maintains the transformation) on the landscape. Traditionally, all forested land lies under the authority of the village *fono* (council of *matai*, or chiefs; O’Meara 1995, 1990). Extant plantations are typically invested in specific *matai* titles, which an individual gains control over upon being named to that title by his (or sometimes her) extended family (‘*aiga*), which owns the title (ibid). Also, an

individual can claim access to land in the traditional manner of *tautua*, that is, by service to a *matai* (chief), which is itself a means of establishing one's candidacy for becoming a *matai* (it is said, "*O le ala i le pule le tautua*," that is, "the way to authority is through service;" Allardice 1985). Forested land can be claimed for new plantations by being the first person to clear and plant a particular plot of land; traditionally this could only be done with consent of the village *fono* and contingent on the individual's possession of a *matai* title in which to invest the claim, although under current norms of an informal (and technically illegal) form of individualized tenure, an individual simply has to clear the land (O'Meara 1995). In any case, access to land, either through patron-client relationships (*tautua*), through accession to a *matai* title through *tautua*, or by clearing forest, involves an investment of labor that either transforms the vegetation (changing forested land to agricultural plots) or maintains that transformation (through continued use of existing plots).

Second, demarcation of ownership occurs largely through the vegetation on a particular plot. O'Meara (1990) explained his difficulties in mapping village lands, because boundaries in the Western sense of a line drawn in Euclidean space and surveyed on the ground, creating a definite division between adjacent plots, do not exist, but rather is delineated by the planted crops (especially coconut trees), thus leaving a wide expanse between the crops of adjacent plots (coconut trees, for instance, are typically spaced roughly 10 meters apart) as areas of indeterminate ownership. O'Meara (ibid) indicates that many coconut trees are planted in areas of newly cleared land primarily for establishment of ownership, and not because of

either subsistence or commercial need. During surveys for this research, one informant often commented that there were “too many coconuts,” and on plots further inland, coconut trees were often planted in single lines along the margins of plots, thus delineating boundaries. In terms of the natural environment, this interplay between social norms of ownership and the landscape has caused the coconuts, a native species to the Pacific, to be dispersed beyond its littoral range to become a dominant feature of lowland areas.

Forested land, to a large degree, is land that is not owned by any specific individual or extended family. Given that ownership of land and its demarcation is contingent upon transformation of the forest, the presence of forests implies a lack of boundaries, and makes boundaries between villages vague; until the land is cleared a boundary does not exist. O’Meara (1990) related one case where an individual laid claim to a plot of land by planting coconuts without clearing the land first; although this was contrary to custom, the claim went unchallenged in the village in part because this allowed the village to claim the land before the neighboring village did. Where ownership of land is an issue, forest is a liability.

Finally, modern institutions of land tenure are less secure than the physical changes left on the landscape. The Lands and Titles Court is the primary institution in Samoa that upholds and enforces land disputes. Its primary mission is to settle disputes according to “custom and usage” and is required to hear the complaints of any “interested party” that files a petition (O’Meara 1995). Not surprisingly, there is a large backlog of cases, such that all someone has to do to effectively oppose

someone else's actions on the land is to simply file a case (as of 1995, the backlog for Savai'i was 25 years; *ibid*, 153). Although the mission of the court is to uphold Samoan custom (*fa'asamoa*), the court has been identified as being an avenue whereby the authority of village *matai* is undermined by people who wish to avoid or overturn decisions made these chiefs, a trend that makes traditional tenure less secure (Meleisea 1987). Additionally, the court's mission to uphold custom and usage has also opposed grass-roots changes in custom and usage, primarily the shift towards an informal system of private tenure, which limits the ability of village level actors to secure claims to their land themselves (O'Meara 1995). Security of tenure arises from land claims being indisputable within the village context (that is, by avoiding challenges in court), and emphasizes the traditional roles of landscape transformation described above.

The village landscapes of Samoa are simultaneously social and natural. That is, there is a considerable degree of intermixing of social and natural processes, such that the various ways in which access to land is negotiated across several social scales is intimately tied into land cover, land use and the social and natural processes of change and transformation. Agriculture is a crucial feature of these transformations, and cuts across several scales as well, and is subject to national, regional and global development opportunities and constraints that operate across scales.

Although the natural landscape can be demonstrated to be highly social, the naturalness of the social landscape in Samoa has received less attention. O'Meara (1990), for instance, described how planters allowed vines to smother their taro plots

between the first and second planting in order to suppress more noxious weeds. He also described how the vine mat was subsequently cleared. In his description, concrete actions of very real people occurred in an abstract nature. Olson (1997) describes the social aspects of nature in pre-European contact Samoa, noting that forests were subject to chiefly taboo and home to *aitu* (lesser spiritual beings, often of ambivalent nature towards people), and belong in the spiritual realm of mana and authority, which changed after conversion to Christianity (and consequently became subject to the modern economy of primary resource extraction). Once again, nature is socialized, in that the forest is interpreted in terms of social process, whereas forest dynamics are not examined.

Conversely, the work of biological ecologists examines the vegetation of managed and fallowed lands, identifying species but keeping people invisible beyond their role in creating the abstract spaces in which concrete flora occur. Mueller-Dombois and Fosberg (1998, relying heavily on Whistler 1992) divide Samoa's vegetation between the various forest types and "modified vegetation," with the latter being divided into managed lands, secondary scrub and secondary forest. In the case of managed lands, these refer to areas under active cultivation and the authors list no species occurring in these areas, but do note that "tree gardens...can be considered almost as natural vegetation" (ibid, 373). Furthermore, the authors define secondary scrub as being the vegetation occurring after cultivation is abandoned, listing *Macaranga harveyana*, *Omаланthus nutans*, *Trema cannabina* and *Hibiscus tiliaceous* as the dominant species in this vegetation category (ibid). Similarly,

Whistler (2002, essentially a variation on his earlier, 1992, classification scheme) separates “disturbed vegetation” from the other types, and includes managed lands, successional vegetation and secondary forest as subcategories, with successional vegetation occurring on “recently disturbed land or recently abandoned managed land” (2002, 118), and lists the species occurring in each type encyclopedically and diligently supplying Samoan names for these plants as well. This categorization of secondary scrub/successional vegetation as “abandoned” agricultural land obscures the social nature of these landscapes, since these areas are only gradually abandoned to the fallows in much the same sense as Denevan and Padoch (1987). Not surprisingly, whether nature is conceptually appropriated by society or society appropriated by nature largely depends on which side of the social/physical science divide the researcher stands.

What seems to be lacking is research that relates social process to natural process. Shifting cultivation often is seen as a threat to forests. From such a perspective, society and nature do not mix. This may not be the best way to conceptualize these landscapes, however, given that the lowland ecosystems of Samoa have been consistently exposed to disturbance from tropical cyclones. The question of whether these ecosystems are resilient to some transformative use (and whether shifting cultivation is ecologically similar to cyclone disturbance) is worth investigating. Separate research from the natural and social sciences suggests that Samoa’s lowlands have been (and are continuing to be) transformed by both social and natural processes, but that the simultaneity of these social and natural phenomena

is poorly understood. *Merremia peltata* has become dominant on these landscapes, and its social nature must be understood if this invasion event is to be understood and managed.

Chapter 4

Methods

Overview

A fundamental principle guiding the design of this study is that landscapes are simultaneously social and natural. The social aspects of the landscape in question, the village lands of Fa'ala, and the essence of the research question, an investigation of a species identified as being an invasive species of environmental concern, suggest that a variety of social values acting across several social scales are influencing what has traditionally been the subject area of the natural sciences (biology and biogeography) in invasion ecology. The research, and its design, must therefore address both the multiple values at work, an arena of the social sciences, as well as address the natural science questions of the *Merremia peltata* invasion. One broad aspect of the study involves vegetation sampling on the landscape, and operates across several spatial scales, from the level of the individual plot, to the landscape, and ultimately examines the global distribution of some of the dominant species observed on the village landscape in relation to hurricane disturbance, the dominant disturbance regime in the region. Second, interviews were conducted with various actors in the relevant arenas, from people in the village to private, non-government and government officials working on the *M. peltata* invasion issue. The methodology answers some of the fundamental biogeographical questions about this invasion, as well as situates it in a broader social milieu.

Vegetation Sampling

A stratified random sample of vegetation plots was taken across the Fa'ala landscape. A randomized sample has been shown to reduce the amount of spatial autocorrelation (Aubrey and Debouzie 2000), and given that increased environmental heterogeneity corresponds to a decrease in spatial autocorrelation (Fortin 1999), then stratification of the sample across environmental types should reduce this effect as well. Stratified sampling was obtained by use of aerial photographs of the region from the year 2000, taken at 1:7000 scale, which covered the Aganoa and the coastal and near inland portions of Fa'ala proper and Laufa'i, and at 1:25,000 scale which covers these same areas and also further inland, above 300 meters elevation, although with poorer resolution. Photographs were scanned, imported into a GIS (ArcView 3.2) and georeferenced using GPS waypoint data from road intersections easily accessible by car, and from field mapping of plantation roads to obtain reference points further inland. A manual classification of texture classes was performed in the GIS, creating a map layer of some 12 texture classes as shown in Figure 4.1. Textures were left as raw classes, because an *a priori* classification of textures into landcover/land use classes was both undesirable, it being preferable to obtain field verification, and necessary to avoid arbitrarily assigning "social" and "natural" categories. The random number function in Excel was used to generate quadrat coordinates with three to four quadrats per texture class chosen so as to give representation across the texture classes and also to have sampling in all of the regions of the landscape. The quadrats that were sampled are depicted in Figure 4.1.

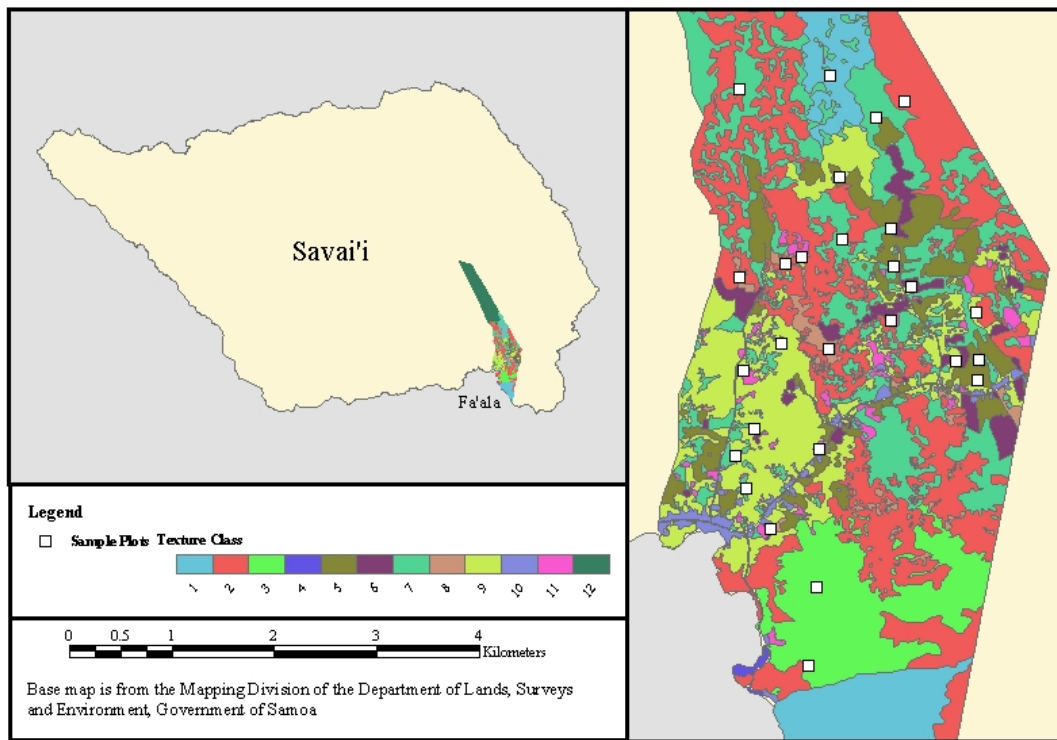


Figure 4.1. Map of Texture Classes and Final Quadrats

A hand-held GPS unit (Garmin GPS 12XL) was used to locate the quadrats in the field. Plots measured 10 meters by 10 meters and were laid out in accord with the four cardinal directions. Internal transects were laid diagonally across the quadrat at 5 meter intervals with sampling points spaced one meter apart, for a total of three transects and 29 sample points (Figure 4.2). Five “control points” were also established inside each quadrat (Figure 4.2). A total of 27 quadrats were sampled.

Both vegetation community data and environmental data were collected. For community data, species were identified along the transect using the point-intersect method at each of the 1-meter-spaced points. Canopy cover (and canopy species) was assessed using a GRS densitometer at each of these points as well. Also, the entire quadrat was examined to note the presence of species not sampled along the transect, in order to give a more complete assessment of species presence/absence. The diameter at breast height (dbh) of all of the woody plants was measured across the entire quadrat. Environmental data were assessed at each of the five control points. This included light and soil temperature data, the former measured using light meters (Extech Instruments) and the latter with six-inch soil thermometers ($\pm 1\%$ accuracy), with measurements being taken hourly from 8:00 a.m. to 4:00 p.m. Soil samples were collected at each control point as well using a corer. Samples were collected in 15 cm depth intervals up to 30 cm in depth, although in practice, the first 15 cm interval was often the only one collected due to the stony character of the soil. Analysis of the soil samples was conducted at the soil lab of the University of the South Pacific’s (USP) Alafua Campus in Apia, Samoa. Soil data analyzed included

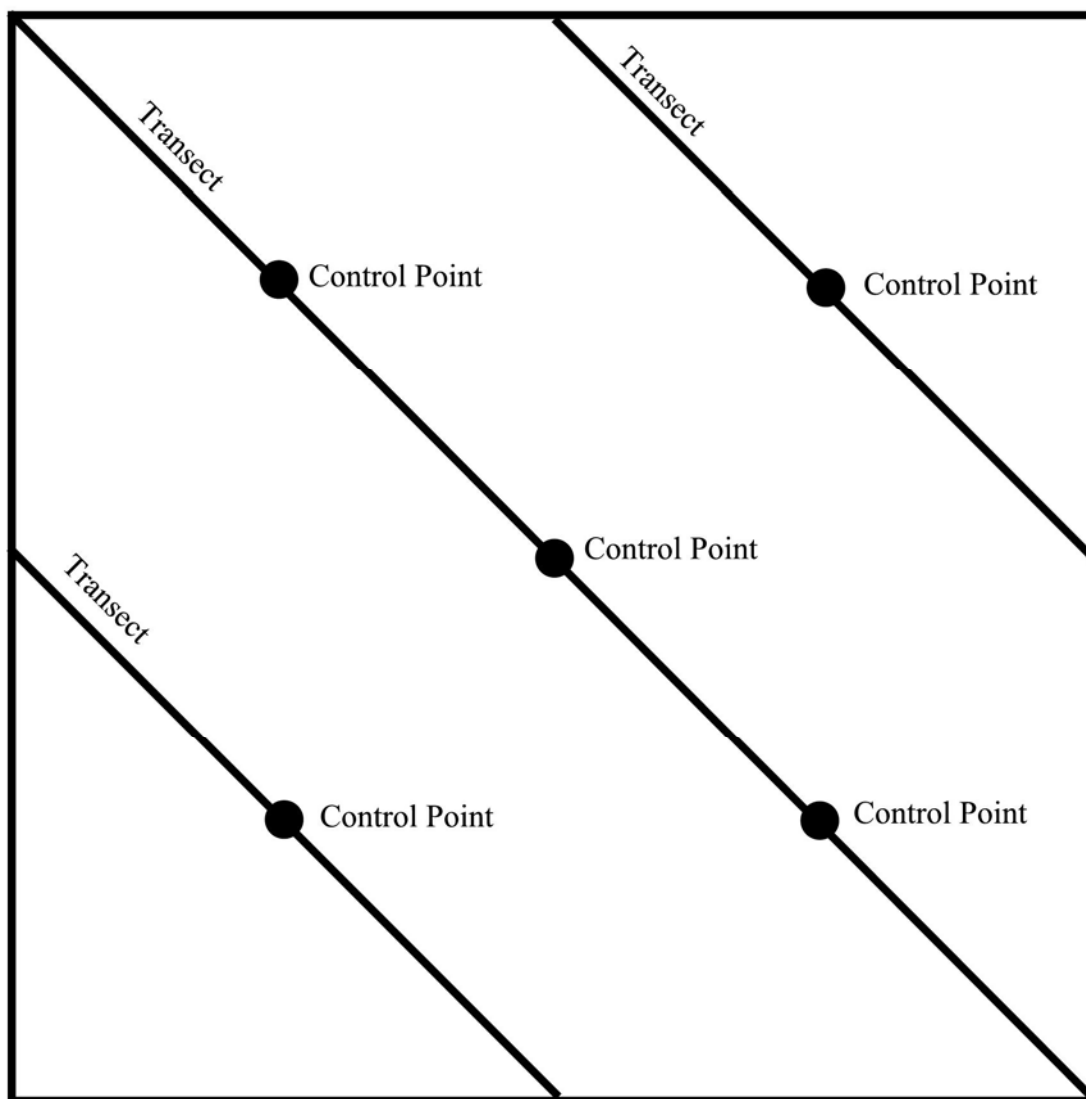


Figure 4.2. Layout of Vegetation Sampling Quadrats

pH level, electrical conductivity, particle size distribution, organic carbon content, available nitrogen, available phosphorus and micro-nutrient (magnesium, calcium, and potassium) availability. The surface organic matter was also collected at each control point and analyzed as plant tissue samples at the USP lab, with data on macro- and micronutrients assessed. Other environmental data collected for each plot included elevation (as measured by the GPS), slope and aspect. The use of the GPS for elevation is problematic, since measurements are made in reference to the ellipsoid, and can vary considerably as well depending on satellite signal strength and general dilution of precision (Leva, et al. 1996). Alternatively, elevation can also be obtained from the GIS from interpolating distances between elevation contour lines (slope and aspect can be assessed similarly). The elevation of each corner of the quadrat was also measured in the field in order to obtain a sense of the slope and aspect of the quad at that particular microscale. Although the entire village landscape runs up the same side of the mountain, and thus has the same broad scale aspect, variation in terrain, at a scale smaller than that recorded in the elevation contour layer of the GIS, was frequently encountered such that the aspect of the sample plots (at its scale) could be considerably different from the overall mountain slope.

Difficulties with the sampling methodology were encountered. First, the air photos used for the manual classification were not orthographically corrected. In the case of the 1:25,000 scale image, that depicts features from sea level up to nearly 700 meters in elevation, there are differences in scale between the upland and lowland regions, which creates problems with selecting plots on the basis of land cover, since

it could not be guaranteed that the cover on the image matched its corresponding cover on the ground, for any given coordinate. Similarly, the use of handheld GPS units to locate the quadrats from these points also introduced a positional error of roughly 4 meters on average. In both cases, the only practical problem occurred in cases where a plot lay near a boundary between texture classes in the GIS, and only created discrepancies between the GIS and actual land cover on two quadrats.

Another difficulty lay in the fact that three years had passed between the time that the photos were taken and the sampling was performed. In two cases, plots that appeared to be freshly cleared (an interpretation of texture class 11, based on evidence of burning found at one of the sites) on the air photos were under fallow during the field season. Finally, the use of GPS to locate quadrats under forest canopy may be problematic. Although there was typically enough signal strength from the satellites to obtain position readings under canopy, the forest quadrats had a noticeable tendency to fall in the spaces away from the largest trees, such that larger, older trees were either on the edges of the quadrat or just outside its limits, a fact which means that these cohorts of trees were underrepresented. I suspect that a combination of weaker and less stable positional readings with the GPS (usually the minimum three satellites were available under canopy) with considerable drift in the position reading and the slightly improved reception where the canopy thinned contributed to the quadrats falling into these spaces. Overall, however, the sampling method proved to be a fairly reliable and convenient means of creating randomly selected plots and setting them up in the field.

The decision to use smaller 10×10 meter plots was a compromise between the amount of area on the landscape to be sampled and the amount of information to be collected. McCune and Grace (2002) outline the arguments for using few and larger versus many and smaller sampling plots. They indicate that smaller plot sizes tend to be biased against rarer species, in terms of their inclusion, but are more accurate in terms of representing the cover of dominant species (cover of rare species being overestimated in large plots); the internal structure of smaller plots can be represented as well, but not with large plots. Additionally, variance in the data becomes less random and more spatially structured as plot size increases, with mean values remaining fairly constant across plot size (Bellehumeur et al. 1997, Bellehumeur and Legendre 1997), although another study indicates that the intensity of spatial autocorrelation only increases up to an area of 200-225 m² (a value between the 10×10 and 20×20 meter plot sizes) before dropping with increasing size (Fortin 1999); the 10×10 meter plots are therefore more likely to represent spatially independent samples than the 20×20 meter plots. In practice, in the vast majority of plots, a 20×20 meter plot yielded no more additional information than a 10×10 meter plot, especially with *Merremia peltata* being the species of interest. In the case of forest plots, however, a larger plot size would have avoided the biasing introduced by using the GPS as a means of locating the plots. The only bias this introduced into the sampling, however, was to under-represent the presence of remnant trees in the taking of diameter measurements; the structure of the forest in terms of cohorts of pioneer species being followed by late pioneer/early climax and other climax-type species is

clearly demonstrated with the smaller plot size, and the contribution of these remnant trees to cover was still captured at the smaller plot size due to their overhanging the quadrats. Given that the main purpose of the study is an examination of *Merremia peltata* and not a direct assessment of forest structure, the smaller quad sizes were deemed appropriate, and this allowed several plots across several of the texture classes to be assessed in a timely manner.

Analysis of Vegetation Data

Two techniques of vegetation analysis were performed. A clustered dendrogram of quadrats based on species presence and cover was conducted to identify community structure (Xie et al. 2004 provides a recent example of this technique). Additionally, ordination (nonmetric multidimensional scaling) was performed to relate plots to underlying environmental variables (e.g., Stallins and Parker 2003), with the results of the cluster analysis aiding this analysis (Rettie et al. 1997). As such, the vegetation analysis takes a broad ecological approach; the community analysis derives from equilibrium-oriented ecology and ordination, whereby the underlying environmental conditions affecting community structure is assessed, is a non-equilibrium approach (Hengeveld 1988).

Community structure was analyzed through use of clustered dendrograms (hierarchical agglomerative cluster analysis). The technique is used frequently in phytosociology, and thus has a strong grounding in equilibrium perspectives of ecology (Kent and Coker 1992). In general, the process entails first the input of the

species data into a raw data table, then performing calculations of similarity or dissimilarity coefficient of each quadrat to the others to produce a dissimilarity/similarity matrix. This information is then used to group the quadrats by similarity into the dendrograms using a sorting strategy (Kent and Coker 1992; McCune and Grace 2002 use the term “linkage method”), and then ultimately interpreting the results on the basis of the knowledge of the researcher into the appropriate number of groups. Thus, although the technique is highly quantitative in nature, the final interpretation relies on the informed subjectivity of the analyst (McCune and Grace 2002, Kent and Coker 1992). For this study, the multivariate ecological analysis software package “PC-ORD 4.2” was chosen to perform the cluster analysis. For the raw data tables, the quadrat identifier was used for the rows and the array of species were arranged in columns, such that the analysis was essentially polythetic based on species composition. The percent occurrence of each species along the 29 transect points was entered for each quadrat, with values ranging from 3.4% (1 of 29 points) to 100%. For species that were observed present in the sample plot but that were not represented along the transect, a value of 1% was assigned. Euclidean distance measures were used to express distance between sample plots in dissimilarity/similarity space, and Ward’s Method was used as the sorting strategy. The resulting diagram was then used to assess relationships, for instance, areas dominated by *Merremia peltata*, forest, fallow, or cattle-stocked plots.

Ordination techniques were used to further analyze community structure and also especially to understand the relationship of the identified groupings of sample

plots to the environmental data taken from each quadrat. The general procedure involves the use of a raw data table of sample plots versus species (the same table as in the cluster analysis) in addition to an environmental data table (sample plots versus environmental data), running these tables through a particular ordination method, and developing a plot of the sample quadrats against two or three axes, which represent independent variables, the interpretation of which is the ultimate task of the analyst (Kent and Coker 1992). This study employs indirect gradient analysis, since the environmental data are used only in the interpretation of the final ordination diagram, and not in the classification of the data themselves prior to running the ordination (Kent and Coker 1992). The ordination technique employed was nonmetric multidimensional scaling (NMS), chosen because of its ability to utilize any distance measure (Euclidean was chosen for consistency with the cluster analysis) and because of its insensitivity to the peculiar needs of more statistically traditional techniques, for instance, those techniques whose results are sensitive to the statistical qualities of the data set such as normality (McCune and Grace 2002). Once again, PC-ORD was employed as the analysis software.

The three techniques described above produce results when combined that give a fairly complete interpretation of the vegetation data. In terms of the *Merremia peltata* invasion, the techniques shed light onto which plant species assemblages are being displaced by, are competitive with, or are mutually constituted by this species, as well as assessing the contribution that underlying environmental conditions and disturbance contribute to the invasion process.

Ethnographic Methods

I split my time between residing and working in the village setting and visiting various government agencies and the OLSS. In the village setting, the main tasks I conducted were field mapping of the village roads and performing a formal interview with people in the village that investigated how they value plants. In regard to the former, the field mapping was undertaken primarily to obtain control points for importing the scanned airphotos into the GIS, so this task has little relevancy for this paper other than it provided an opportunity to meet people in their fields, and to discuss their activities and their perspectives toward *Merremia peltata*. Both these informal interviews conducted on an *ad hoc* basis and the formal ones were conducted in the Samoan language, in which I am fluent.

In regard to the the professional/government/international (foreign governments, expatriates and development organizations)/non-government sector, hereafter referred to as the “urban sector,” I consulted the Department of Forestry (a Division of the Ministry of Agriculture, Forestry, Fisheries and Meteorology; MAFFM), the Division of Natural Resources, the Parks Department and the Mapping Division of the Department of Lands, Surveys and Environment (DLSE), and the NGO O le Siosiomaga Society (OLSS). I consulted with Forestry, Parks and Natural Resource Directors and their staff to become familiarized with their knowledge and perspectives of the *Merremia peltata* invasion. I contacted the Mapping Division primarily to obtain aerial photographs of the Fa’ala area in order to scan and import them into a GIS, so as to obtain the stratified random sample of vegetation plots.

Additionally, the OLSS was contacted to obtain information in regards to the administration of the Tafua Peninsula Rainforest Preserve.

Both formal, structured interviews and informal interviews were conducted. The more informal interviews were conducted using a method of progressive contextualization (Vayda 1983), whereby information gleaned from one interview led to new avenues of investigation. Interviews were conducted both in the village setting and in the urban sector because these multiple arenas are very closely tied together through formal cooperation, movement of people from one job to another within and between these arenas, and by its spatial concentration in Apia.

Urban sector interviews were conducted largely in the early stages of the field season and covered a variety of topics. Initial interviews concerned the *Merremia peltata* invasion itself. Information from these interviews led to inquiries in regard to national and international quarantine efforts, the events and legalities of logging in the Tafua Peninsula Rainforest Preserve. Claims made by actors in the urban sector were cross-examined with people in the village setting, and vice versa. The purpose here was not so much to verify claims (although it served this vital function), but more specifically to see the interconnectivity of social groups across Samoan society, from the village level into the urban sector, including its international components, through the spread of certain ideas, concepts and policies.

Informal interviews in the village setting again were initially concerned strictly with local opinions in regard to *Merremia peltata*. These interviews often were performed impromptu, typically as people were encountered on the plantation

roads as other research tasks were being performed. Divergent opinions regarding *M. peltata* were apparent between people in the village setting and the urban sector, a point leading to further inquiries in the urban sector and informing the design of the formal interviews. Other inquiries included investigating knowledge of rhinoceros beetle control policy and limited inquiries into the village involvement with logging in the Tafua Peninsula Rainforest Preserve.

The formal, structured interview was designed to understand the criteria people use in valuing plants. This format was decided upon after several informal interviews which revealed that many people in the village regard *Merremia peltata* as a beneficial species, especially in relation to taro cultivation, a claim that was in apparent opposition to the concerns of the regional environmentalist perspective and also to a seven village survey conducted on Savai'i by the Natural Resources Division of the Department of Lands, Surveys and Environment in which villagers identified *Merremia peltata* and *Mikania micrantha* as the weeds of greatest concern.

Participants were adults, both male and female, that were household managers. That is, the participants carried the bulk of the effort in maintaining the household, through their labor in agriculture or other productive activities, and therefore had considerable daily contact and experience with the local biodiversity. The formal interview consisted of two parts, one being a form of "Q methodology" (Robbins and Krueger 2000) in which the subjectivity of plant value was assessed and the other being a session of direct questioning on a variety of topics.

The assessment of criteria used to value plants was conducted by showing participants a set of photographs of a variety of local plants and discussing them. Table 4.1 lists the plants used in these interviews. Some of the plants that were chosen were already known by the researcher to be valued and others despised, and some were simply selected because they were common in disturbed areas. Mainly weedy species were selected, in order to focus discussion more closely on exotic and/or invasive species (nearly all of the plants used were non-native); well known economic or highly used species were avoided. Identification of the plants was performed before the interviews using Whistler (1995). Both men and women were queried on an individual basis, and a total of twelve interviews were conducted. More interviews were desired, but a political rift in the village that occurred during the interview period, described in the next chapter, created difficulties in securing cooperation due to factional concerns. The interviews ultimately had to be discontinued to make time for vegetation sampling. The results that were obtained are nevertheless worth discussing and are included as part of the study. At the beginning of the session, participants were informed that the objective of the survey was to learn why they considered these plants as beneficial or otherwise. Participants were asked to identify the plant in each of the photographs, how they regarded the plants, why they regarded them that way, whether the plants were difficult to control and how they controlled them, and if there were any other uses for the plant, such as medicinal.

Table 4.1. Plant species used in the formal structured interview

| Species | Family | Introduction |
|-----------------------------------|------------------|---------------------|
| <i>Merremia peltata</i> | Convolvulaceae | Native |
| <i>Mikania micrantha</i> | Asteraceae | Recent (NWT) |
| <i>Pseudelephantopus spicatus</i> | Asteraceae | Recent (NWT) |
| <i>Desmodium heterophyllum</i> | Fabaceae | Recent (OWT) |
| <i>Mimosa invisa</i> | Fabaceae | Recent (NWT) |
| <i>Mimosa pudica</i> | Fabaceae | Recent (NWT) |
| <i>Pueraria lobata</i> | Fabaceae | Ancient (OWT) |
| <i>Vigna marina</i> | Fabaceae | Recent (NWT) |
| <i>Dioscorea bulbifera</i> | Dioscoraceae | Ancient (OWT) |
| <i>Passiflora foetida</i> | Passifloraceae | Recent (NWT) |
| <i>Blechnum pyramidatum</i> | Acanthaceae | Recent (NWT) |
| <i>Hyptis pectinata</i> | Lamiaceae | Recent (NWT) |
| <i>Stachytarpheta urticifolia</i> | Verbenaceae | Recent (NWT) |
| <i>Kyllinga polyphylla</i> | Cyperaceae | Recent (OWT) |
| <i>Cenchrus ciliaris</i> | Poaceae | Recent (OWT) |
| <i>Eleusine indica</i> | Poaceae | Ancient (OWT) |
| <i>Paspalum conjugatum</i> | Poaceae | Recent (NWT) |
| <i>Paspalum paniculatum</i> | Poaceae | Recent (NWT) |
| <i>Nephrolepis hirsutula</i> | Nephrolepidaceae | Pantropical |

Key: Recent = post-European contact era; Ancient = post-Polynesian colonization; OWT = Old World Tropics; NWT = New World Tropics.

Source: Whistler 1995, 2002.

The main obstacle encountered with this particular aspect of the methodology involved the difficulty that some people had in abstracting plant identifications from the photographs. In some cases, the clarity of the photographs made plant identification difficult. In some cases, it obscured scale, such that the actual size of the plants in question was ambiguous. In other cases, the presence of other plants in the photograph was distracting. Some participants had more trouble than others abstracting from the photographs. In any case, the difficulties lay mainly in identifying the plants, but even with discrepancies in identification, the criteria that people used in valuing plants still became apparent. Since the ability of people to identify the plants was not at issue, nor being assessed, this difficulty did not add any significant error to the assessment.

The second part of the interview consisted of direct questioning in regard to a variety of topics. Some questions involved *Merremia peltata* directly, such as why they thought it was doing so well on the landscape, and whether the government should do anything about it. Other questions sought to test claims made in the urban sector. One in particular involved methods to control rhinoceros beetle; participants were asked if they considered rhinoceros beetle to be a problem, and also what methods they undertook to control it. Responses to these questions seldom resulted in any patterns of response. Some responses were reflexive on the assessment of plant value (especially as it concerns gender differences), however, and others, especially when testing claims made in the government sector, revealed the degree to which information flows between the urban and rural sectors.

Summary

This study examines a fundamental contradiction in the understanding of invasion biologists in regard to *Merremia peltata*: that it is behaving invasively despite being a native species. The landscapes on which this species occurs, by and large, are not under management practices dictated by the norms of Western science. Indeed, the conventional wisdom on invasive species asserts that non-native species are aided by human agency. The research design must therefore span both a scientific perspective, in order to contextualize this invasion in terms commensurate with invasion biology, as well as a social science perspective, because the expression of social forces on the landscape are deemed critical to the invasion process. Methods thus utilize both standard ecological sampling and analysis and also involve more ethnographic methods, seeking to understand the plurality of perspectives on this plant species as well as the power laden social networks that put these perspectives into action.

The next chapter portrays the results of the vegetation analysis, giving strong arguments for the nativity of *Merremia peltata*, the role of disturbance in creating invaded landscapes, and ultimately pointing to the primary agricultural export oriented economies of the colonial and post-colonial periods as the source and scale of this disturbance. Afterwards, the ethnographic analysis of *Merremia peltata* is presented, revealing the social networks in which the plant is contested. Final chapters discuss the relevance of these findings to island biogeography and cultural

ecology (discussing the inherent vulnerability of islands to invasions, and humanity's role in driving the process) and discuss new theoretical perspectives for investigating the invasives phenomenon.

Chapter 5

The Landscape

Overview

This chapter presents results that describe the landscape from a variety of perspectives. First, the Fa’ala landscape is classified into regions employing the local place names that people used, and were determined from immersion in village life. The physical and social characteristics of these places are presented as well, including an examination of people’s interactions with the natural landscape based on observations in the field, and with implications for issues of land tenure security. The final section examines changes on the landscape relative to demographic, economic and land cover factors, and is explored primarily through GIS analysis. The landscape is presented both ideographically, as well as by situating it in the context of structural change over the past fifty years.

Description of the Fa’ala Landscape

The village lands of Fa’ala can be conceptually divided into five regions of indeterminate boundary, based on place names used by the people of the village. Figure 5.1 illustrates these regions, showing considerable amounts of overlap due to the inherent vagueness of the place concepts. The village consists of two clusters of settlements, “Fa’ala Proper” and “Laufa’i” that are separated by a ridge of weathered lavaflow regolith (“O le Fatu”) that extends from the upper slopes of the mountains to

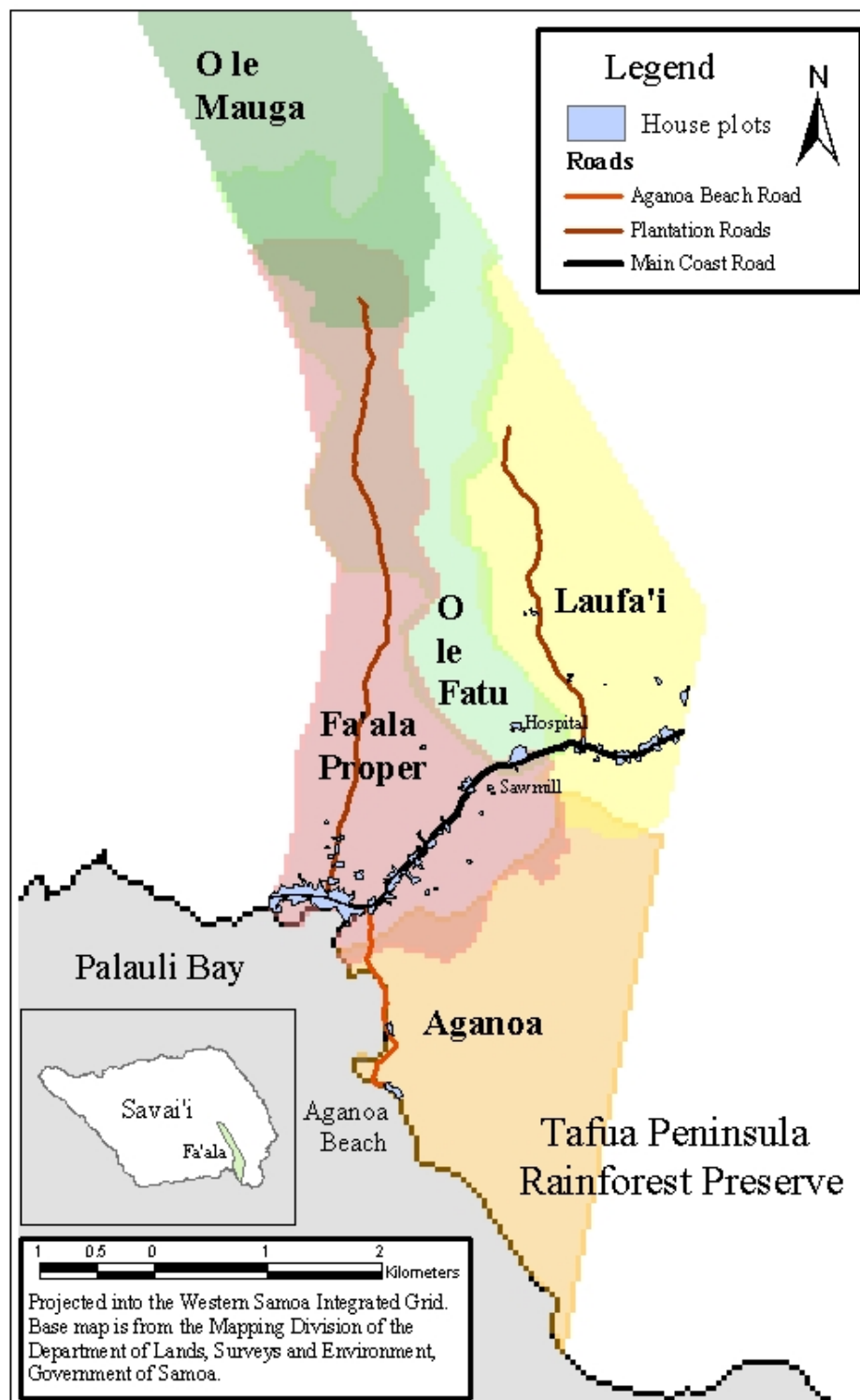


Figure 5.1. Map of the Regions of the Fa'ala Landscape

the lavaflows of “Aganoa,” part of the Tafua peninsula. Each region has its own special configuration of social nature.

When people use the term “Fa’ala,” they are generally referring to the area of densest settlement on the eastern shore of Palauli Bay, just west of the Tafua peninsula, although village lands extend eastward into the western third of the peninsula. This area of dense settlement is referred to here and henceforth as “Fa’ala proper”, where the need to specify this particular area arises, as opposed to simply “Fa’ala,” which for the purposes of this study refers to the greater surrounding landscape in general. In this region, house plots abut the rocky coastline, and littoral vegetation is highly mixed with houses, house gardens, and grazing lands (mostly pigs and chickens but occasionally cattle tethered to trees). Further inland, along the westernmost of the village’s two plantation roads, this pattern gradually gives way to a landscape of barbed wire, cattle, coconut trees, fragmented lowland forest and large expanses of open landscape dominated by *Merremia peltata*.

Cattle grazing is the prominent economic activity in this area, and one family runs a small dairy operation. The livestock are kept in former coconut and taro plantations that are enclosed in barbed wire and often exhibit a varied recovery toward natural forest cover that illustrate the social-nature of these plots. For instance, I often encountered vegetation indicative of managed lands, secondary scrub, and secondary forest on the same plot and came across cattle and pigs as well as people gathering coconuts, firewood and fragrant *moso’oi* (*Cananga odorata*) flowers for making *ula* necklaces for church service the following day. The largest

barbed-wire enclosed cattle plots lie just beyond the last house plots encountered along the road, after crossing the second of two cattle guards (some cattle are free-ranging in this area), but this landscape gives way to the fragmented forests and vine beds at the point that the gentle sloping coastal plane abuts a valley-and-ridge system that runs parallel to the road.

Soils in these areas consist mostly of loose basalt boulders with a thin paste of organic matter and decomposing litter, a condition described as *soata* in Samoan. Little taro cultivation is apparent from the road, although sporadic taro plantations can be found in the valley behind the first ridge that is nestled up on the east side of the road, and scattered *ta'amu* (*Alocasia macrorrhiza*, giant taro) growing wild dots the landscape. In the forest fragments, *Pometia pinnata* (*tava* in Samoan) is the most common of the taller trees seen, and several individuals, apparent survivors of the cyclones of the early 1990s, tower above the landscape.

The area around the easternmost plantation road is known locally as Laufa'i, and is the area where most of the village's agriculture is located. The area is not as densely settled as Fa'ala proper, and house plots in this area are nearly contiguous in distribution with those of the neighboring village, Maota. Soils in this region are deeper than those of the *soata* inland from Fa'ala proper, and the rocky valley-and-ridge system lies several hundred meters west of the road. Many of the plots immediately inland of the house plots have cattle, with the associated barbed wire fencing (although in some cases stone walls serve the same purpose), but cattle are not nearly as prominent here as in Fa'ala proper. Taro plantations and coconut groves

are the most prominent feature of this landscape, with the coconuts becoming less prominent further upslope. It is apparent that agriculture is not performed as extensively now as in the recent past, owing to the abundance of fallowed plots and over-grown coconut plantations. That is, taro plantations extend back from the road no further than 100 meters and are highly intermixed with plots in various coverage of successional vegetation, although coconut groves can be found extending back further than 500 meters in a nearly contiguous patch. With active management of coconut groves, fallen brown coconuts (*popo*) and young sprouting nuts (*o'o*) are removed for the domestic production of *pe'epe'e* (coconut cream), livestock fodder, replanted, or sold for export. As a result, under active management a coconut plantation is maintained in a roughly 10-meter rectilinear distribution, without new trees sprouting beneath the parent tree. Further from the road and areas of active use, however, brown coconuts frequently are found beneath trees, with many sprouting (although none were so old as to be exhibiting woody trunk growth), so this easing of gathering of coconuts (and maintenance of coconut plantations) seems to be a relatively recent phenomenon. On some plots, easing overall land use pressure in the coconut groves has allowed for the growth of secondary forest species, especially *Rhus taitensis* (*tavai*), in some cases with these forest species reaching a taller height than the coconuts (interestingly, creating a kind of mixed littoral – lowland forest). The landscape bespeaks a period of more active agriculture in the recent past than currently. In many of the plots west of the road, and especially closer to the central

valley-and-ridge system, *Merremia peltata* becomes a dominant feature on the landscape.

The valley-and-ridge system that lies between the two plantation roads is being termed “le Fatu” (“the stone”) for purposes of this study. The term comes from the local designation of the government hospital facility in the area, now apparently no longer utilized, as “o le falema’i i luga le fatu” (the hospital on top of the stone), as opposed to the main hospital facility on the island in Tuasivi. Here, the “stone” refers to a large dome of basalt upon which the facility is constructed. The designation of “*fatu*” extends over the valley-and-ridge system because these features of the landscape appear to be a contiguous ridge. On the Laufa’i side, the boundary between the gently sloping plains and the ridge is quite distinct, with the ridge forming a sudden 15-20 meter rise with such a linear run and uniformly straight profile as to tempt one into thinking that it is an archeological feature. The boundary on the west side is less distinct, as it seems to permeate the entire east-west breadth of the upslope portion of Fa’ala proper. Le Fatu is further characterized by little human use and frequent occurrence of *Pometia pinnata* as the dominant tree species and *Merremia peltata* as the dominant ground cover in open areas of this fragmented forest landscape. Mueller-Dombois and Fosberg (1998) and Whistler (2002) indicate that *Pometia pinnata* occurs frequently on stony soils, and such is definitely the case with this broad expanse of *soata*.

Further upslope from Fa’ala proper, Le Fatu and Laufa’i lies a region generally referred to as “le Mauga” (the mountain). This is simply a designation used

in casual conversation to refer to the distant upslope areas beyond the reach of the plantation roads, more so than a formal place name. For instance, whenever I explained that I had been sampling vegetation beyond the ends of the plantation roads, people would often cross-examine with a question such as “ua, i luga le mauga?” (“what, up on the mountain?”), so I used this general conceptualization in the classification scheme depicted on Figure 2.8. Given that *Merremia peltata* is limited in its geographical range to below 300 meters in elevation, this region went unexplored by myself, at least to the extent that montane forest species were not observed.

Finally, the area south of the main coast road and comprising the westernmost third of the Tafua peninsula is locally referred to as Aganoa, and is an area subject to much cross-scale contestation. This region is dominated by lowland forest cover primarily of the type identified as *Pometia* forest (Mueller-Dombois and Fosberg 1998) or lavaflow forest (Whistler 2002) characterized by dominance of *Pometia pinnata* on *soata* terrain. *Merremia peltata* is also common in the canopy, and often the dominant ground cover in gaps. This forest is part of the Tafua Peninsula Rainforest Preserve, itself a product of contention between multiple local, commercial, government, non-government and international actors.

The Tafua Peninsula Rainforest Preserve is a private arrangement between three villages and a conservation agency, mediated by a local NGO, and constantly threatened by development interests. The Tafua covenant was negotiated by botanists Thomas Elmqvist and Paul Cox between the Swedish Society for Nature

Conservation (SSNC) and the villages of Tafua, Fa'ala and Salelologa between January 1990 and January 1991 (Cox 2000). Under the agreement, \$800,000 of development assistance was offered in return for the villages agreeing to not log the forest for fifty years (ibid). The project exists as strictly a civil agreement between the villages and the SSNC, and enjoys no formal protection under Samoan law. The government apparently had offered to make the area a National Park, but the villages rejected this offer over concerns they would lose sovereignty over their lands.

The project has suffered a variety of setbacks over the years, however. Salelologa, for instance, negotiated a deal with the government whereby they sold all of their land in the Tafua peninsula to the government for its development of Salelologa into a township on par with the capital, Apia. Fa'ala is also rumored to have allowed some logging in its part of the reserve, citing the need to create a boundary line between it and the village of Tafua, a point noted with some incredulity by Whistler (2002), before the local NGO, O le Siosiomaga Society (OLSS, which acts as an intermediary between the SSNC and the covenant villages), intervened. One informant in Fa'ala indicated, however, that the intervention occurred before the logging actually happened. Since this appeared to be a very sensitive issue, and given a political crisis that arose in the village during this stage of questioning (described below), I undertook no further questioning on the project, for fear that it would compromise my ability to perform the vegetation survey, which had not begun at that time. The alleged logging is said to have occurred straight back from the saw mill in the area, but a comparison of aerial photographs from 1990 and 2000 with flyovers

during the field season revealed no significantly apparent change in cover, and it is highly likely that informants in the urban sector (NGO affiliates and forestry department personnel who only had second hand reports) may be victims of rumors. It is not disputed by anyone, however, that the village had made arrangements with a local logger (who owns the sawmill in Fa'ala) to log in the reserve, and upon intervention, shifted operations up the westernmost plantation road inland of Fa'ala proper.

Explanations for the difficulties the conservation project face vary. In its Tourism Development Plan for 1992-2001, the Government of Western Samoa (GWS 1992) cited the vagueness of ownership over forest land and the rapid depletion of project funds as destabilizing factors, and predicted that villages would be likely to abandon the agreement once the next village financial crisis arose. Whistler (2002) expresses frustration over the actions of the villages in not honoring the agreements. Cox (2000) indicts both the SSNC and the OLSS by spending the money on bureaucracy, failing to initiate many of the projects promised, by creating perceptions on the part of villagers that the project money was being used by OLSS members for personal extravagance, and for making villagers feel deprived of control and respect over their own project.

From this perspective, the project lost credibility because it largely failed to deliver what it promised. Fa'ala and Salelologa did not renege until after the last of the project money had been exhausted (Whistler 2002), ten years into a fifty year agreement, although the vast majority of the funds had been exhausted after the first

two (GWS 1992). For Fa'ala, the project donated an electric generator for the village, which the village subsequently donated to the hospital since it was not really needed because power outages seldom last very long, and by constructing a road to a beach on the west coast of the peninsula and developing some modest beach facilities there, for which the village charged visitors a nominal fee for its use. The village has recently leased the land to an outside family to run a surfing resort, for which the village earns \$20,000 SAT (Samoan tala, about \$6667 USD) per year in rent. The resort has had electricity, piped water and phone lines connected to it, for which easements on either side of the road were cleared of trees. Another tourism interest became established halfway along the length of the road around 1998, but essentially never developed beyond a day-use facility for locals. During the field season, a family built a house and burned and planted a small taro plantation in the land cleared for the easement. People in Fa'ala have largely decided to develop the area under its own initiative.

The vagueness of ownership over forested land, alluded to by the government tourism report (GWS 1992), has been largely unexplored as a contributing factor to the difficulties faced by the conservation project. Under traditional arrangements, forested land has little value on its own and boundaries between villages do not exist until someone clears and plants the land (O'Meara 1990). Additionally, the nature of the vegetation also has some interplay into perceptions of control over land. One field assistant would frequently gather *tauaga* (*Heliconia laufao*, also more properly called *laufao* in Samoan; *tauaga* refers to the fibers taken from the stalk that are used

in bathing and washing dishes but is often applied to the plant itself). This plant is often found growing in forests or on fallowed plots. While gathering some off a remote and apparently abandoned fallowed plot, I asked my assistant if the owner of the land might not be upset by taking the plant, but was told that the *tauaga* is a wild plant of the forest (*vao*), and hence its removal did not constitute theft. Similarly, *lau maile* (*Allyxia* sp.), a liana with fragrant leaves found exclusively in forests and valued for making *ula* (necklaces, similar to Hawaiian *lei*), could be gathered with impunity. The same assistant would not touch other people's cocoa, however, even though we had passed one tree in particular with large, ripe pods frequently over several days, and the assistant expressed concern and frustration (and temptation) that the pods would not be gathered by the owner before their impending spoilage. Species associated with forests thus seem to be fair game for collection, whereas economic crops are not. As a particular plot of land that is in fallow comes to resemble forest more, and includes more forest species, the ability of other people to utilize the land increases, and ownership of the land becomes more contestable. Along these lines, Whistler (2002) indicates that the Faleolupo Preserve, the model agreement in designing the Tafua covenant, suffers from a dispute between the village of Faleolupo and the neighboring village of Papa which claims the forest land.

Commercial logging (money for cutting trees) and conservation agreements which compensate villages for not logging (money for not cutting trees) gives the land value not defined by custom. Logging the land is one means of establishing use and ownership that is more in line with tradition, but the conservation agreements

provide no mechanism for establishing ownership. The village of Papa thus has the right to press for compensation. On the Tafua Peninsula, the breakdown in relations between the various parties created ownership issues. The village of Salelologa was compensated for its land by the government, although during the field season the village has sued the government over inadequate compensation, and its first act was to cut roads which circumscribed the boundaries of its lands in the peninsula with a concrete transformation of the forest landscape. The village of Tafua fired OLSS and hired another NGO to mediate with the SSNC, leaving administration of its part of the preserve under different management than Fa'ala, which has maintained its relationship with OLSS.

There is also some resentment amongst people in Fa'ala over the use of the name Tafua for the reserve. Although the official name is the Tafua Peninsula Rainforest Preserve, where "Tafua" refers to the peninsula as a whole and not the village, it is common to refer to the area as the "Tafua Reserve" and Fa'ala residents complain about this because part of it is their land. Hence, there are sovereignty issues over the land between the two villages, ownership has become an issue, and it may not be so surprising that Fa'ala considered using logging to create a boundary. What appears to be at issue ultimately, is the various ways in which the forest landscape is valued (as commodity, as development opportunity, as threatened nature, as threatened sovereignty) but the conservation agreements fail to directly incorporate these concerns, and thus the actors involved must act outside the terms of the agreement to meet these needs. The conservation interests traded on commodity

values to achieve the preservation of naturalness but got opportunism instead. The villagers traded on commodification to achieve a development opportunity but got threatened sovereignty. The logging interests trade development opportunities for commodification but achieved only conservation. Although a forest ecosystem may be considered stable, it is only as stable as its social construction, and the current situation appears to be built on the same loose stony ground as the forest itself.

As a final note on a description of the village, it must be noted that political tensions within the village were high at the time of fieldwork, resulting in an official fission of village leadership. At issue was confidence in the *pulenu'u* of the village. Literally “village boss” and roughly translated as “mayor,” the *pulenu'u* is a representative of the Samoan government to the village, and the appointment is rotated amongst the extended families of the village. During the early stages of fieldwork, the *pulenu'u* was Laulu Fa'aola, who was closely supported by the high chief of the village, Laulu Fouvale, with whose family I was residing in the village. Laulu Fa'aola's leadership was being challenged by the former *pulenu'u*, Fuiava Toetau, who wanted him removed from office, and took the complaint to the Lands and Titles Court, who subsequently upheld Laulu Fa'aola's office. After the decision, the village formally split, and refused mediation by the village council of the neighboring village of Vaito'omuli. Although these rifts are not uncommon, most villages accept offers of mediation to resolve disputes (O'Meara 1990), so the refusal is unusual. The root causes of the split are unclear, beyond the dispute over leadership, and informants gave varying causes, one of which involved disagreement

over how the money from the Aganoa beach facility rents were to be distributed. Nevertheless, this rift put my research assistants and myself in an awkward position, because we were strongly associated with Laulu Fa'aola's faction, and my attempts to be as inclusive as possible created tensions with my hosts. As a result, I opted to concentrate on the biogeographic aspects of the research.

The Development Context

Like most developing countries, Samoa has experienced rapid population growth during the past century, a fact that has some consequences on the landscape. Figure 5.2 graphs population growth from 1902 – 2001, and illustrates that growth has occurred predominantly on 'Upolu, whereas overall population growth on Savai'i has been slower with total numbers declining over the past decade, such that population numbers have remained more or less static for the past 30 years. Paulson (1994) indicated that the amount of cleared forest land between 1956 and 1989 has increased with population growth, but that per capita area of cleared land has increased, and suggests that the expansion of taro production, which requires freshly cut swidden plots, for overseas export to be the primary cause of this expansion. Table 5.1, however, indicates that this relationship only holds true for the demographic region referred to by the Government of Samoa's Department of Statistics as the Rest of 'Upolu (Figure 5.3). Figure 5.4 shows changes in forest cover between 1954 and 1989. During this period, GIS analysis that I performed shows that the area of non-forested land per capita has remained relatively constant, although

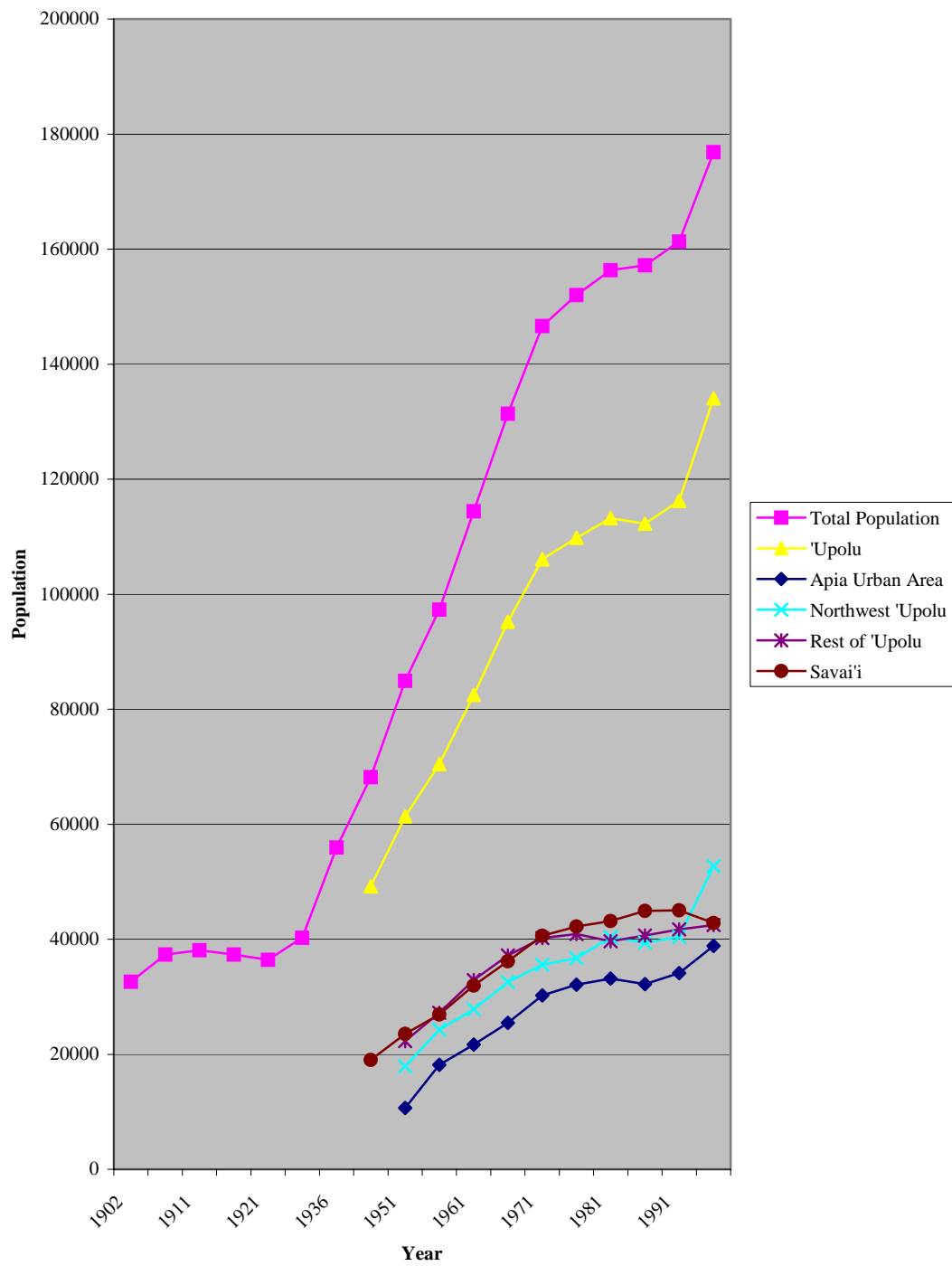


Figure 5.2. Population Growth for Samoa and Its Regions 1902-2001

Table 5.1. Population growth and expansion of forest clearing

| Region | Population | | | Unforested Land Area (ha) | | | Population Density (people/ha) | | | Unforested Land per capita (ha/person) | | |
|---------------------------|------------|---------|----|---------------------------|---------|-----|--------------------------------|-----------|-----|--|------|-----|
| | 1956 | | % | 1954 | | % | 1954/1956 | | % | 1954/1956 | | % |
| | 1956 | 1991 | | 1954 | 1989 | | 1956 | 1989/1956 | | 1956 | 1991 | |
| Samoa | 97,327 | 161,298 | 66 | 74,179 | 118,411 | 60 | 1.31 | 1.36 | 4 | 0.76 | 0.73 | -4 |
| Upolu | 70,429 | 116,248 | 65 | 39,350 | 62,794 | 60 | 1.79 | 1.85 | 3 | 0.56 | 0.54 | -3 |
| Apia Urban Area | 18,153 | 34,126 | 88 | 2,937 | 3,229 | 10 | 6.18 | 10.57 | 71 | 0.16 | 0.09 | -42 |
| Northwest Upolu | 24,246 | 40,409 | 67 | 16,887 | 22,808 | 35 | 1.44 | 1.77 | 23 | 0.70 | 0.56 | -19 |
| Rest of Upolu | 27,244 | 41,713 | 53 | 19,442 | 36,673 | 89 | 1.40 | 1.14 | -19 | 0.71 | 0.88 | 23 |
| Savai'i | 26,898 | 45,050 | 67 | 34,830 | 55,617 | 60 | 0.77 | 0.81 | 5 | 1.29 | 1.23 | -5 |
| Palauli E & W, Satupaitea | 4,807 | 7,888 | 64 | 5,009 | 7,904 | 58 | 0.96 | 1.00 | 4 | 1.04 | 1.00 | -4 |
| Fa'ala | 597 | 929 | 56 | 1,139 | 1,018 | -11 | 0.52 | 0.91 | 74 | 1.91 | 1.10 | -43 |

Source: Department of Statistics and the Mapping Division of the Deptment of Lands, Surveys and Environment, Government of Samoa

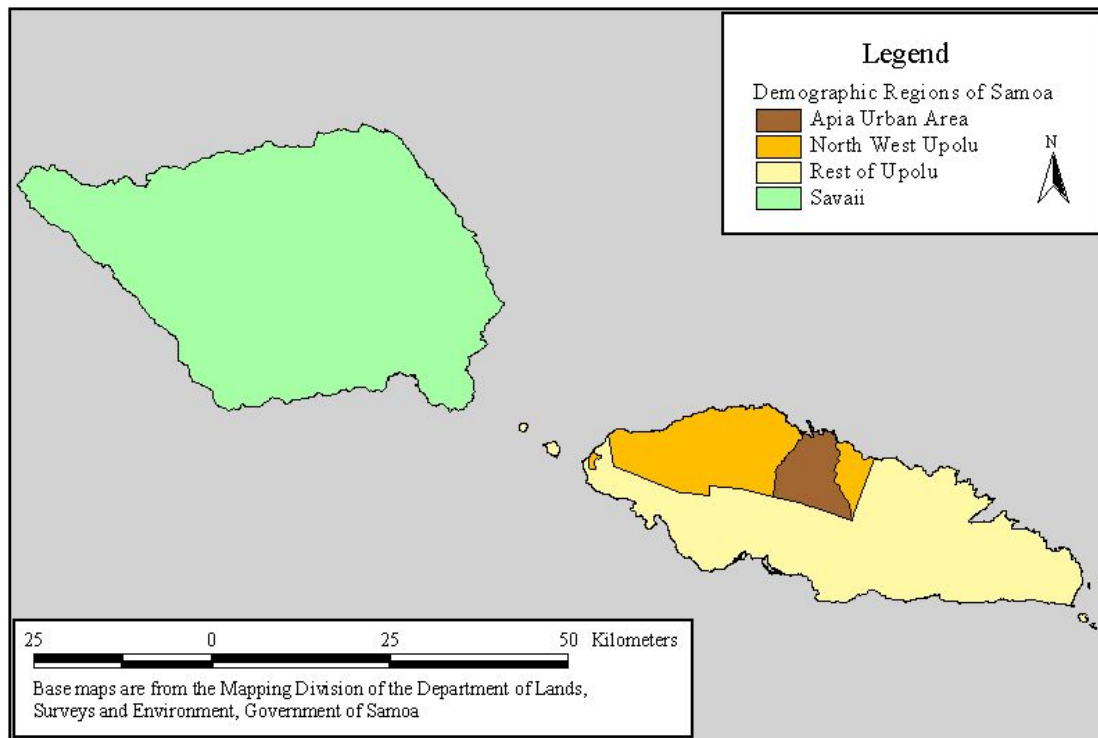


Figure 5.3. Map of the Demographic Regions of Samoa

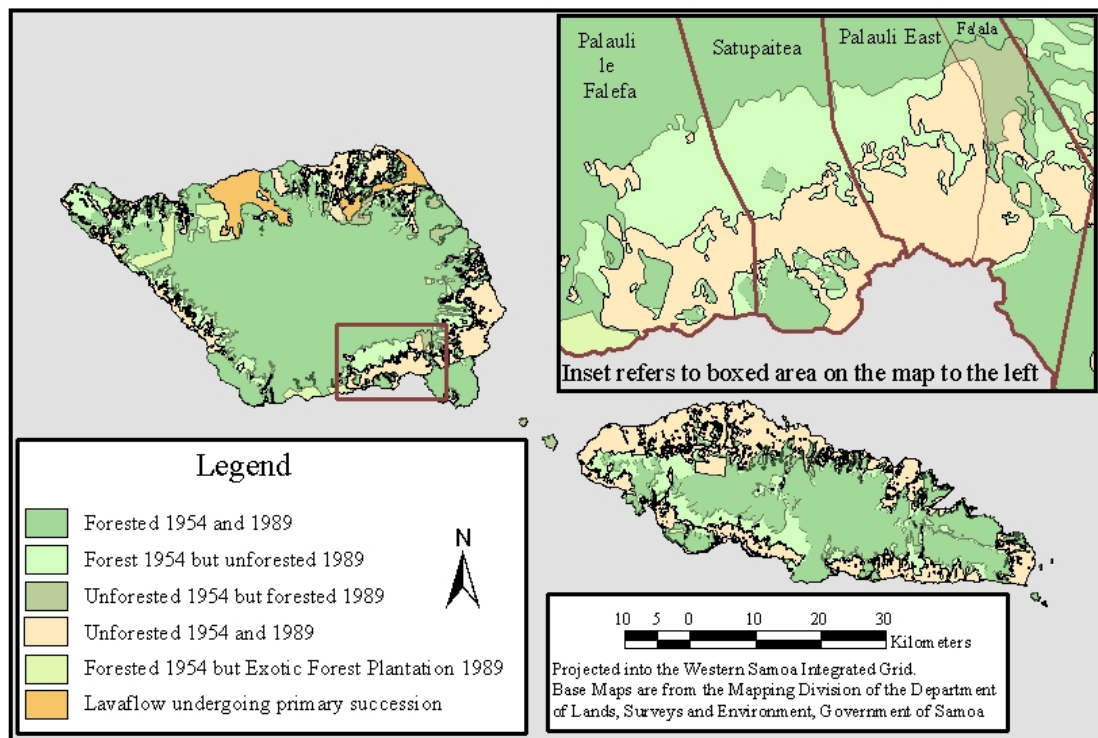


Figure 5.4. Map of Change in forest cover, 1954-1989.

with a slight decrease (4%). For the rural areas, Northwest 'Upolu, the most populous area of Samoa inclusive of the capital Apia, has seen population growth outpace the expansion of land clearance (indeed, there is little land left to clear). On the other hand, the Rest of 'Upolu has the lowest population growth of any of the regions, yet has the highest rate of land expansion. Savai'i's rates are closer to the national averages. Interestingly, the percentage change of population and cleared land for Samoa, 'Upolu as a whole and Savai'i are approximately equal.

Although the deforestation is closely tied with agriculture, the variation in distribution of changes in population and land-clearing are intimately bound to the broader economic opportunities available to households. Table 5.2 shows the sources of income for households disaggregated by region from the (Government of Samoa 2001), and Figure 5.5 displays the three most commonly listed sources of income, wages and salary, remittances, and plantations across these regions (ibid.). Households in Apia and Northwest 'Upolu appear to be more dominantly oriented toward wage and salary earning jobs, with households in Northwest 'Upolu also having a greater emphasis on remittances and agriculture. These two regions also are the greatest recipients of internal migrants in Samoa. Households in the Rest of 'Upolu appear to have the most diversified household economies with the greatest emphasis on remittances and agriculture of all the regions. Households in Savai'i are the most likely to have a single source of income, and agriculture seems to dominate a little more than remittances, although both only provide income for approximately

Table 5.2. Sources of household income by region, 2001

| Income Source | Apia | | | | Total |
|------------------|------------|------------------|----------------|---------|-------|
| | Urban Area | Northwest 'Upolu | Rest of 'Upolu | Savai'i | |
| Salary and Wages | 75.3 | 60.4 | 35.4 | 16.7 | 47.7 |
| Business | 18.9 | 11.6 | 7.7 | 4.3 | 10.6 |
| Plantation | 10.6 | 37.6 | 57.2 | 26.3 | 33.2 |
| Fishing | 3.3 | 7.7 | 25.2 | 10.7 | 11.4 |
| Handicrafts | 3.4 | 6.4 | 16.9 | 9.5 | 8.9 |
| Old-Age Pension | 14.8 | 14.7 | 23.0 | 12.9 | 16.2 |
| Remittances | 29.0 | 41.1 | 60.2 | 25.5 | 39.0 |
| Gifts | 5.1 | 5.7 | 5.2 | 3.8 | 5.0 |
| Traditional | 3.0 | 6.4 | 13.2 | 12.1 | 8.5 |
| Others | 12.4 | 12.3 | 15.9 | 10.3 | 12.7 |
| Sum | 175.8 | 203.9 | 259.8 | 132.0 | 193.2 |

Source: Government of Samoa. 2001. *Census of Population and Housing*. Apia,

Samoa: Department of Statistics.

Note: The numbers represented are percentage figures. A household could cite as many sources of income as they had, thus the total numbers add up to be greater than 100.

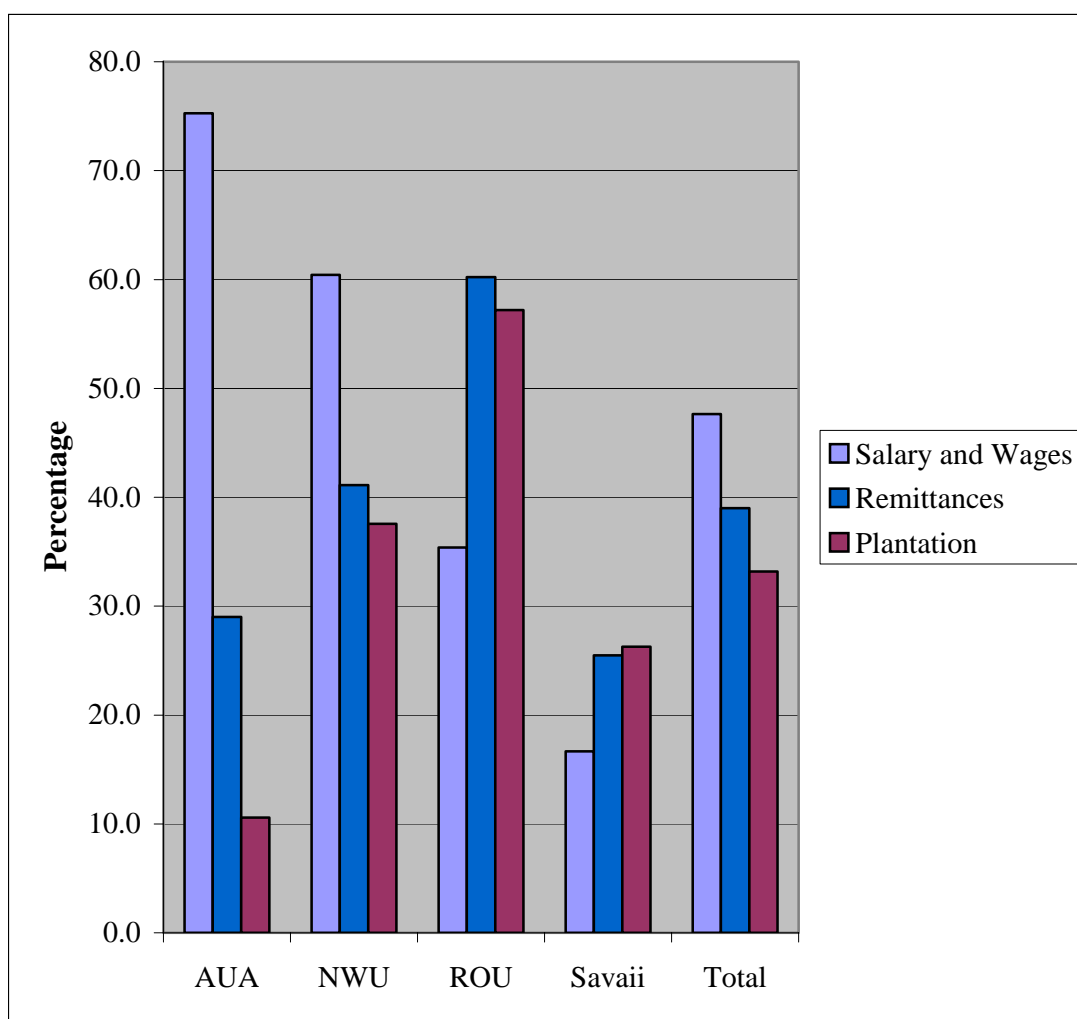


Figure 5.5. Dominant sources of household income by region, 2001

Source: Government of Samoa. 2001. *Census of Population and Housing*. Apia, Samoa: Department of Statistics.

one quarter of households on Savai'i. Agricultural land pressure on Savai'i may therefore be closer to subsistence level than in any of the other regions in Samoa.

This uneven distribution of population growth and deforestation within 'Upolu that nevertheless evens out to the same levels of population density with the more subsistence oriented Savai'i may simply indicate that the market opportunities afforded to the households of the Rest of 'Upolu provide for the subsistence needs of those in the capital and in the northwest of the island.

Whereas the patterns of population growth and land-clearing occurred in the 35-year period running from 1956 to 1991, or 1954 to 1989, respectively, the information regarding household incomes derives from the 2001 census, and the decade between these periods saw considerable upheaval in agriculture. Two major events, the tropical cyclones Ofa and Val of 1990 and 1991, respectively, and the taro blight of 1994, altered both the landscape and the ways that people relate to it. Figure 2.7 displays the volume of exports of the most dominant agricultural commodities from 1988 through 2001. This figure examines mainly coconut products (copra, copra meal, coconut oil, and coconut cream) and taro; other agricultural commodities such as bananas and cocoa, saw a brief boom during the 1960s and 1970s, before losing competition to other countries (O'Meara 1990). Banana production was lost primarily to the development of the industry in Central America (ibid) and thus the shift in momentum toward taro (and its side-effect of expanding cleared lands) is strongly linked to global economic change. The effects of the two cyclones can readily be seen on the coconut industry that all but disappears during this time period

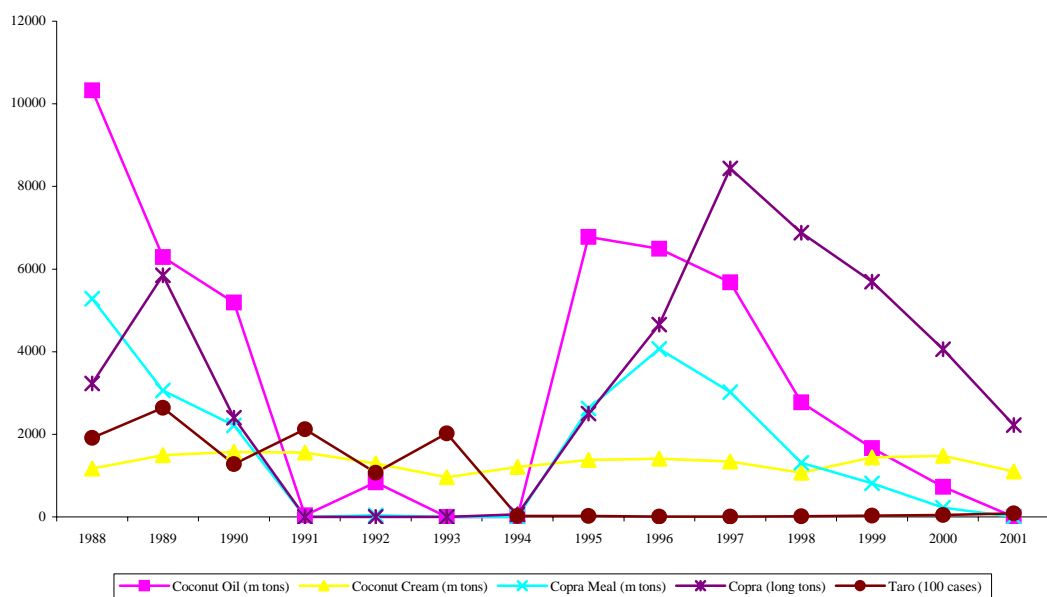


Figure 5.6. Volume of Agricultural Commodity Exports 1988-2001

Source: Central Bank of Samoa.

immediately after the hurricanes and for a few years thereafter due to damage to the coconut plantations and processing infrastructure, but taro production is largely unaffected. Indeed, Paulson (1993) noted that after cyclone Ofa, households that were invested largely in monocropping taro, ostensibly for export, proved to be the most secure in their food supplies after the cyclones more so than families who maintained diverse crops, including banana and breadfruit, which sustained 100% losses; taro is rather resilient to wind damage, simply losing its leaves and resprouting. With the subsequent cyclone Val, many farmers took advantage of the thinned forests to expand their taro plantations, both to take advantage of the export opportunities and to increase their potential food supply in the face of another possible cyclone (Paulson 1993, Paulson and Rogers 1997). Although monocropping taro was implemented as a food security strategy in the face of uncertainty against future tropical cyclones, the system left most of Samoa's agricultural production vulnerable to pests and disease, and a fungus (*Phytophthora colocasiae*, taro leaf blight or *lega* in Samoan) claimed almost the entire crop within a few months, and considerable amounts of land were put into fallow as a result (Paulson and Rogers 1997). The coconut industry briefly recovered after this period, but volume has steadily declined since that time, and currently there are no viable agricultural exports that are traded in significant quantities.

Other new sources of income for households that bear mentioning are fishing and cattle husbandry. In the late 1990s, long-line tuna fishing technology became available for small boats, and a local tuna fishing industry, for both local markets and

export, arose, such that even individuals in the rural villages could become involved. Table 5.2 indicates that fishing has become an important source of income in the rural areas, although not serving as many households as agriculture and remittances. This source of income may be reflected on the terrestrial landscape by a reduction in reliance on agriculture and its corresponding reduction in resource pressure on the landscape. Cattle husbandry by smallholders (on their own initiative) has been increasing since the late 1980s, after a series of poor results from attempted introductions through development projects beginning in the 1970s, and enables these smallholders to participate in a diverse household economy through providing inputs for traditional ceremonial gift giving, providing income for investing in other economic pursuits such as starting businesses, or simply by providing monetary income (Maiava 2001). The popularity of cattle has risen in conjunction with the decline in other agricultural markets (ibid) and will undoubtedly alter the landscape in unique ways. Previous research by myself (Kirkham 1999) included an interview with a planter who indicated that cattle were a good hedge against periods of monetary shortfalls and that it was a good way to use the land once it was no longer viable for taro. This suggests that keeping cattle may also be influenced by land tenure issues, since keeping cattle can maintain claims to use of the land. Indeed, barbed-wire fencing has become a ubiquitous feature of the rural Samoan landscape, but the role that cattle (and fencing) play in securing and demarcating land ownership has not been commented on in the literature.

The totality of the above discussion emphasizes the interwovenness of the social forces surrounding Samoa's development to processes on the landscape, especially in regard to lowland deforestation, even if the activity in question does not directly modify the landscape. Although emphasis is placed on the relationship between population growth and land cover change, no Malthusian explanation of landscape change is intended, nor any attempt to assert an alternative Boserupian scenario made. Although population density tends to even out between the two main islands despite internal differences within 'Upolu, this sheds no light on whether agriculture is performed with any differences in intensity between the main regions of Samoa. Rather, the point is simply to demonstrate that differing patterns of land-cover change are closely associated to the different distributions of economic opportunities in the country, and thus that rural landscapes are social products of complex interactions that cross several spatial scales, from the local to the regional/global.

For instance, the export of taro to the cosmopolitan centers around the Pacific Rim (especially New Zealand) can be interpreted from a Malthusian point of view, in that the increased pressure on the landscape is being used to feed excess population growth that has immigrated, but has much more to do with culture and identity. Mainly the Pacific Islander community living overseas was consuming the exported taro. The argument could thus be made that expansion of cleared land in Samoa was the result of population pressure both within and outside of Samoa's borders. There is no reason, however, that Pacific Islanders living abroad cannot consume food

produced in the cosmopolitan countries; consumption of taro abroad depends upon Pacific Islanders maintaining their food preferences, which is a function of culture, of the unique character of Samoan overseas migration that has a high return migration rate, persistence of remittance rate, and slow acculturation, and quite possibly also to the discursive aspects of having a Pacific Islands identity as a minority group in a European dominated society. Interestingly, although Samoans living at home in Samoa had to change their diet in the wake of the taro leaf blight, Samoans living overseas did not, since the preferred variety of taro was grown on other Pacific Islands (most notably Fiji), and contributes to the inability of Samoa to recapture its market share of supplying Pacific Islanders with the foods they are used to. This maintenance of food preference by Pacific Islanders living overseas has contributed greatly to the deforestation and subsequent fallowing of land in Samoa.

It is apparent, then, that landscape change has occurred due to feedback between the natural and social realms, with changes in global agricultural markets (an expression of cultural values) resulting in expansion of forest clearing, exacerbated by cyclones due to the mirrored social needs of improved food and financial security monocropping taro represented, followed by taro leaf blight (negative feedback), with social response back toward diversified subsistence crop production and cattle, with an increase in the amount of land under fallow. Society is not simply imposing change on the natural landscape, but rather the social changes and changes on the landscape are formed in dialog between the social and natural realms.

Summary

The landscape of the study site is the product of both natural and social forces. The unique character of the physical landscape of the village has shaped settlement and agricultural activities there, but is not simply a product of physical influences. Complex social interactions at the village level and beyond have shaped the opportunities and constraints presented to people in their activities. With Samoa embroiled in a global and regional economy revolving around migration, markets, and development aid, the social forces interacting with the landscape are simultaneously global and local. The ensuing chapter demonstrates these linkages to the dominance of *Merremia peltata* on the landscape.

Chapter 6

Vegetation Analysis Results

Overview

Analysis reveals a landscape dominated by four species: *Merremia peltata* (*fue lautetele*), *Mikania micrantha* (*fue saina*, mile-a-minute vine), *Nephrolepis hirsutula* (*vaotuaniu*), and *Cocos nucifera* (*niu*, coconuts). Five generalized vegetation categories are discerned (with terminology following Whistler 2002 except where noted); early primary and mature secondary lavaflow forest (or *Pometia* forest, Mueller-Dombois and Fosberg 1998), secondary forest/growth, secondary scrub, vine scrub (a form of secondary scrub/growth where the dominant vegetation is *Merremia peltata* and *Mikania micrantha* vines and, in some cases, *Nephrolepis hirsutula*), and Coconut scrub (secondary scrub/growth, ranging in maturity from scrub to mature secondary forest, growing in coconut plantations). These categories are differentiated by disturbances (natural and human initiated) that vary by frequency of, duration of, and time elapsed since the disturbance, human alteration of community composition, and the direct effects of both on environmental factors. The evidence presented here suggests that *M. peltata* is a vital part of the natural regeneration of lowland rainforest and capable of displacing other weedy non-native species (with *Mikania micrantha* being a highly notable exception). Other exotic weeds are confined to secondary and coconut scrub (free from *Merremia peltata* dominance), with soil nutrients, soil temperature difference, canopy cover and light availability, and competitive exclusion

playing a greater role in structuring these communities. Cluster analysis illustrates these groupings, and nonmetric multidimensional scaling provides insight into specific species and environment interactions.

Cluster Analysis

The dendrogram produced by cluster analysis is present in Figure 6.1, with the major groupings and sub-groupings of the vegetation labeled. These groupings are based on the similarity of species composition of each of the sample plots, and Table 6.1 lists the most common species (comprising at least three percent of total sample cover), their total cover across broadly defined groups (as a percentage of cover as measured across all of the sample plots), as well as their percentage cover in selected sub-groups, used to identify the five general vegetation classes (percentage based on the cover of that species within that sub-group only). In general, the two broadest divisions in the vegetation, labeled as Groups I and II, are defined largely by the dominance of *Merremia peltata* for the former and *Cocos nucifera* for the latter.

Within Group I, two smaller groups are discernable. Group Ia (corresponding to the vegetation class “vine scrub,” above) is characterized by a mixture of mainly *Merremia peltata*, but with a strong co-occurrence of *Mikania micrantha* and sometimes *Nephrolepis hirsutula*. These areas typically lack a variety of plant species, with the vines providing a dense mat on the ground surface. Other species that do occur are often other vines (*Dioscorea bulbifera* being fairly common), or a variety of ferns growing in the shady microclimatic spaces formed between the vine

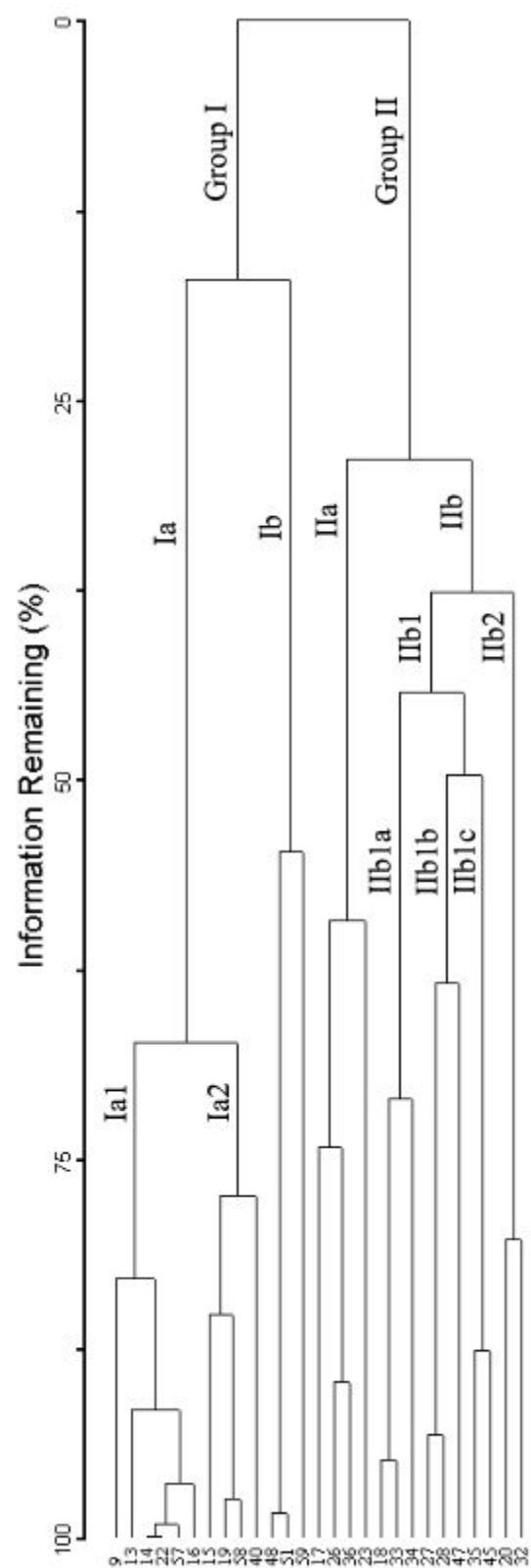


Figure 6.1 Cluster dendrogram with group labels

Table 6.1. Most common species and their cover across various clusters

| Cover as percentage of subgroup area | | | | | | | | | | | | | | | | | | | |
|--------------------------------------|------------------|-------------------|-------|--|---------|----------|-----|-----|-------|-----|-------|-------|----|------|-----|--|--|--|------|
| I | | | | | | | | | | | | | | | | | | | |
| II | | | | | | | | | | | | | | | | | | | |
| Species | Family | Nativity | Type | Cover as percentage of total survey area | | | | | | Ib | | | | | Iib | | | | Iib2 |
| | | | | Group I | | Group II | | Ia | | Ila | Iib1 | | | Iib2 | | | | | |
| | | | | Total | Group I | Group II | Ia1 | Ia2 | Iib1a | | Iib1b | Iib1c | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| <i>Merremia peltata</i> | Convolvulaceae | Native | Vine | 52 | 39 | 13 | 90 | 82 | 60 | 0 | 55 | 7 | 83 | 6 | | | | | |
| <i>Mikania micrantha</i> | Asteraceae | Tropical America | Vine | 43 | 24 | 19 | 57 | 73 | 5 | 12 | 54 | 29 | 16 | 90 | | | | | |
| <i>Nephrolepis hirsutula</i> | Nephrolepidaceae | SE Asia & Pacific | Fern | 32 | 11 | 21 | 0 | 50 | 29 | 50 | 77 | 45 | 19 | 4 | | | | | |
| <i>Cocos nucifera</i> | Arecaceae | Native | Tree | 14 | 0 | 14 | 0 | 0 | 0 | 45 | 40 | 20 | 12 | 0 | | | | | |
| <i>Opismenus compositus</i> | Poaceae | Naturalized | Grass | 13 | 0 | 13 | 1 | 2 | 0 | 12 | 4 | 53 | 43 | 19 | | | | | |
| <i>Ischaemum timorense</i> | Poaceae | SE Asia | Grass | 9 | 1 | 8 | 0 | 8 | 0 | 54 | 0 | 0 | 1 | 0 | | | | | |
| <i>Blechnum pyramidatum</i> | Anacardiaceae | Tropical America | Herb | 9 | 1 | 9 | 1 | 4 | 0 | 9 | 38 | 17 | 9 | 9 | | | | | |
| <i>Hyptis rhomboidea</i> | Lamiaceae | Tropical America | Herb | 9 | 2 | 7 | 7 | 4 | 0 | 17 | 6 | 0 | 0 | 57 | | | | | |
| <i>Cananga odorata</i> | Annonaceae | Naturalized | Tree | 8 | 7 | 2 | 2 | 0 | 55 | 0 | 5 | 0 | 14 | 0 | | | | | |
| <i>Pometia pinnata</i> | Sapindaceae | Native | Tree | 8 | 7 | 1 | 0 | 2 | 64 | 4 | 1 | 0 | 0 | 0 | | | | | |
| <i>Ruellia prostrata</i> | Anacardiaceae | Tropical America | Herb | 8 | 0 | 8 | 0 | 0 | 0 | 25 | 0 | 22 | 1 | 21 | | | | | |
| <i>Dioscorea bulbifera</i> | Dioscoreaceae | Tropical Asia | Vine | 7 | 4 | 3 | 14 | 8 | 0 | 0 | 21 | 6 | 1 | 2 | | | | | |
| <i>Paspalum conjugatum</i> | Poaceae | Tropical America | Grass | 8 | 2 | 6 | 6 | 6 | 0 | 0 | 17 | 14 | 1 | 31 | | | | | |
| <i>Funtumia elastica</i> | Apocynaceae | Tropical Africa | Tree | 5 | 2 | 3 | 0 | 0 | 20 | 18 | 2 | 0 | 4 | 0 | | | | | |
| <i>Diplazium harpeodes</i> | Dryopteridaceae | Pacific | Fern | 5 | 4 | 1 | 9 | 3 | 13 | 1 | 6 | 0 | 6 | 1 | | | | | |
| <i>Kleinhovia hospita</i> | Sterculiaceae | Native | Tree | 5 | 0 | 5 | 0 | 0 | 0 | 0 | 1 | 7 | 54 | 0 | | | | | |
| <i>Omalanthus nutans</i> | Euphorbiaceae | Native | Shrub | 4 | 0 | 4 | 0 | 0 | 0 | 15 | 8 | 0 | 1 | 10 | | | | | |
| <i>Faradaya amicornum</i> | Verbenaceae | Native | Liana | 3 | 3 | 0 | 0 | 6 | 18 | 0 | 0 | 0 | 5 | 0 | | | | | |
| <i>Cyathea spp.</i> | Cyatheaceae | Pacific | Fern | 3 | 3 | 1 | 7 | 0 | 8 | 0 | 5 | 0 | 1 | 0 | | | | | |
| <i>Macaranga harveyana</i> | Euphorbiaceae | Native | Tree | 3 | 2 | 0 | 1 | 16 | 0 | 0 | 3 | 0 | 0 | 1 | | | | | |
| <i>Rhus taitensis</i> | Anacardiaceae | Native | Tree | 3 | 0 | 2 | 0 | 0 | 2 | 16 | 0 | 0 | 1 | 0 | | | | | |

mat and the surface, if that surface were represented by an extremely uneven ground or marked by having several fallen trees. In reference to the latter, these plots often appear to have been recently slashed and burned. Also, in many cases these plots occur on (but are not limited to) soils that are characterized by regolith with a very thin layer of decomposing organic matter (*soata*). Two woody species that are often found in association with this type of cover are *Macaranga harveyana* (*laupata*) and *Pipturus argenteus* (*fau sogā*). Both were observed to have several branches sprawling beneath the vine mat with leafy growth emerging below the mat at several locations, creating the appearance of several small individual specimens growing in the plot. Although these individuals would likely be healthier growing in the absence of the vines, they nevertheless are able to compete and coexist with the dense *Merremia peltata* cover which raises questions as to whether a successional sequence, or multiple recovery pathways, are occurring.

The early primary and mature secondary lavaflow rainforest correspond to Group Ib of Figure 6.1. Here, *Merremia peltata* is largely relegated to the canopy, and other, more herbaceous vines such as *Mikania micrantha* and *Dioscorea bulbifera* (*soi*) are largely absent, although the former is common in gaps and clearings. Despite recent disturbance by hurricanes, these forested areas retain a largely indigenous species composition, with the indigenous *Pometia pinnata* (*tava*) and the naturalized *Cananga odorata* (*moso'oi*) being common. Interestingly, these lowland rainforest plots have a higher similarity to the vine scrub plots than to any of the Group II vegetation.

The dominance of coconut trees characterize group II, with *Mikania micrantha* and the fern *Nephrolepis hirsutula* being common, in addition to a wide variety of non-native weedy species and grasses. *Merremia peltata* may sometimes be present in these plots, and its cover can vary considerably. Where its cover is high, such as in the IIB1a and IIB1c subgroups, it is because of its presence in the canopy of the vegetation and not as groundcover. Group II areas reflect a more sustained disturbance to the vegetation, primarily through human action. The dominance of coconuts in these areas is a direct consequence of human dispersal, since this species is littoral by nature, and the sampling occurred outside of the littoral zone. These areas are dominated by village agricultural activities, including both cultivation and animal husbandry.

Subgroup IIB2, secondary scrub, adheres fairly closely to the description given by Whistler (2002), in that the vegetation is dominated by mostly non-native weedy species such as *Mikania micrantha* especially, but also the herbaceous weeds *Hyptis rhomboidea* (*vao mini*) and *Ruellia prostata* (*vao uli*), and the grass *Paspalum conjugatum* (*vao lima*). The naturalized grass *Oplismenus compositus* (*vao fali*) and the native shrub *Omalanthus nutans* (*mamala*) are common as well. In these plots, *Merremia peltata* and *Nephrolepis hirsutula* are largely absent. Where coconuts are present (coconut scrub/growth, Subgroup IIA), however, *N. hirsutula* is much more abundant, *Ischaemum timorense* is the most abundant grass, and *Mikania micrantha*, *Hyptis rhomboidea*, and *Paspalum conjugatum* are less prevalent. In addition, the native tree *Rhus taitensis* (*tavai*) and the exotic invasive rubber tree *Funtumia elastica*

(*pulu vao*) are common. *Omalanthus nutans* and *Oplismenus compositus* have similar cover in both of these classes. The NMS analysis, below, elucidates the distinction between these classes in more detail.

The three subgroups under Iib1 are lumped together under the moniker of “secondary forest/growth” and are characterized by having all four of the dominant species present, as well as being heavily influenced by grazing cattle and foraging pigs. In these plots, the tree species are more similar to those of Group I, such as *Cananga odorata* and to a much smaller extent, *Pometia pinnata* and *Macaranga harveyana*, with *Kleinhovia hospita* (*fu’afu’a*) being more common in these areas than in Group I. Classification of these plots into Group II is due to the prevalence of coconuts, and the presence of understory species more reminiscent of Group II plots. Indeed, Group Iib1a plots are typified by highly fragmented stands of secondary forest interspersed with grazed patches, where the former tend to have a greater similarity in species composition to Group I while the latter are more similar to Group II, including *Morinda citrifolia* (*nonu*) and *Psidium guajava* (*kuava*) not shown in Table 6.1. Group Iib1c plots, by contrast, are more uniformly shaded, but have highly disturbed and denuded ground surfaces. Group Iib1b plots are closer to houses and tend to show the effects of extensive use more. The introduced tree *Flueggea flexuosa* (*poumuli*), valued for use as house posts due to its straight-growing character, are common here, as are other utilized tree species, and *Merremia peltata* vines, although present, are not dominant. All these plots across the Iib1 subgroups have coconuts, but show a different composition of secondary forest growth than

subgroup IIa, the latter of which tends to have a much higher occurrence of *Rhus taitensis* than Subgroups under IIb1. These two apparently different successional pathways are discussed in more detail below.

The most salient feature to note here is that the landscape is divided into two broad categories, the *Merremia peltata* dominated part and the human modified part. This broad division suggests a closer association of *M. peltata* and natural forests in two ways. One, there is a greater similarity between the forests (Group Ib) and *M. peltata* dominated areas (Group Ia). Second, the Group II plots exhibit greater human alteration of community structure than does Group I. Both of these features suggest that *Merremia peltata* is more characteristic of a “natural” species than an exotic invader. The conventional wisdom regarding invasive species is that these species become established in habitats highly modified by people, then eventually infiltrate more natural areas; in terms of this dendrogram, an invasive species would establish itself in a Group II area first, then, over time, work its way into Group I areas. Hence, an invasive species should be well represented in both Group I and Group II areas. *Mikania micrantha*, *Paspalum conjugatum*, and *Funtumia elastica*, all non-native to Samoa, exhibit this distribution, and the vast majority of other non-native species are largely confined to Group II areas. A few species, such as *Ischaemum timorense*, *Blechum pyramidatum*, and *Hyptis rhomboidea*, have some representation in Group I areas, but the bulk of their distribution lies in Group II. These patterns for non-natives fit well with the long-standing general principles of invasion biology. *Merremia peltata*, however, is more firmly established in Group I areas, which runs

counter to conventional wisdom. Indeed, it seems likely that the invasion of the landscape by *M. peltata* is one coming out of the stands of remnant forest. The “invasion” may be more of an indication of the native forests reclaiming land from human use than an exotic species escaping from areas of human dominance.

The cluster dendrogram, although it indicates the grouping of the different sample plots based on the composition of the plant species, does not indicate whether the distribution of invasives is the product of the ability of individual species, a product of soil heterogeneity, or natural or human produced disturbance. Ordination results, on the other hand, provide a more detailed perspective on disturbance, soils and the distribution of *M. peltata* and non-native species on the landscape.

Nonmetric Multidimensional Scaling Results

With a total of 99 iterations run, a three-dimensional solution was obtained that had a final stress of 10.81 and a final instability of 0.00001. Figures 6.2, 6.3, and 6.4 display the graph of the ordination plots, showing the groupings of sample plots as indicated in the cluster dendrogram. The greatest contrast between Groups I and II from the dendrogram (Figure 6.1) is best seen in the plots of Axis 1 against either Axis 2 (Figure 6.2) or Axis 3 (Figure 6.3). Figure 6.2 shows the greatest distinctions between individual subgroup types, although Figure 6.3 provides more information on the distinctions between Group II subgroups. Figure 6.4 (Axis 2 vs. Axis 3) provides the greatest distinction between areas dominated by native species and those that have more non-natives. The aggregation of variables (both species and

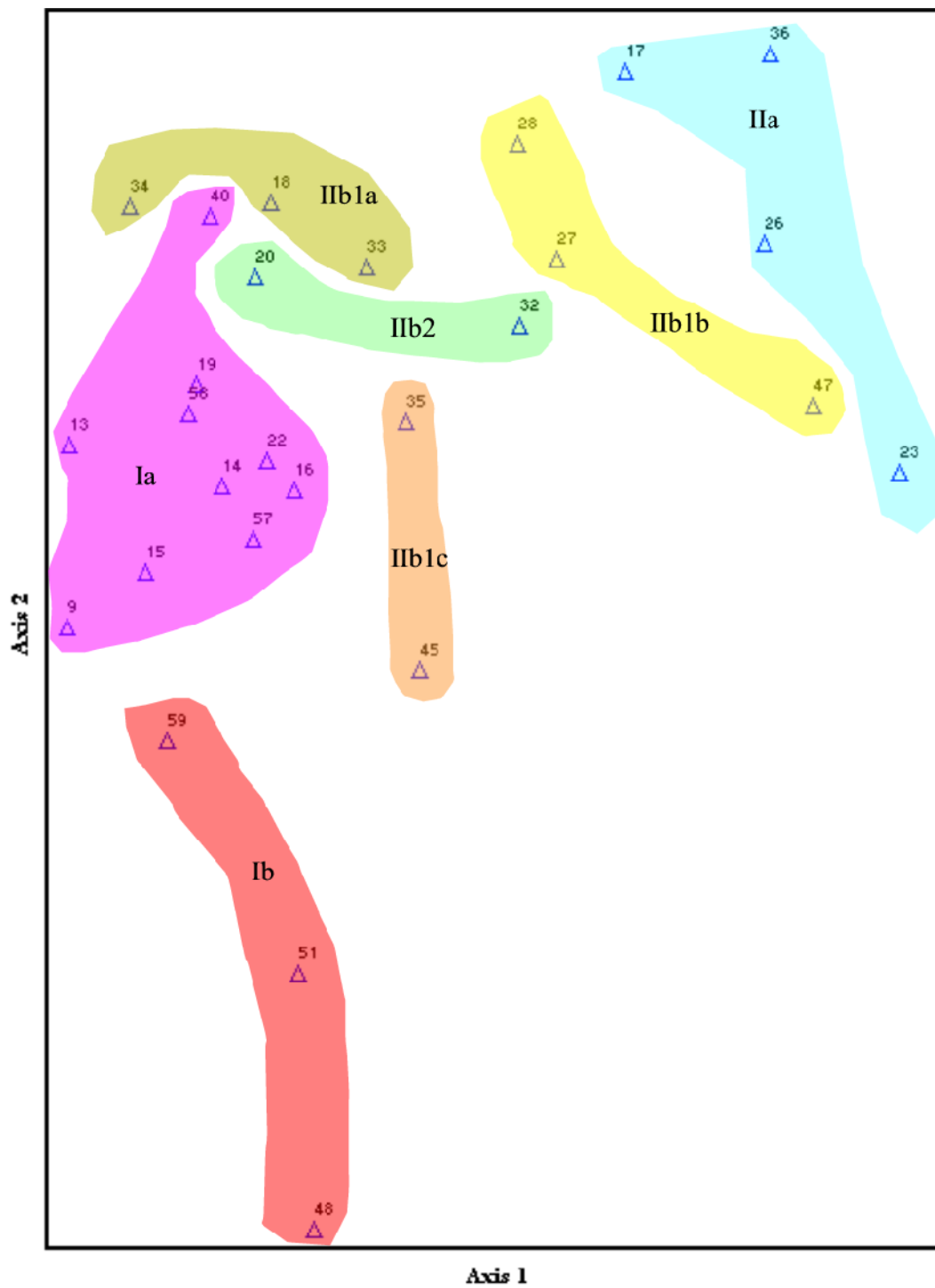


Figure 6.2. NMS Results: Axis 1 vs. Axis 2. Note: Axis 1 represents duration of disturbance and Axis 2 represents frequency of disturbance.

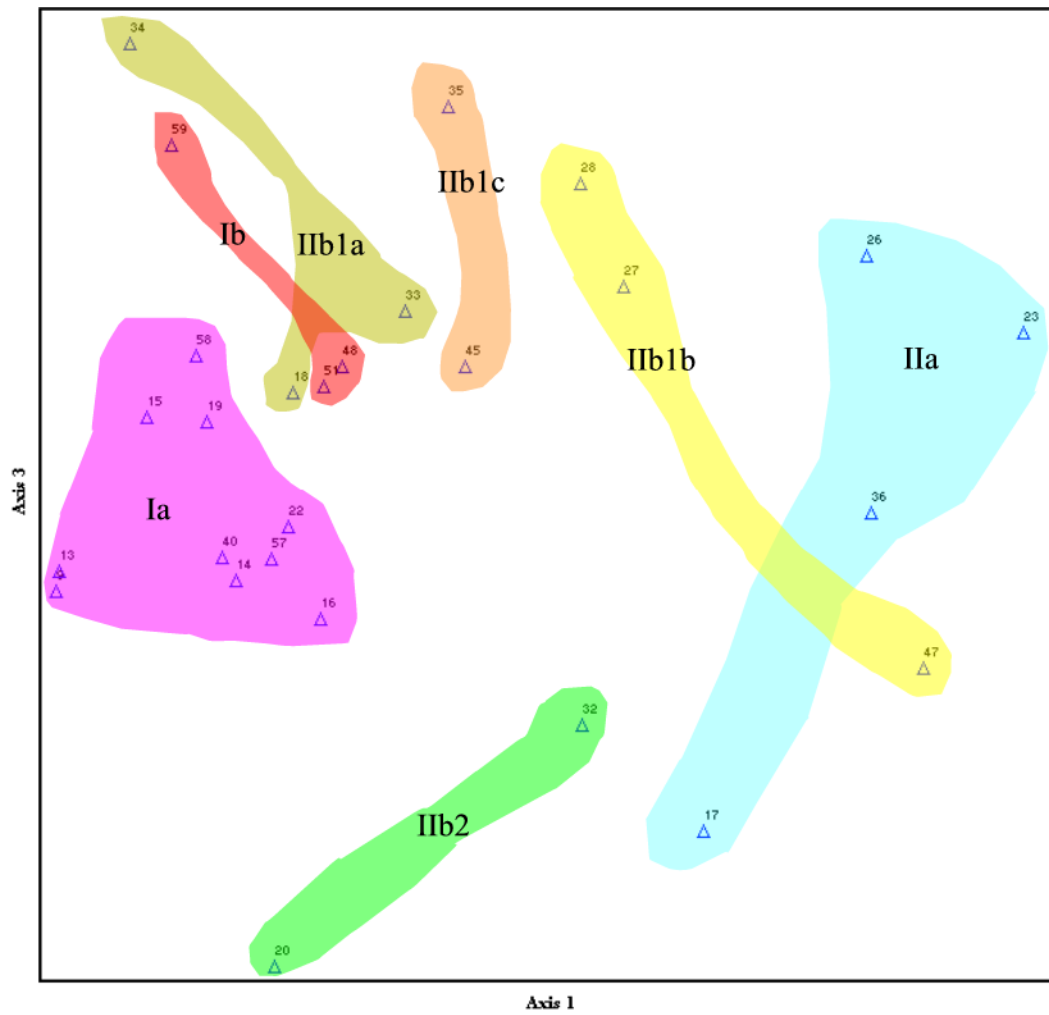


Figure 6.3. NMS Results: Axis 1 vs. Axis 3. Note: Axis 1 represents duration of disturbance and Axis 3 represents canopy cover.

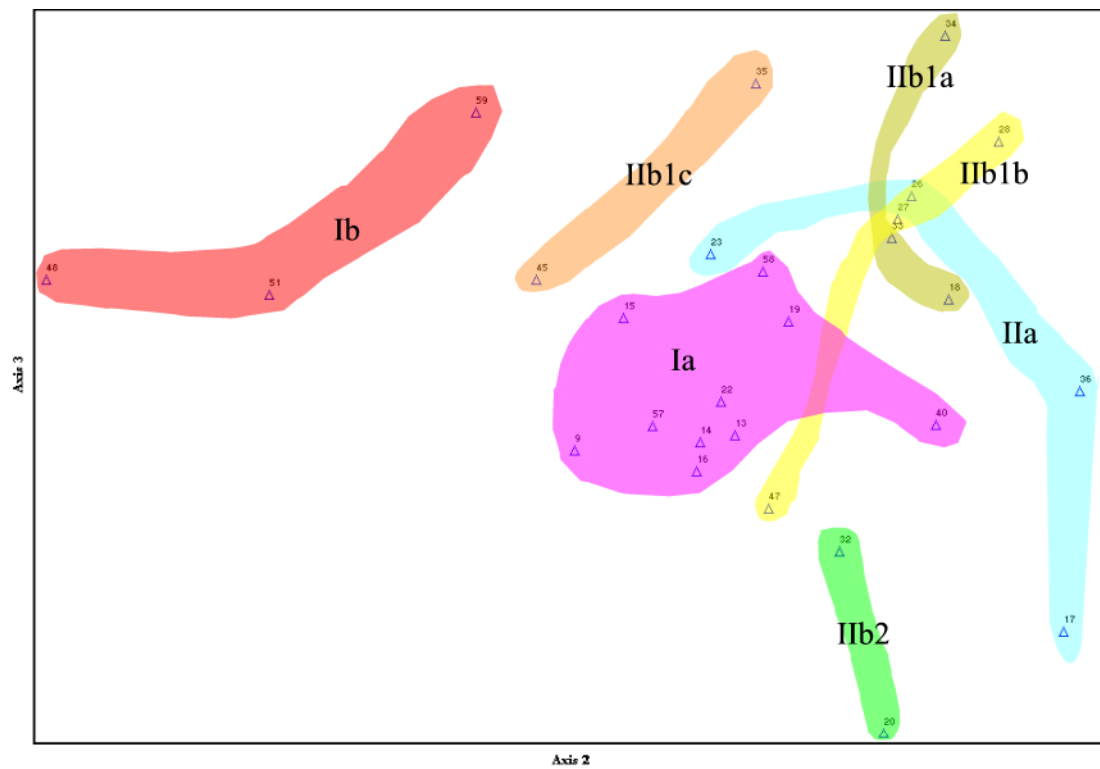


Figure 6.4. NMS Results: Axis 2 vs. Axis 3. Axis 2 represents frequency of disturbance and Axis 3 represents canopy cover.

environmental) represented by Axis 1 tends to distinguish between areas that are influenced by *Merremia peltata* and *Mikania micrantha* and of those by coconuts (contrasting vine scrub with coconut scrub). Axis 2 contrasts the lowland lavaflow forests with coconut scrub, and the ranked Pearson R and R^2 values of the species and environmental variables for this axis provide a strong contrast between native and exotic species. On both Axis 1 and 2, soil fertility factors provide the strongest correlations, although these associations are strongest along Axis 2. The available phosphorus, nitrogen, and organic carbon have high negative R-values (that is, are associated more with the lowland forest and vine scrub than coconut scrub), whereas the phosphorus in the surface organic matter is higher under coconut scrub (high positive R values on both Axes 1 and 2). Axis 3 provides contrast between *Nephrolepis hirsutula* dominated areas and secondary scrub, and provides the greatest insight into distinguishing the subgroups of Group II. Shade, light, and large ranges of daily soil temperatures have the highest R-values on this axis. Table 6.2 shows the ranked Pearson R and R^2 values for the highest ranked species and environmental variables along all three axes.

The NMS analysis provides much that is relevant regarding the *Merremia peltata* invasion, especially in regard to biodiversity (that is, number of species in each plot), interactions with other species (those that it is equally competitive with and those that are displaced), influence on succession and interactive effects with disturbance. Where *M. peltata* groundcover is high (that is, vine scrub), the lowest number of species was recorded for each sample plot. Conversely, where *M. peltata*

Table 6.2. Pearson's R and R² values for all Axes

| Variable | Nativity | Axis 1 | | Axis 2 | | Axis 3 | |
|---------------------------------------|----------------------|--------|----------------|--------|----------------|--------|----------------|
| | | R | R ² | R | R ² | R | R ² |
| <i>Aglaia samoensis</i> | Native | -0.074 | 0.005 | -0.746 | 0.557 | 0.094 | 0.009 |
| <i>Alocasia macrorrhiza</i> | Naturalized | -0.039 | 0.002 | 0.118 | 0.014 | -0.507 | 0.257 |
| <i>Arthropteris repens</i> | Melanesia | -0.079 | 0.006 | -0.674 | 0.454 | 0.088 | 0.008 |
| <i>Asplenium nidus</i> | E Africa - Pacific | -0.049 | 0.002 | -0.610 | 0.372 | 0.267 | 0.071 |
| <i>Blechnum pyramidatum</i> | Tropical America | 0.160 | 0.026 | 0.579 | 0.335 | 0.025 | 0.001 |
| <i>Cananga odorata</i> | Naturalized | -0.171 | 0.029 | -0.783 | 0.613 | 0.210 | 0.044 |
| Canopy | | 0.318 | 0.101 | -0.238 | 0.057 | 0.526 | 0.277 |
| <i>Cocos nucifera</i> | Native | 0.685 | 0.469 | 0.544 | 0.296 | 0.206 | 0.042 |
| Compaction Ratio | | -0.292 | 0.085 | -0.447 | 0.200 | -0.123 | 0.015 |
| <i>Cordyline fruticosa</i> | Naturalized | 0.134 | 0.018 | -0.529 | 0.280 | 0.185 | 0.034 |
| <i>Davallia epiphylla</i> | W. Pacific | 0.475 | 0.226 | 0.036 | 0.001 | 0.169 | 0.029 |
| <i>Diospyros samoensis</i> | Native | 0.020 | 0.000 | -0.688 | 0.473 | 0.141 | 0.020 |
| Distance from Houses | | -0.547 | 0.299 | -0.349 | 0.122 | -0.004 | 0.000 |
| Elevation | | -0.473 | 0.224 | -0.063 | 0.004 | -0.119 | 0.014 |
| <i>Epipremnum pinnatum</i> | Native (?) | -0.074 | 0.005 | -0.744 | 0.554 | 0.094 | 0.009 |
| <i>Erythrospermum acuminatissimum</i> | Native | -0.080 | 0.006 | -0.737 | 0.543 | 0.095 | 0.009 |
| <i>Faradaya amicornum</i> | Native | -0.176 | 0.031 | -0.756 | 0.572 | 0.152 | 0.023 |
| <i>Ficus tinctoria</i> | Native | -0.031 | 0.001 | -0.642 | 0.412 | 0.097 | 0.009 |
| <i>Funtumia elastica</i> | Africa (Tropical) | 0.223 | 0.050 | -0.547 | 0.299 | 0.276 | 0.076 |
| <i>Glochidion ramiflorum</i> | Native (?) | 0.047 | 0.002 | -0.572 | 0.327 | 0.188 | 0.035 |
| <i>Hyptis rhomboidea</i> | Tropical America | 0.318 | 0.101 | 0.311 | 0.097 | -0.493 | 0.243 |
| <i>Ischaemum timorense</i> | SE Asia | 0.436 | 0.190 | 0.480 | 0.230 | -0.236 | 0.056 |
| <i>Kyllinga polyphylla</i> | Africa (Tropical) | 0.463 | 0.214 | 0.254 | 0.065 | -0.294 | 0.086 |
| <i>Merremia peltata</i> | Native | -0.854 | 0.729 | -0.450 | 0.203 | 0.208 | 0.043 |
| <i>Mikania micrantha</i> | Tropical America | -0.563 | 0.317 | 0.279 | 0.078 | -0.297 | 0.088 |
| <i>Myristica fatua</i> | Native | -0.292 | 0.085 | -0.600 | 0.360 | 0.404 | 0.163 |
| <i>Nephrolepis hirsutula</i> | SE Asia & Pacific | 0.075 | 0.006 | 0.334 | 0.112 | 0.748 | 0.560 |
| Number of Species | | 0.090 | 0.008 | -0.428 | 0.183 | 0.456 | 0.208 |
| <i>Oplismenus compositus</i> | Naturalized | 0.542 | 0.294 | 0.303 | 0.092 | 0.370 | 0.137 |
| <i>Palaquium stehlinii</i> | Native | -0.080 | 0.006 | -0.737 | 0.543 | 0.095 | 0.009 |
| <i>Planchonella garberi</i> | Native | -0.145 | 0.021 | -0.551 | 0.304 | 0.307 | 0.094 |
| <i>Planchonella samoensis</i> | Native | -0.079 | 0.006 | -0.674 | 0.454 | 0.088 | 0.008 |
| Plant Tissue Phosphorous | | 0.643 | 0.413 | 0.657 | 0.432 | -0.255 | 0.065 |
| <i>Pometia pinnata</i> | Native | -0.091 | 0.008 | -0.766 | 0.587 | 0.304 | 0.092 |
| <i>Pseudelaphantopus spicatus</i> | Tropical America | 0.478 | 0.228 | 0.119 | 0.014 | -0.214 | 0.046 |
| <i>Pyrrosia lanceolata</i> | E Africa - W Pacific | -0.108 | 0.012 | -0.345 | 0.119 | 0.524 | 0.275 |
| <i>Rhus taitensis</i> | Native | 0.472 | 0.223 | -0.090 | 0.008 | 0.182 | 0.033 |
| <i>Rourea minor</i> | Native | -0.120 | 0.014 | -0.723 | 0.523 | 0.095 | 0.009 |
| <i>Ruellia prostrata</i> | Tropical America | 0.827 | 0.684 | 0.329 | 0.108 | 0.029 | 0.001 |
| Soil Nitrogen L1 | | -0.280 | 0.078 | -0.639 | 0.408 | -0.073 | 0.005 |
| Soil Organic Carbon L1 | | -0.344 | 0.118 | -0.581 | 0.338 | -0.160 | 0.026 |
| Soil Phosphorus L1 | | -0.351 | 0.123 | -0.611 | 0.373 | -0.166 | 0.028 |
| Soil Temperature Difference | | 0.098 | 0.010 | 0.163 | 0.027 | -0.540 | 0.292 |
| <i>Stachytarpheta urticifolia</i> | Tropical America | 0.472 | 0.223 | 0.472 | 0.223 | 0.427 | 0.182 |
| <i>Sterculia fanaiho</i> | Native | -0.080 | 0.006 | -0.737 | 0.543 | 0.095 | 0.009 |
| Surface Compaction | | -0.087 | 0.008 | -0.541 | 0.293 | 0.293 | 0.086 |
| <i>Synedrella nodiflora</i> | Tropical America | 0.510 | 0.260 | 0.177 | 0.031 | -0.206 | 0.042 |
| <i>Syzygium inophylloides</i> | Native | -0.068 | 0.005 | -0.724 | 0.524 | 0.091 | 0.008 |
| <i>Syzygium samarangense</i> | Naturalized | -0.174 | 0.030 | -0.730 | 0.533 | 0.166 | 0.028 |
| <i>Theobroma cacao</i> | Tropical America | -0.079 | 0.006 | 0.033 | 0.001 | 0.541 | 0.293 |

cover was high, due to its presence in the canopy of lowland forest (Ib) especially and most of the Group II plots, the numbers of species are at their highest. For its correlation values, along Axis 3 ($R = +0.456$) it is strongly associated with canopy and a variety of native and non-native tree and woody shrub species and along Axis 2 ($R = -0.428$) it is strongly associated with native forest cover. Along Axis 3, the numbers of species are bolstered primarily by a mixture of native and non-native species, whereas on Axis 2, the higher numbers of species are generally composed of natives. Along both axes, having the sample plot under canopy contributed greatly to the number of ecological niches for a variety of species to inhabit, providing habitat for trees, shrubs, epiphytes and vines, whereas in the vine scrub, as few as four species were recorded in a sample plot, with structure being heavily weighted toward vines.

Figure 6.5 illustrates the drop in species numbers on vine scrub plots. As noted above, where ground cover is uneven, often due to the presence of fallen trees, a greater number of species, primarily ferns, was present in the microclimatic spaces. The implications of these findings on the threat to biodiversity posed by *M peltata* point toward disturbance as being an important factor in how large an impact this plant has on species numbers, especially in regard to how the disturbance structures the landscape. A disturbance that clears a patch of land of larger-structure vegetation (i.e. trees) and leaves a fairly uniform surface (such as using bulldozers to clear a forest patch) will see fewer species under the vine mat than slash-and-burn cultivation (leaving fallen trees that create a higher structure for the vines and exploitable niches

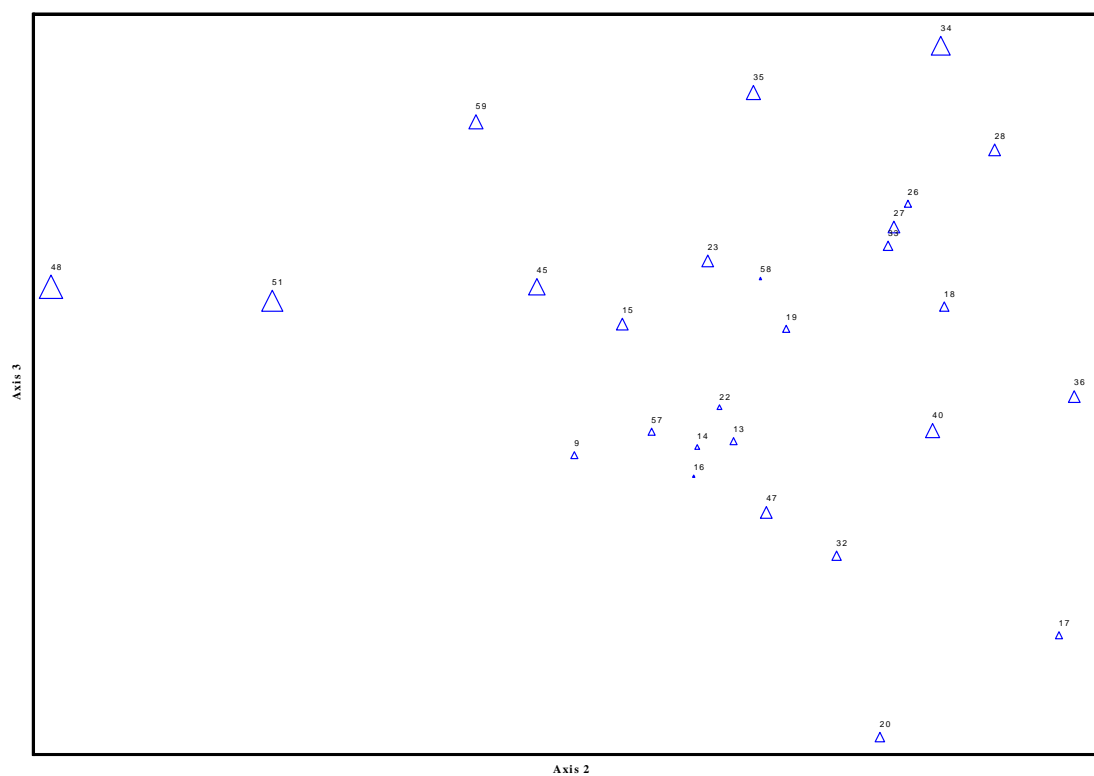


Figure 6.5. Number of species across Axes 2 and 3

beneath). Furthermore, disturbances that occur without removal of trees or shrubs (such as low-intensity cattle grazing in and amongst a patchy landscape of secondary growth and scrub) typically have higher numbers species than the latter two examples. The biodiversity issue lies not with *Merremia peltata* itself, but with the overall fluctuating structure of the vegetation on the landscape on which it occurs.

Results indicate that there is a broad contrast in soil nutrient characteristics across Group I and Group II plots, and this may be the result of both *Merremia peltata* and coconuts. Figures 6.6, 6.7, and 6.8 illustrate the levels of organic carbon and available nitrogen and phosphorus in the soil, respectively, Figures 6.9 and 6.10 illustrate the levels of nitrogen and phosphorus in the decaying surface leaf litter, respectively, and 6.11 and 6.12 give electrical conductivity and pH, respectively, which are also fertility indicators. Nutrient levels tend to be higher in the Group I plots in general, as is electrical conductivity. Interestingly, there is a marked contrast between the Group I and II plots in regard to levels of phosphorus in the soil and in the leaf litter. In the case of the former, phosphorus levels are higher in the soil than in the leaf litter, whereas in the latter, soil phosphorus levels are low compared to levels in the leaf litter. Since Group I areas are dominated by *Merremia peltata*, this may indicate that this species is fairly efficient at cycling phosphorus in contrast to the variety of ground cover species in the Group II plots where phosphorus may be locked up longer in leaf litter.

Many of these plots with vine scrub have some of the highest nutrient values, and these values may be related to slash-and-burn agriculture, especially in relation to

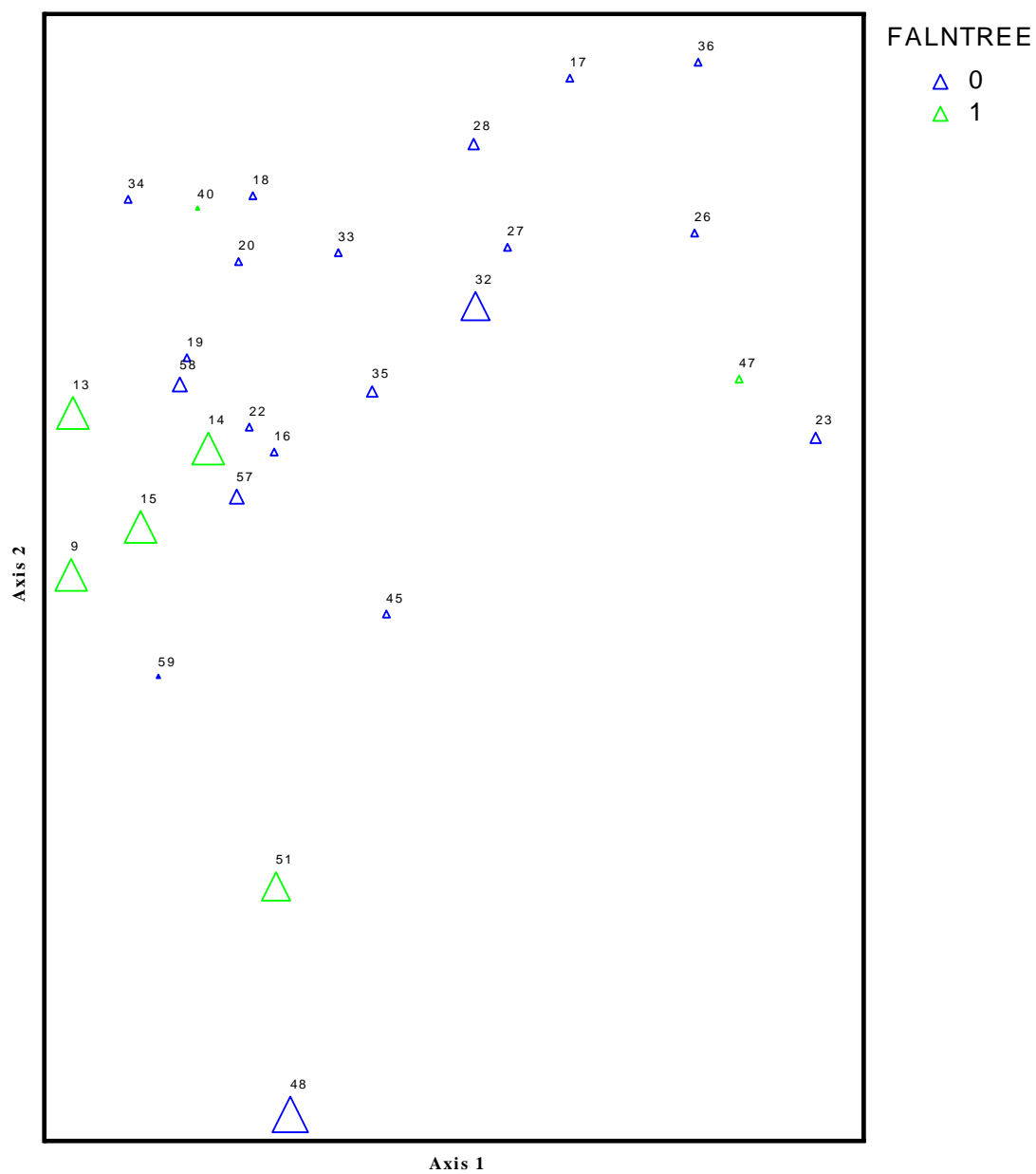


Figure 6.6. Soil organic carbon on Axes 1 vs. 2 indicating fallen trees

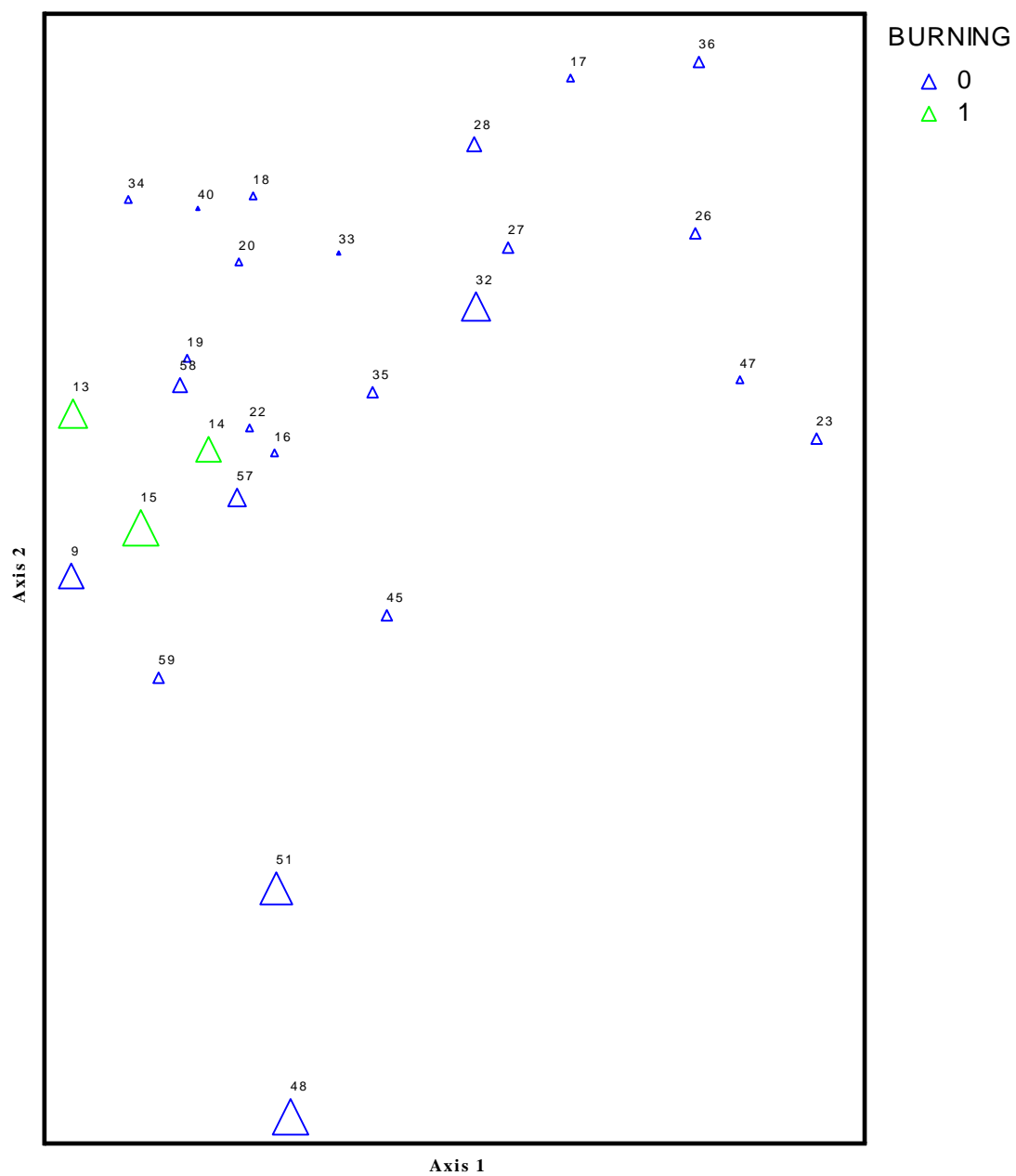


Figure 6.7. Soil available nitrogen on Axes 1 vs. 2 indicating burning

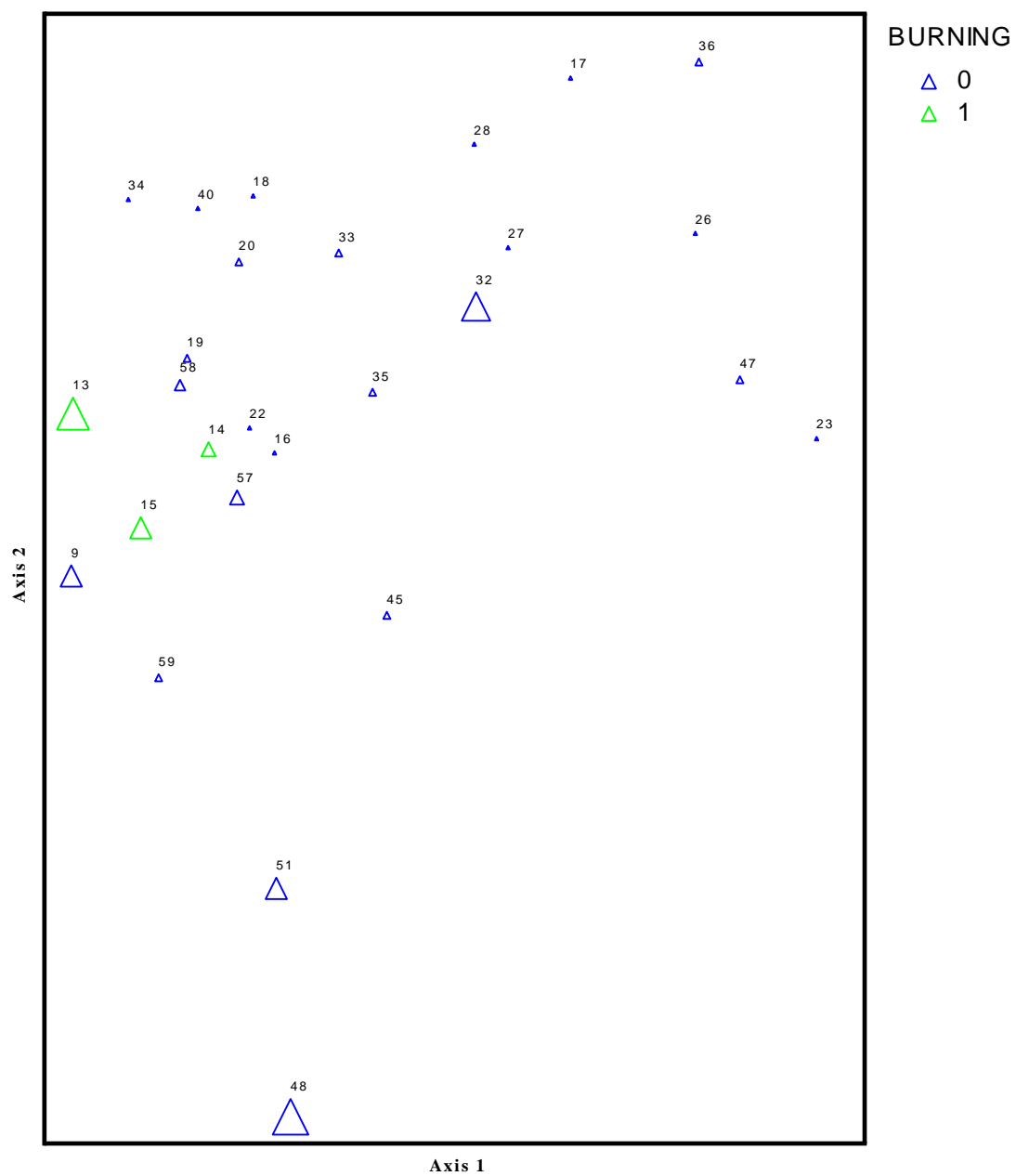


Figure 6.8. Soil available phosphorus on Axes 1 vs. 2 indicating burning

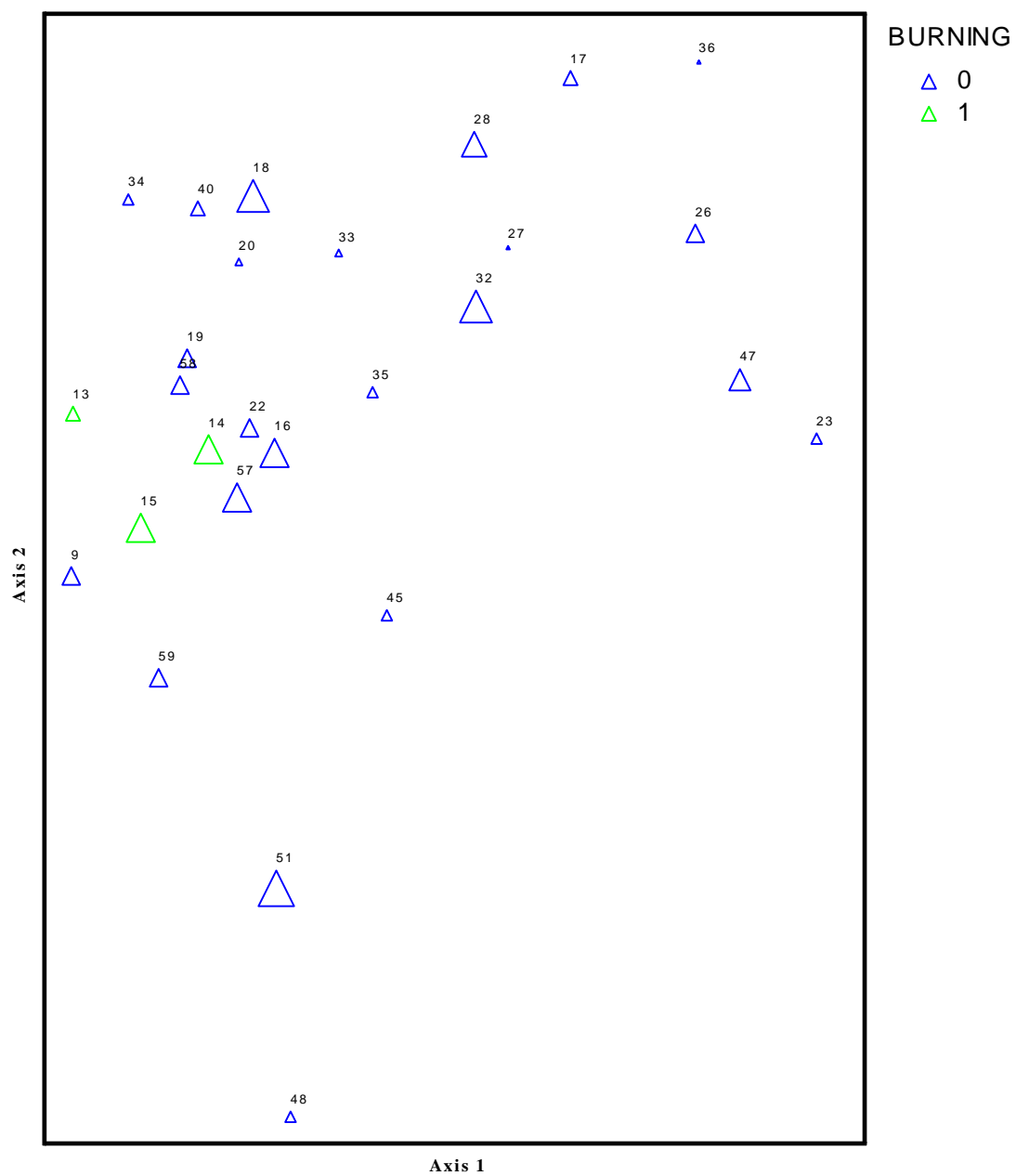


Figure 6.9. Leaf litter nitrogen on Axes 1 vs. 2 indicating burning

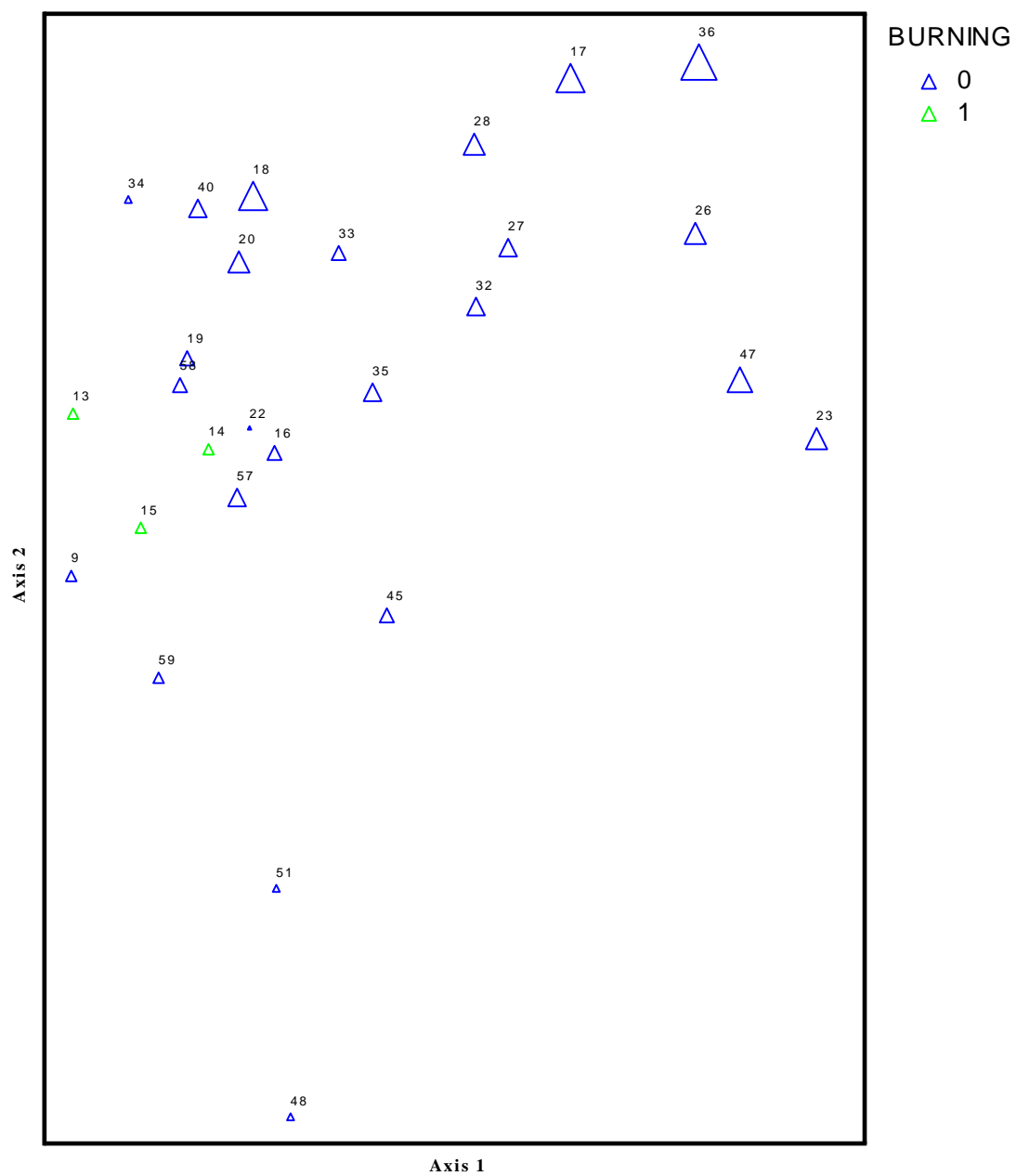


Figure 6.10. Leaf litter phosphorus on Axes 1 vs. 2 indicating burning

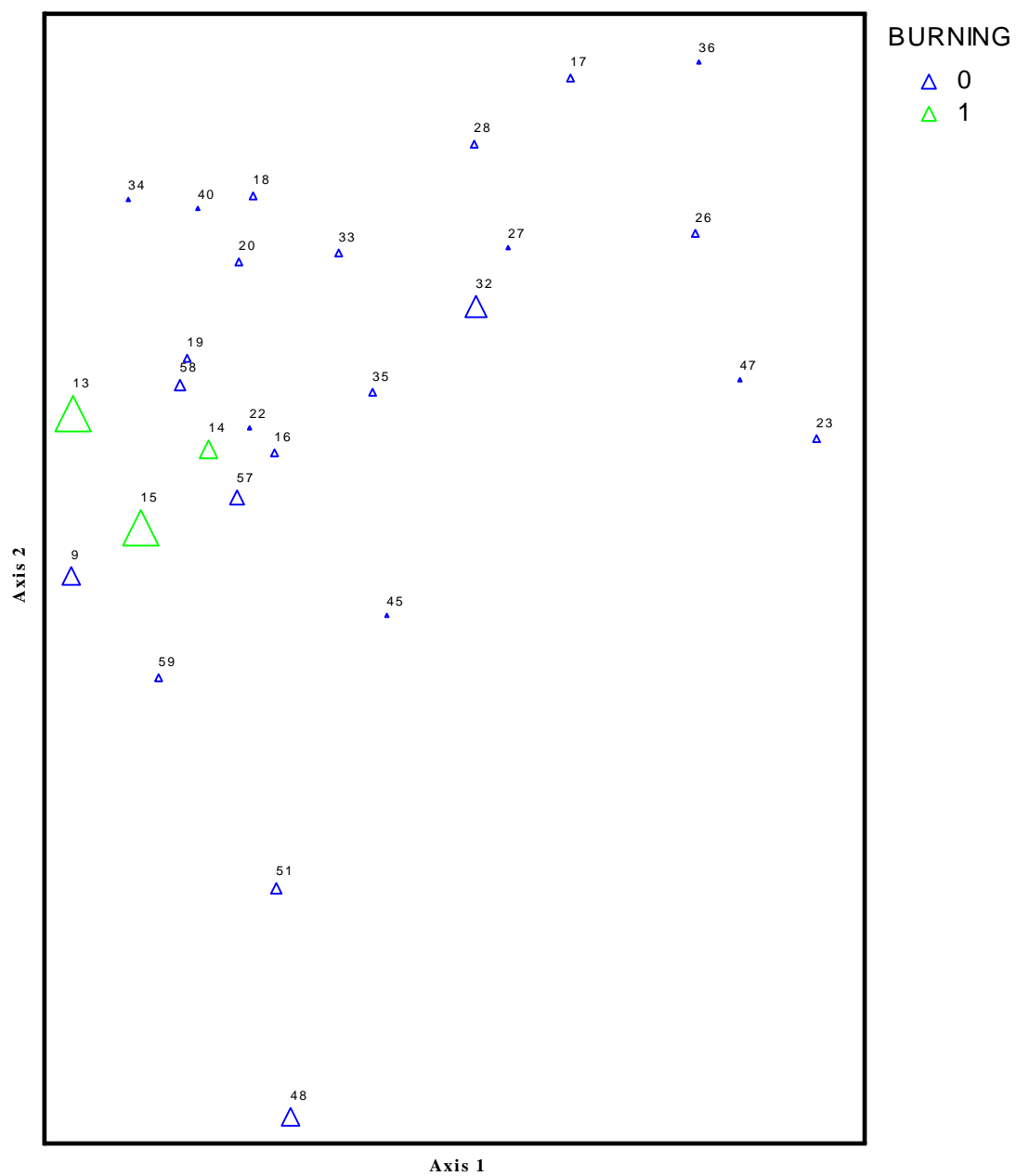


Figure 6.11. Soil electrical conductivity on Axes 1 vs. 2 indicating burning

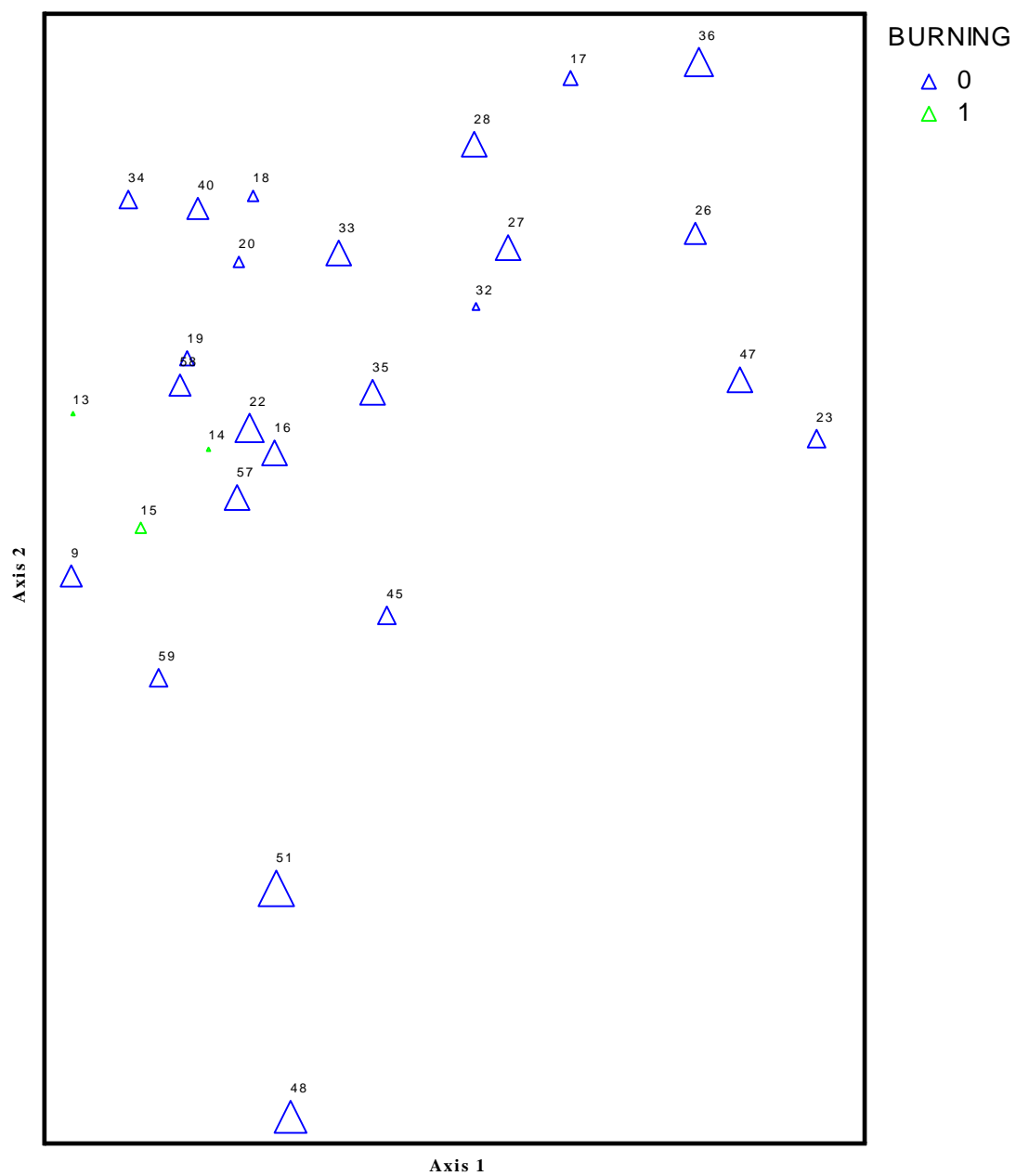


Figure 6.12. Soil pH on Axes 1 vs. 2 indicating burning

burning. Along Axis 1, non-vegetative variables that account for significant levels of variation in the data are largely indicative of human preference in disturbing the natural vegetation. Areas of vine scrub, represented by the dominance of *Merremia peltata* and *Mikania micrantha*, representing 73% and 32% of variation in the data respectively, tend to be farther from houses and at higher elevations. Additionally, many of these vine scrub plots exhibit evidence of having been burnt (Figures 6.7 through 6.12 indicate burnt plots) and frequently possess fallen trees (shown in Figure 6.6), although in the case of the latter, it was not always clear if the trees were deliberately cut down (although stumps in plots 14 and 15 were obviously cut) or whether they were blown down in the hurricanes of 1990 and 1991. Many of these vine scrub plots are thus recently fallowed swidden fields. These more remote plots, inland (upslope) from the villages along the plantation roads, appear to be subject to less frequent disturbances of short duration. Soil nutrients appear to be higher in these burnt plots, as well as electrical conductivity, indicating that fertility would be improved, but an examination of Figure 6.12 reveals a marked drop in pH, indicating greater acidity, and an offset to fertility, on these burnt plots as well.

In contrast, plots that lie in coconut plantations have a marked drop in soil nutrient levels. In addition to the nutrients, electrical conductivity is considerably less, the soils are slightly more acidic than Group I in general, but less acidic than the burnt vine scrub plots, leaf litter nitrogen is lower, but, as noted above, leaf litter phosphorus is somewhat higher. On these soils, *Nephrolepis hirsutula*, *Blechnum pyramdatum*, *Hyptis rhomboidea*, *Mikania micrantha*, *Oplismenus compositus*,

Paspalum conjugatum, *Psidium guajava* (occurring frequently at low levels of cover), *Ruellia prostrata*, and *Stachytarpheta urticifolia* are all frequently observed on these soils (Figures 6.13 – 6.23). Of these species, the majority of the non-native weedy species appear to be competitively displaced by *Merremia peltata*, with the notable exception of *Mikania micrantha* and *Paspalum conjugatum*. *M. micrantha* appears to have similar distributions to both *Merremia peltata* and *Nephrolepis hirsutula*, and these three species may mutually aid each other, with the fern providing a lattice-work structure for the vines. *P. conjugatum* appears to be a generalist, capable of establishing in variable soil and light conditions, and occurs somewhat frequently with *Merremia peltata*. Others, such as *Hyptis rhomboidea* also appear to be generalists in terms of nutrient and light needs (although it has its most dominant cover under conditions of both high light and nutrients), but is generally displaced by *M. peltata*. In plots where the two both exist, *H. rhomboidea* often lies close to the base of trees, where the area is periodically shaded, allowing *H. rhomboidea* to be more competitive with *M. peltata*. *Stachytarpheta urticifolia*, on the other hand, occurs almost exclusively of *M. peltata*.

Three native/naturalized species that occur frequently in Group II plots and often in Group Ib plots (lowland lavaflow forest) are *Rhus taitensis*, *Morinda citrifolia* (*nonu*) and *Omalaanthus nutans*, although the latter is mainly confined to Group II areas (Figures 6.24 – 6.26). Although these species can occur in a variety of habitats, none appear capable of competing with vine scrub and are largely absent. *Rhus taitensis* is an important pioneer tree species, especially in the Group II areas,

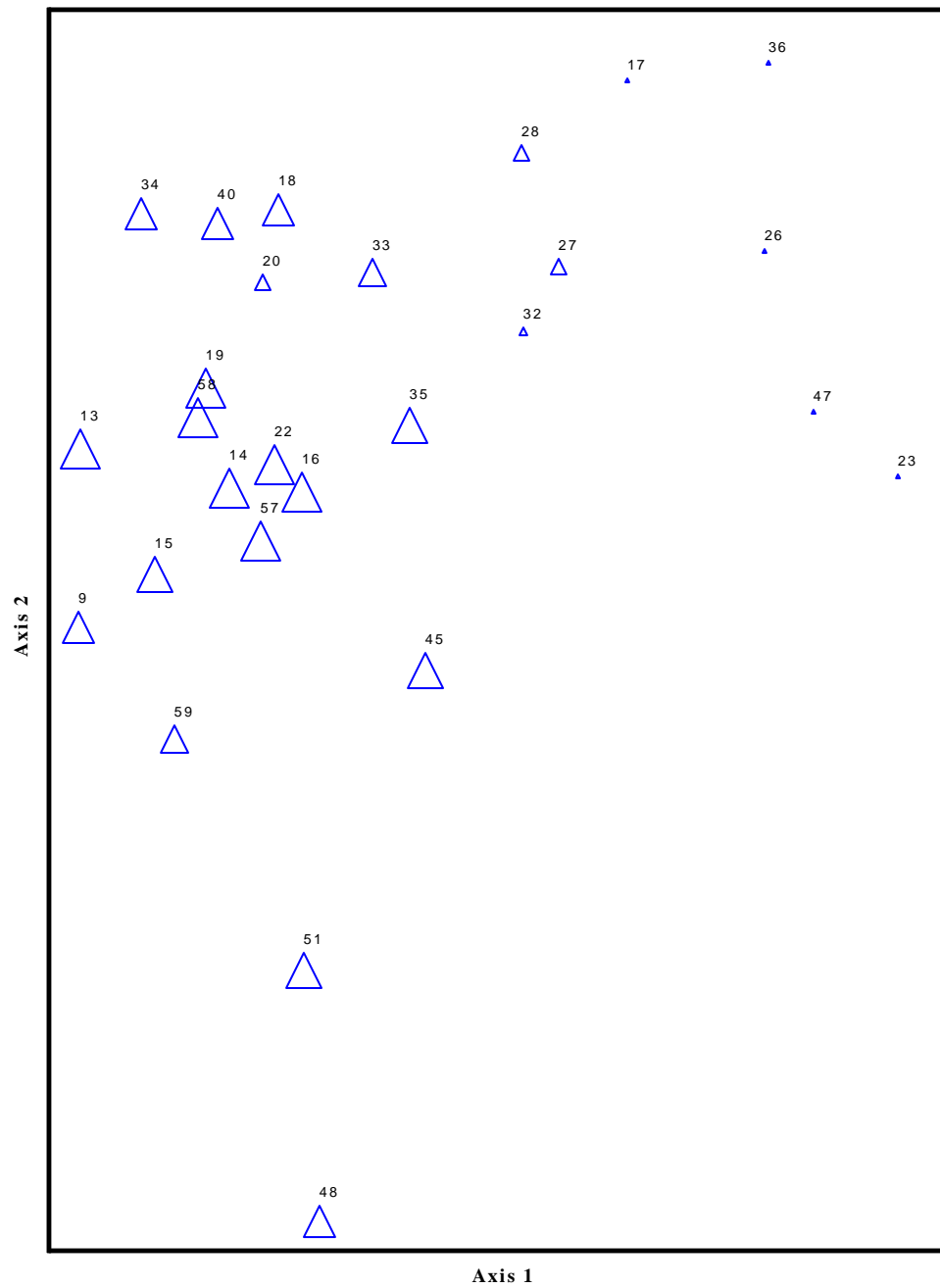


Figure 6.13. *Merremia peltata* on Axes 1 vs. 2

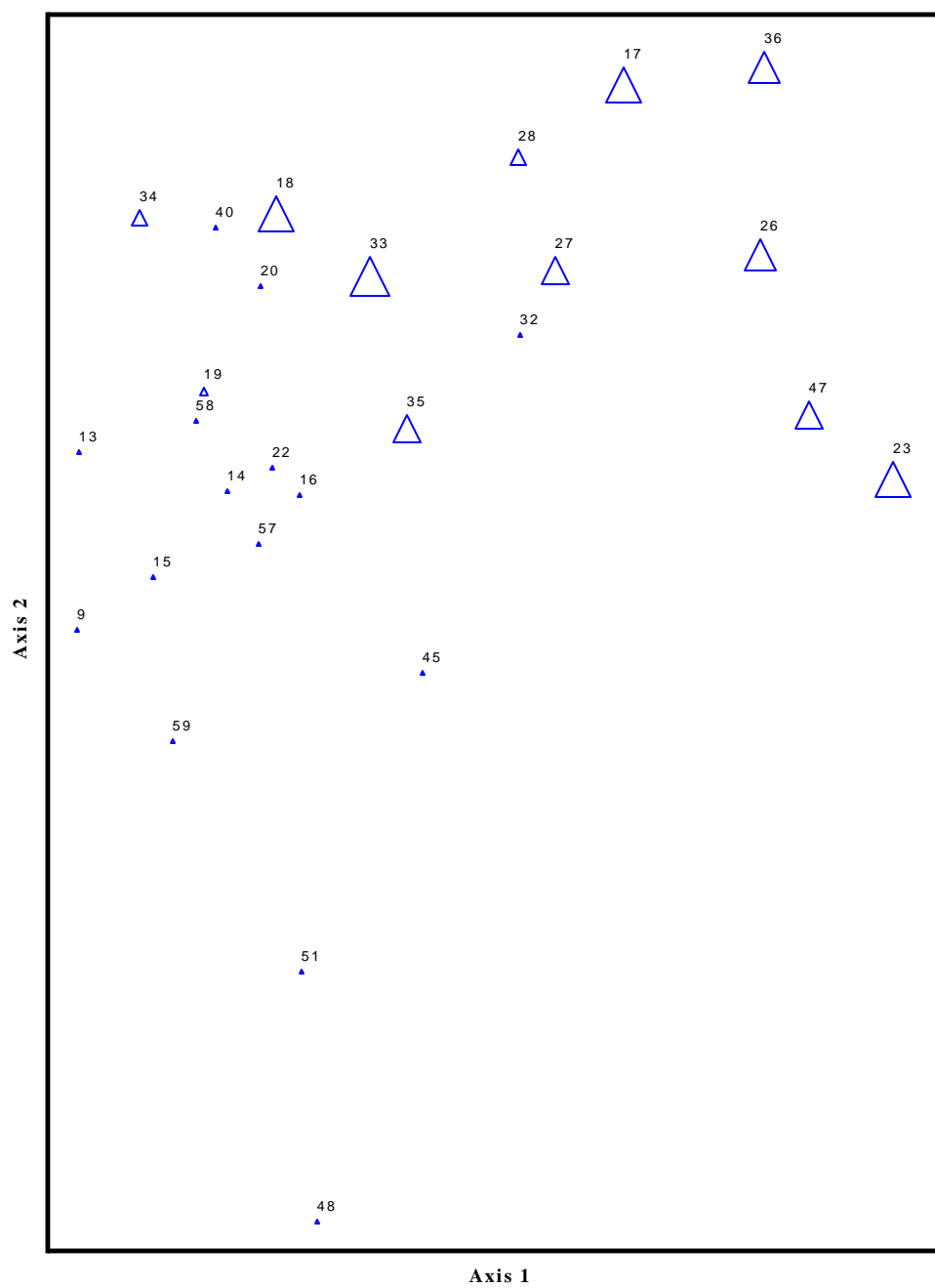


Figure 6.14. *Cocos nucifera* on Axes 1 vs. 2

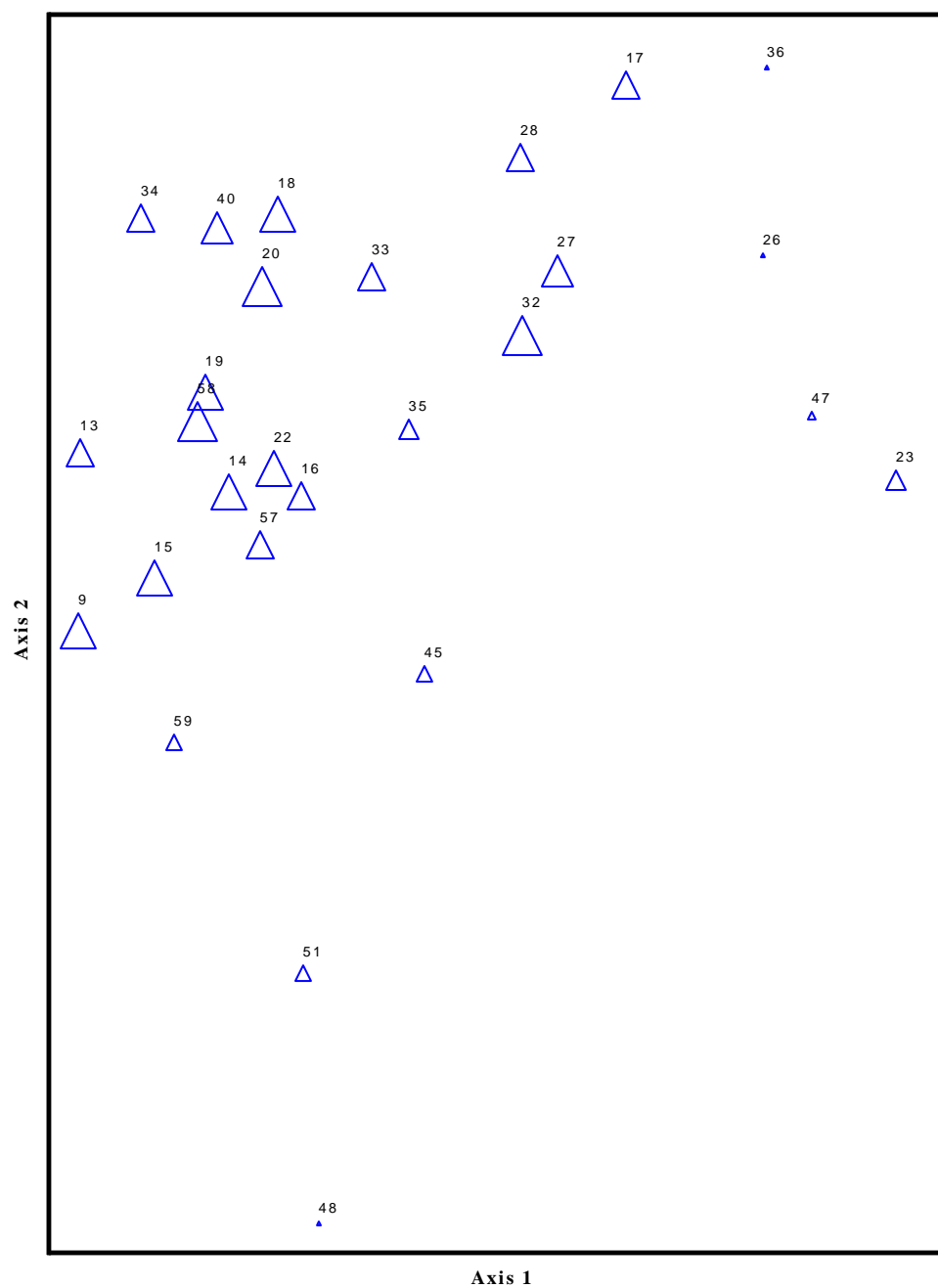


Figure 6.15. *Mikania micrantha* on Axes 1 vs. 2

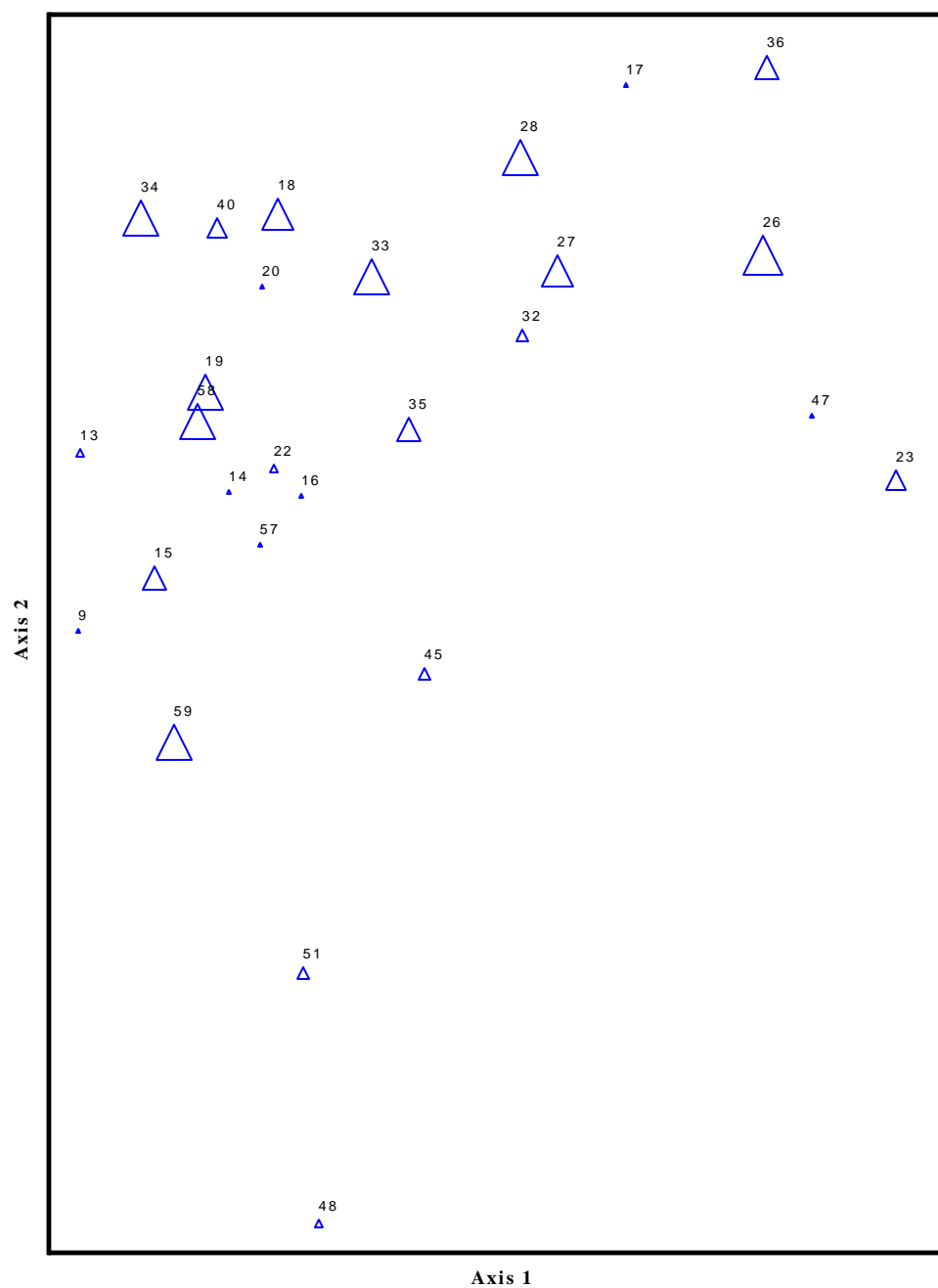


Figure 6.16. *Nephrolepis hirsutula* on Axes 1 vs. 2

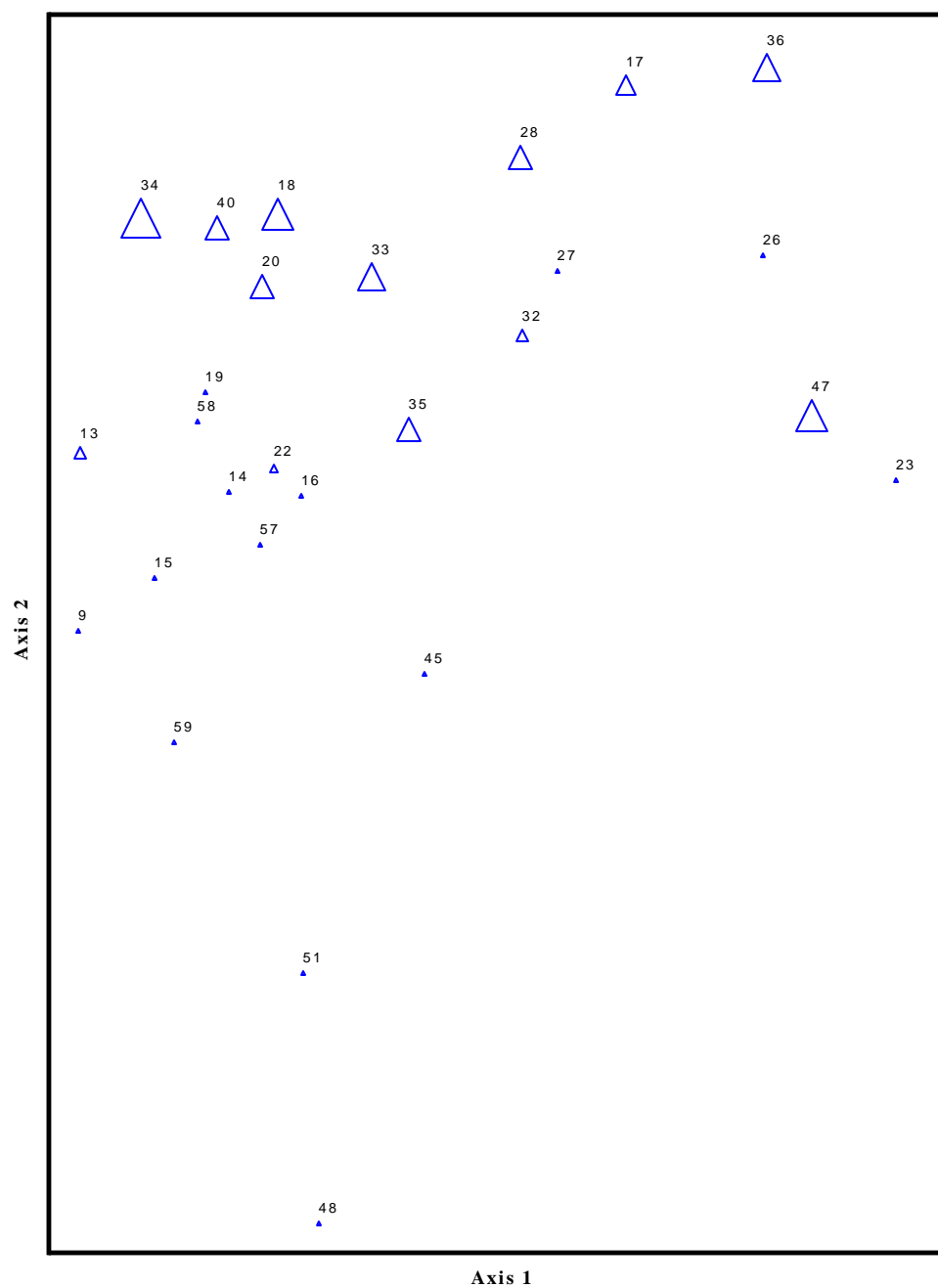


Figure 6.17. *Blechum pyramidatum* on Axes 1 vs. 2

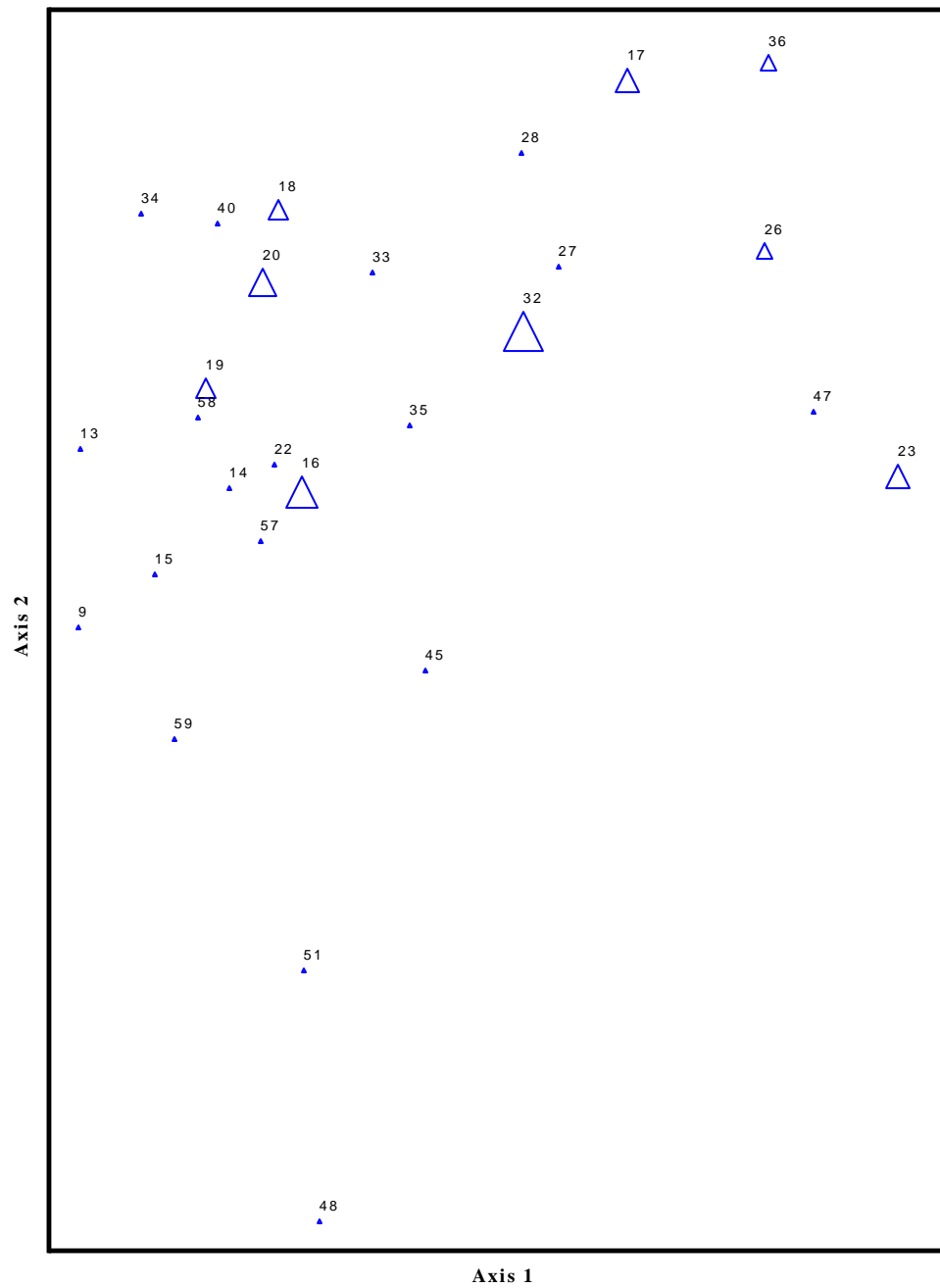


Figure 6.18. *Hyptis rhomboidea* on Axes 1 vs. 2

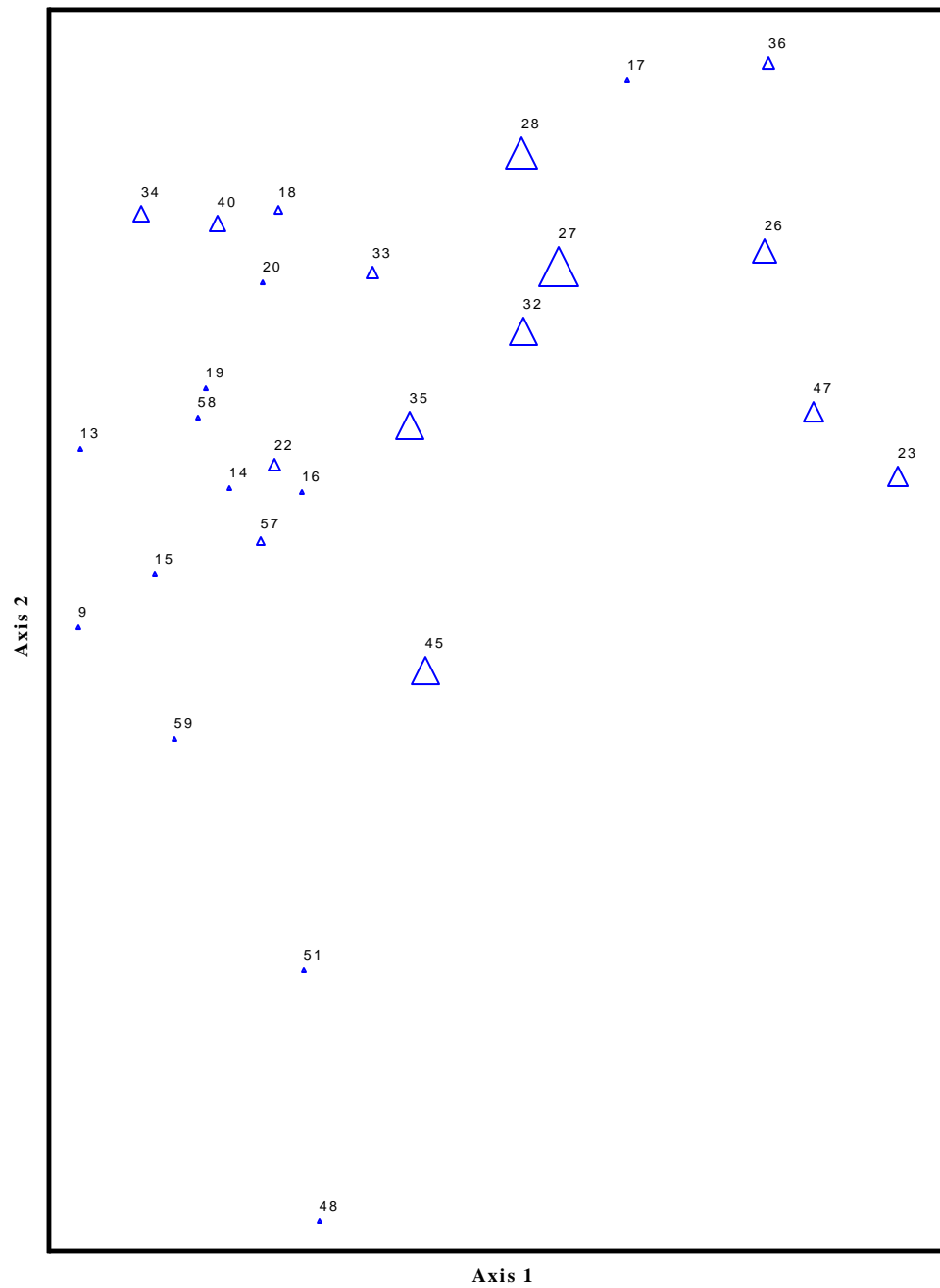
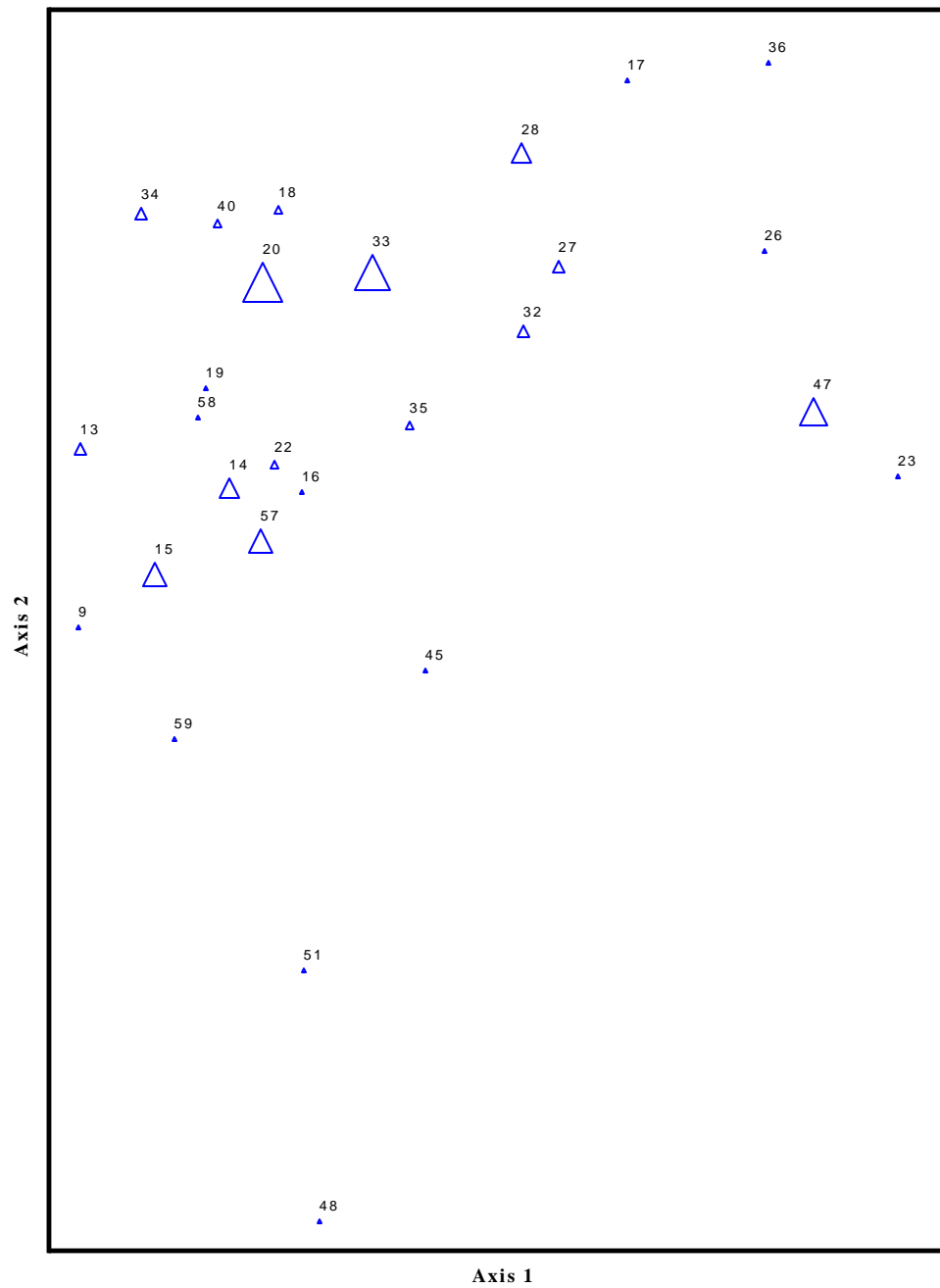


Figure 6.19. *Oplismenus compositus* on Axes 1 vs. 2



Format 6.20. *Paspalum conjugatum* on Axes 1 vs. 2

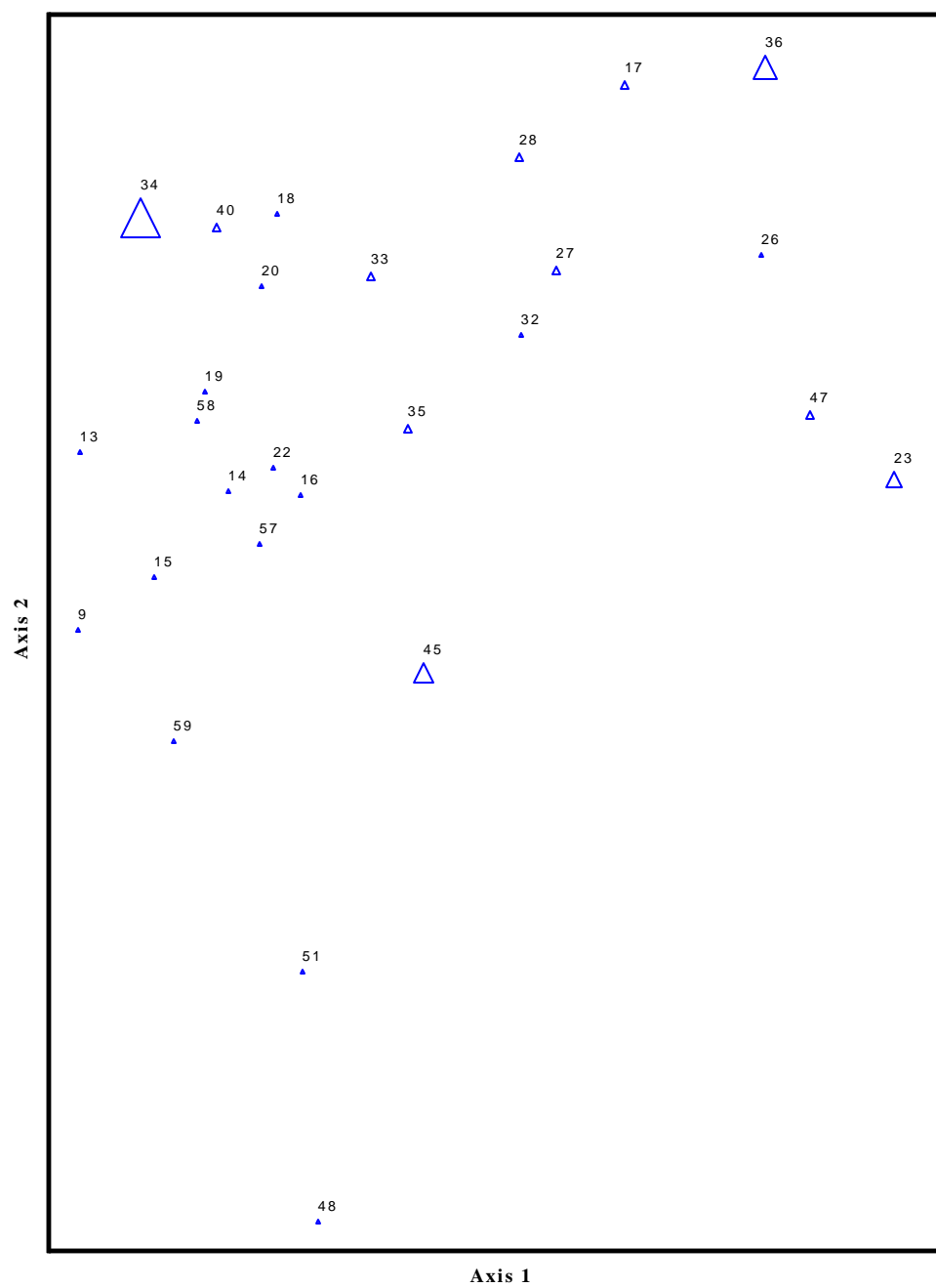


Figure 6.21. *Psidium guajava* on Axes 1 vs. 2

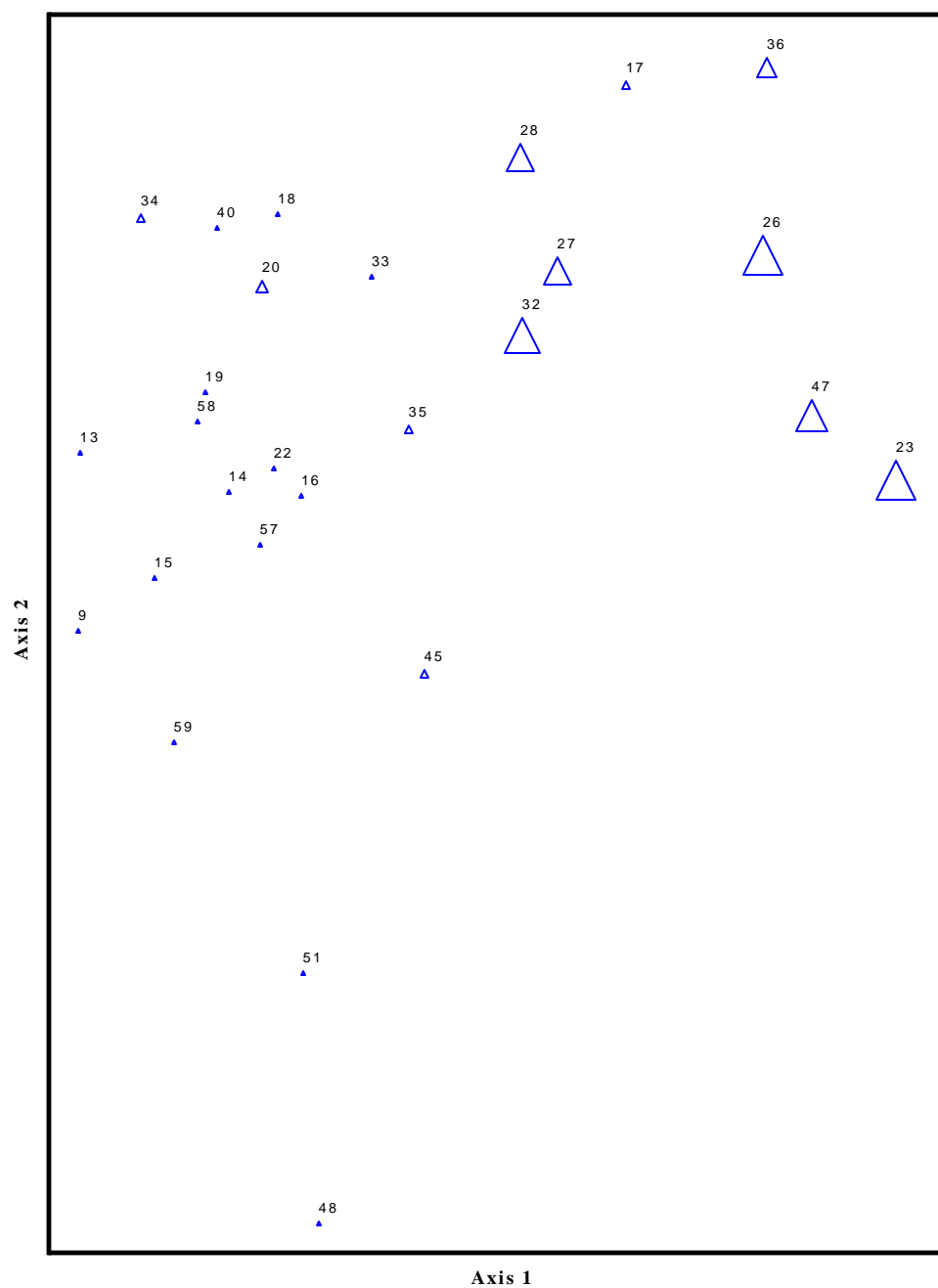


Figure 6.22. *Ruellia prostrata* on Axes 1 vs. 2

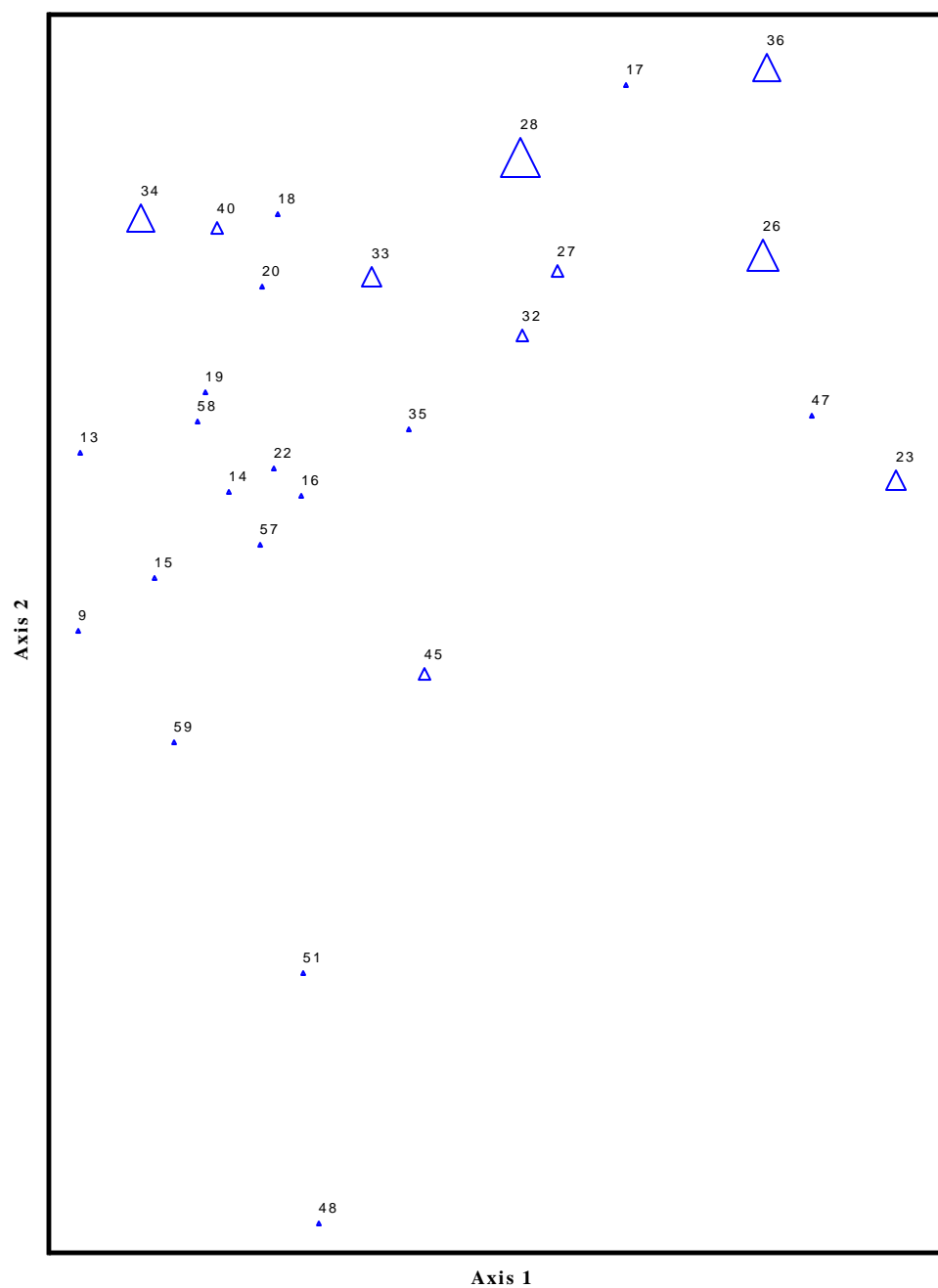


Figure 6.23. *Stachytarpheta urticifolia* on Axes 1 vs. 2

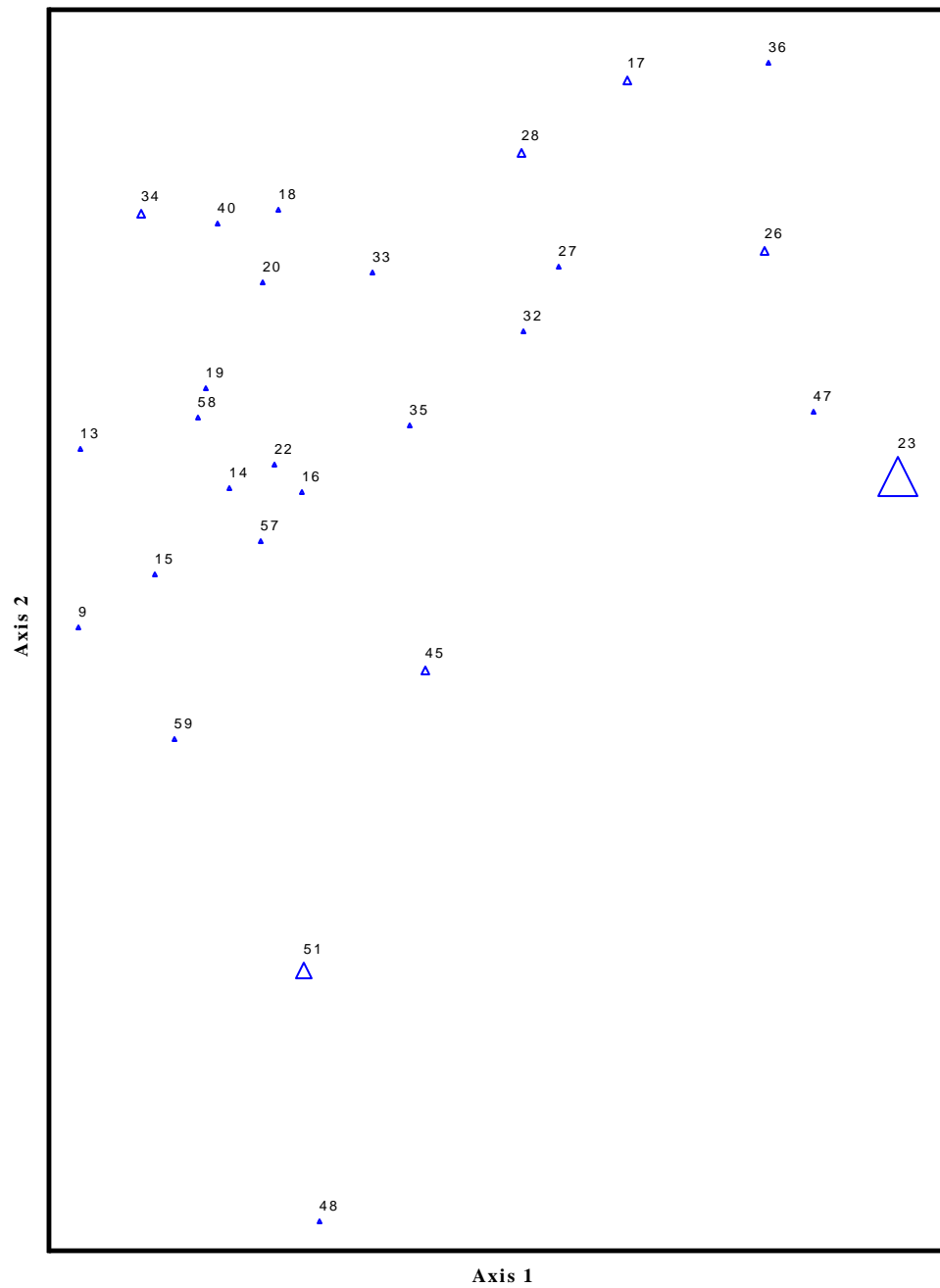


Figure 6.24. *Rhus taitensis* on Axes 1 vs. 2

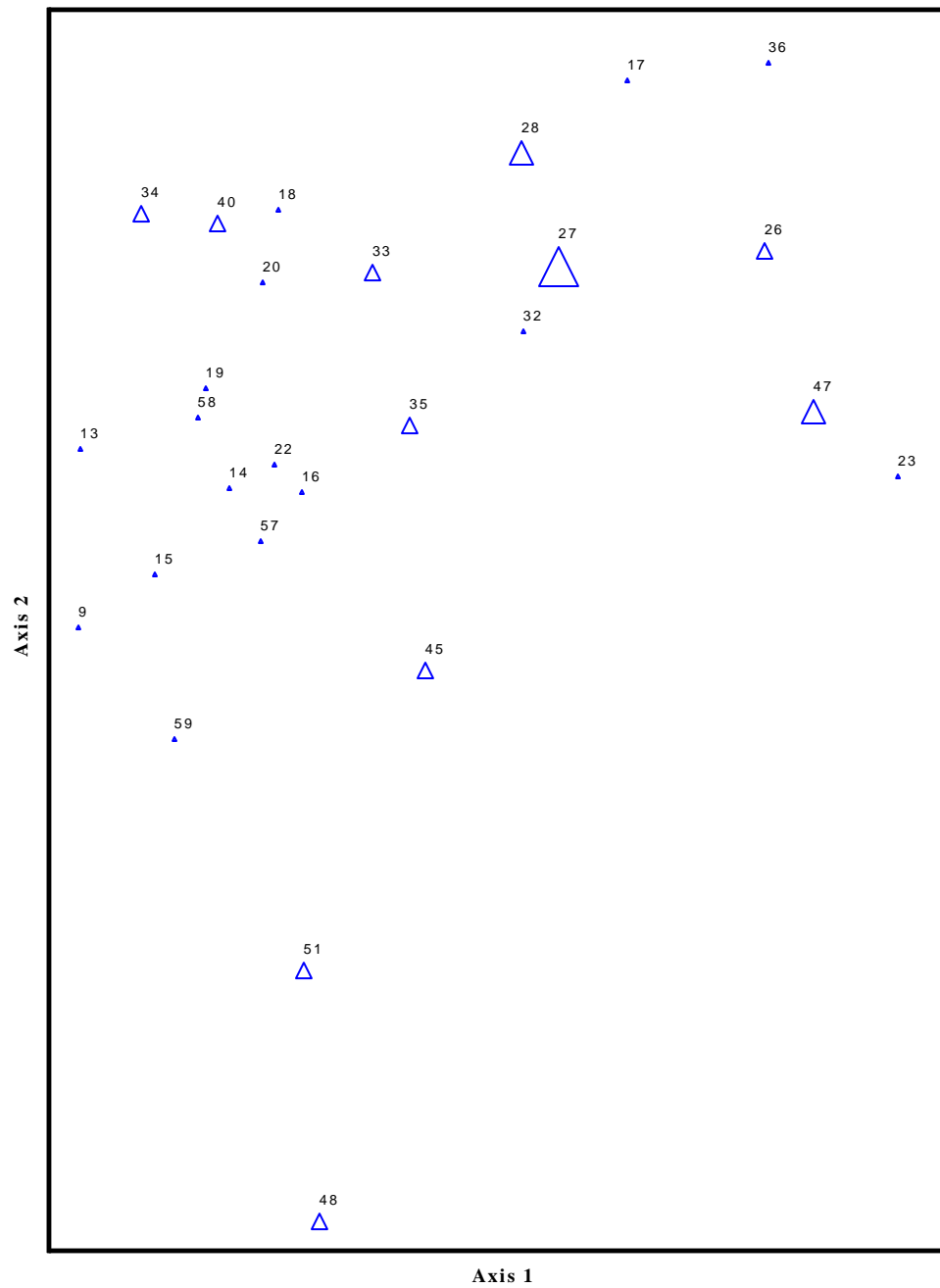


Figure 6.25. *Morinda citrifolia* on Axes 1 vs. 2

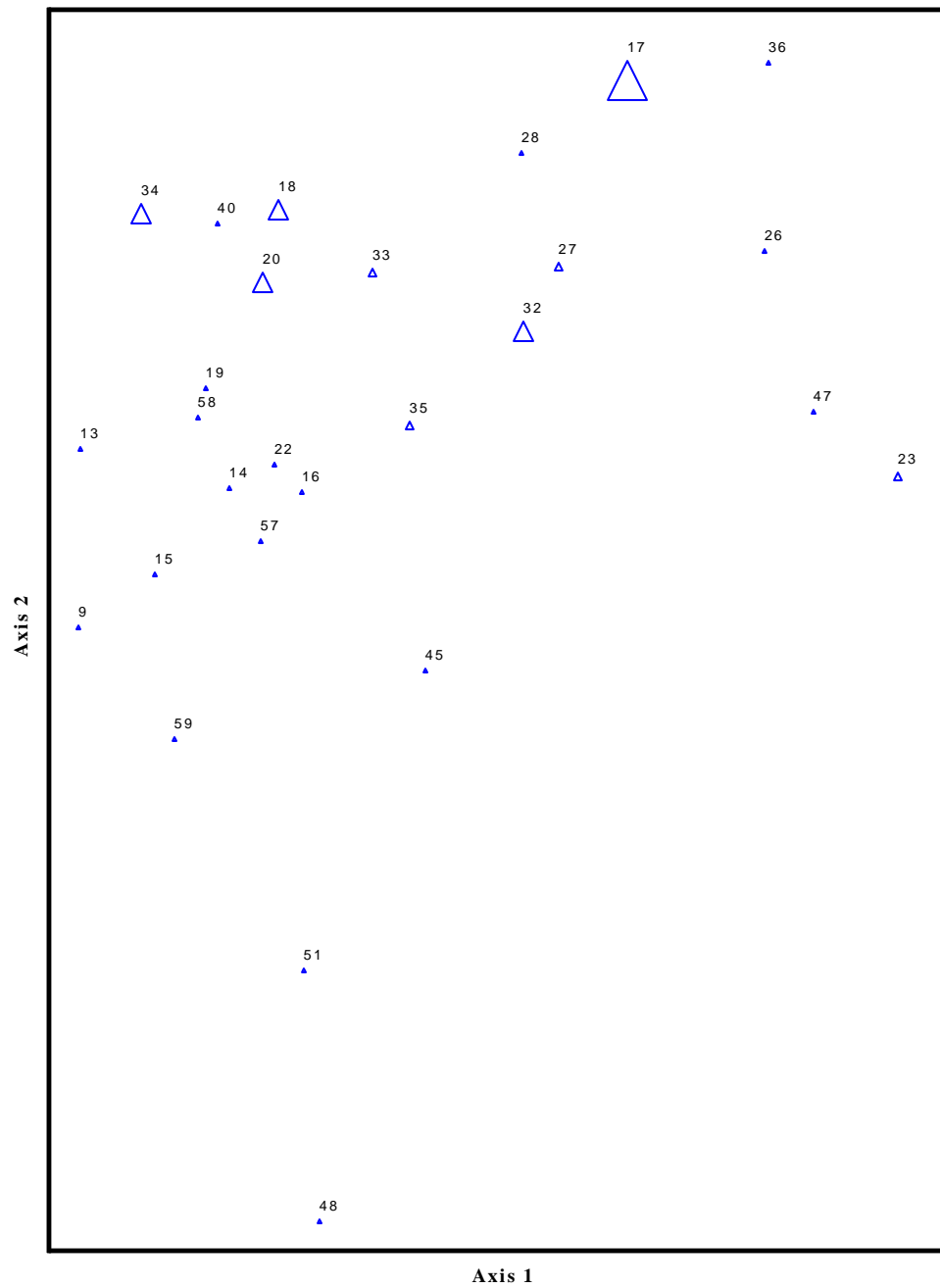


Figure 6.26. *Omalanthus nutans* on Axes 1 vs. 2

often occurring in coconut plantations (often new sprouts at low levels of cover in subgroups IIa, IIb1a, and IIb1c) where it is capable of competing with most ground cover. In many places, a forested plot appears on close inspection to be comprised of a mixture of coconuts and mature *R. taitensis*, with the latter often eclipsing the coconuts in height.

Within the Group I plots, there are several species that frequently co-exist with *Merremia peltata*, and that indeed appear to form a successional sequence. *Macaranga harveyana*, *Kleinhovia hospita* and *Pipturus argenteus* all frequently appear together with *Merremia peltata* and are capable of growing among the vine mat of heavy vine scrub ground cover (Figures 6.27 – 6.29). In the case of *M. harveyana* and *K. hospita*, both have leaves of similar size and shape to *Merremia peltata* (Figure 6.30), which may allow them to successfully compete photosynthetically with the vine. *Macaranga harveyana* and *Pipturus argenteus* were found growing branches throughout the vine mat, emerge above the mat, and expose their leaves to the sunlight (Figure 6.31 and 6.32). One *Kleinhovia hospita* was observed to have branches that snaked along the surface of the ground before driving vertically upwards in its characteristically straight fashion, where, overhead, it supported a thick mat of *Merremia peltata* (the mat was sufficiently thick that the bottom layer was decomposing). Apparently, the *K. hospita* had originally grown beneath the vine mat, as described for the other two tree species above, then, after emerging above the mat, grew sufficiently to lift the vines from the ground (Figure 6.33). These species, through their ability to compete with *Merremia peltata* ground

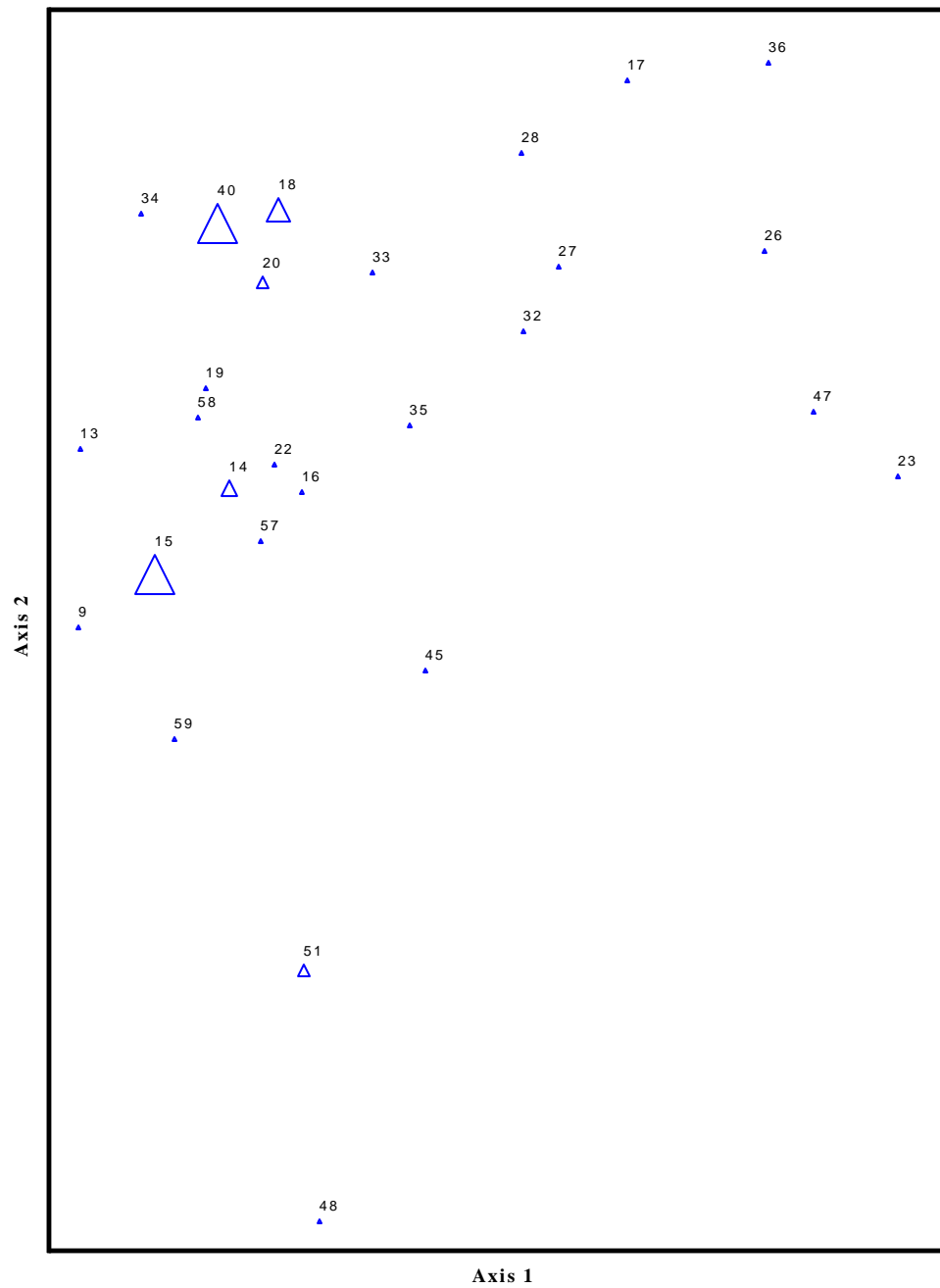


Figure 6.27. *Macaranga harveyana* on Axes 1 vs. 2

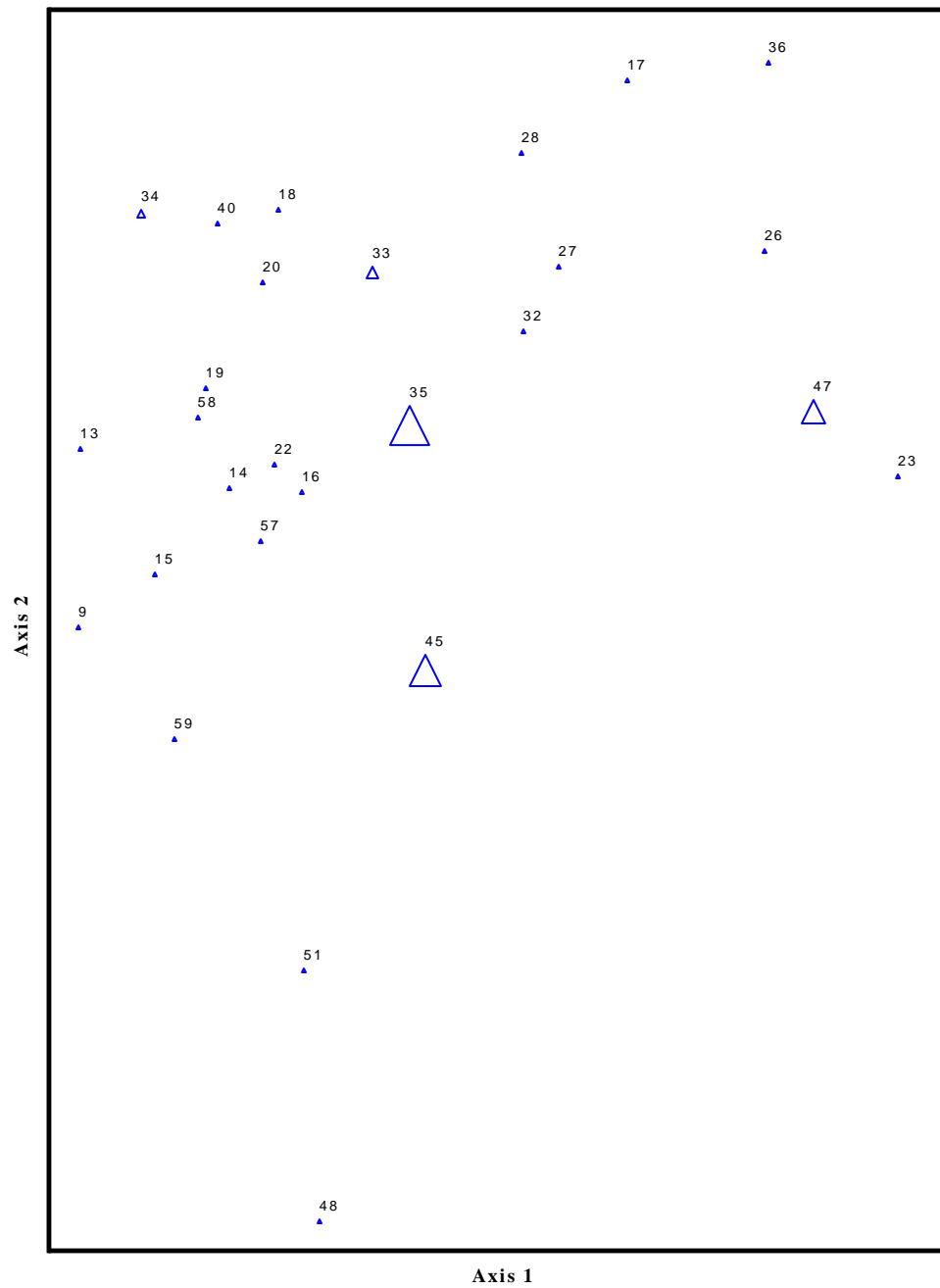


Figure 6.28. *Kleinhovia hospita* on Axes 1 vs. 2

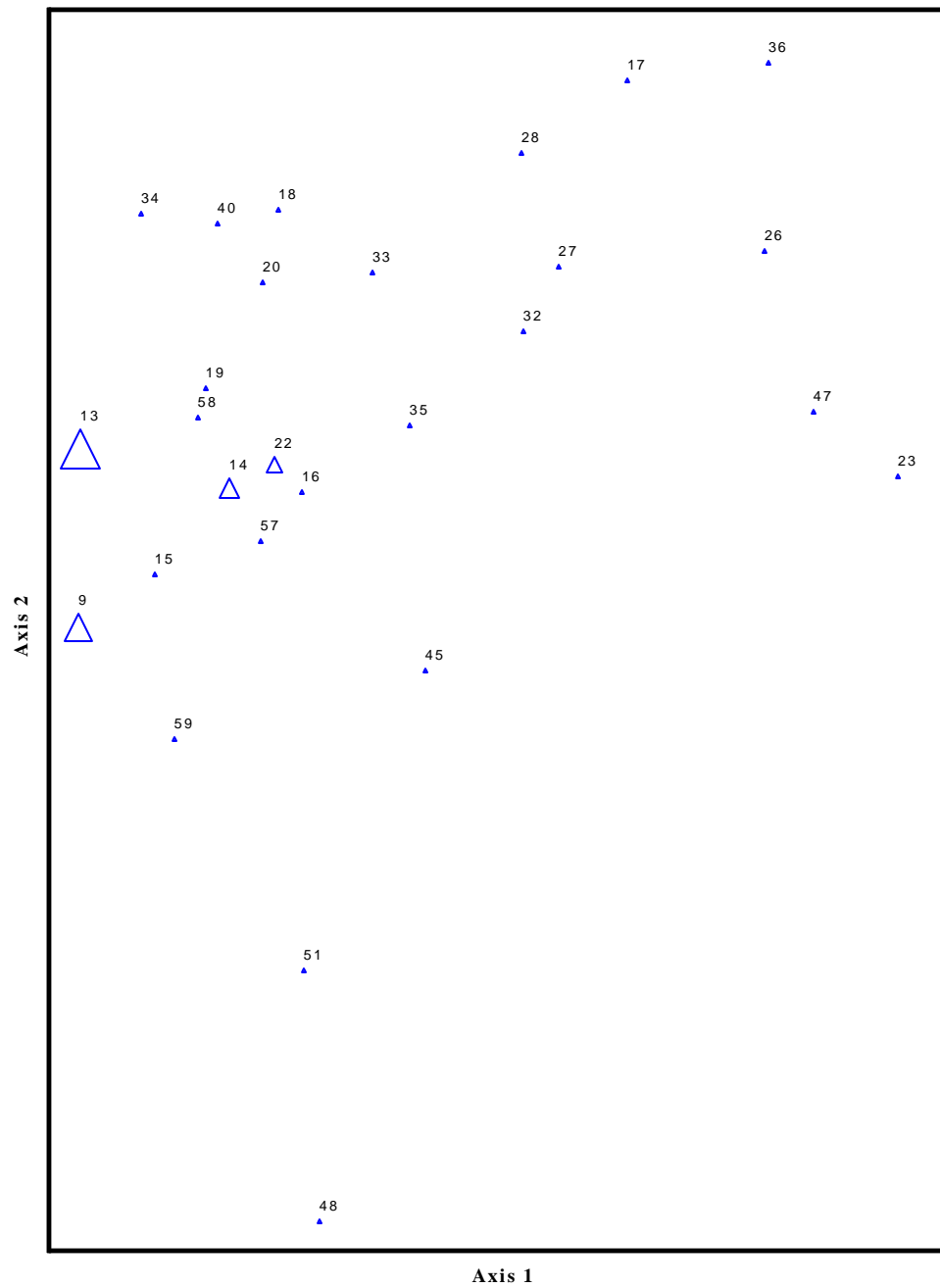


Figure 6.29. *Pipturus argenteus* on Axes 1 vs. 2



Figure 6.30. Comparison of leaf size and shape of various *Merremia peltata* competitors. Top row, right to left: *Macaranga harveyana*, *Kleinhovia hospita*, *Pipturus argenteus*. Bottom Row: *Merremia peltata*.

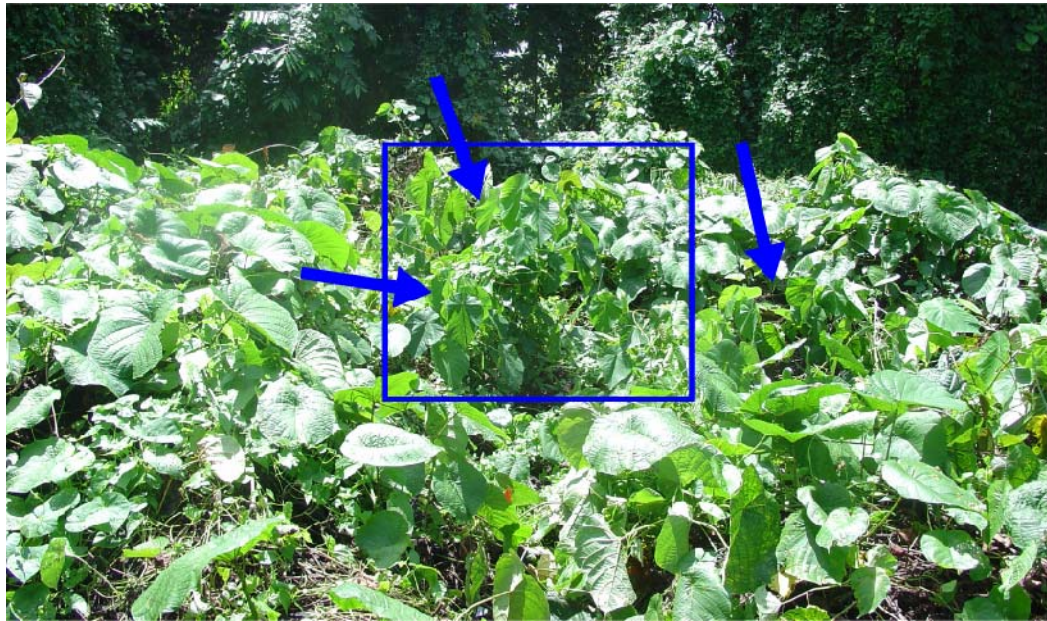


Figure 6.31. *Macaranga harveyana* growing in vine scrub (Plot 14). Arrows indicate this plant's location, and the lower photograph expands the boxed area. Note that the three areas all indicate parts of a single individual.



Figure 6.32. *Pipturus argenteus* growing in vine scrub (Plot 14). Arrows indicate its location in the landscape. The bottom photograph is an enlargement of the boxed area on the top photograph.

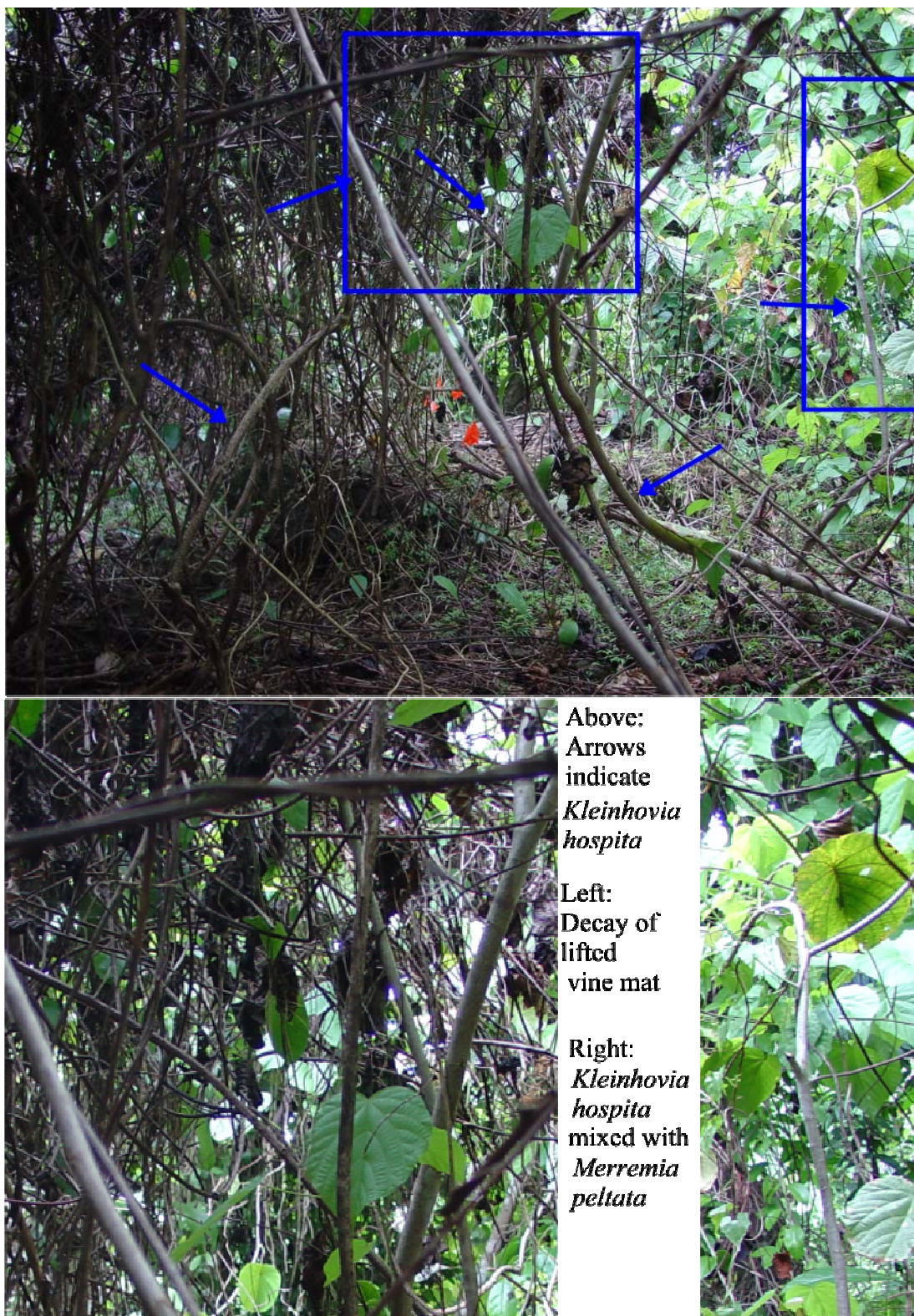


Figure 6.33. *Kleinhovia hospita* growing with *Merremia peltata* cover (Plot 45).

cover may represent one of the earliest successional stages of lowland forest regeneration. Indeed, *Merremia peltata* groundcover itself may be the earliest stage of forest regeneration.

Cananga odorata and *Pometia pinnata* are two other tree species that are somewhat competitive with *Merremia peltata*, although at more advanced stages of succession. Both of these species are found in lowland lavaflow forest (Subgroup Ib) and in varying amounts in secondary forest/growth (Subgroup IIB1), as well as in some of the vine scrub plots that include edges of the environments listed above (Plots 9 and 15), as detailed in Figures 6.34 and 6.35. *Cananga odorata* appears simultaneously vulnerable to and resilient against *Merremia peltata*, providing a lattice work for it to climb into and be especially smothered, yet nevertheless able to protrude a few branches from beneath the vines into the sunlight. Figure 6.36 illustrates just such an example, and in the upper left background of Figure 6.31, a few branches are evident emerging from the vine veil. *Pometia pinnata*, on the other hand, does not compete well against vine mat groundcover (no sprouts were observed growing in these environments), but seems to sprout under conditions of high shade (where competing groundcover is sparse). Where *Merremia peltata* cover is dense in the canopy of secondary forest species (such as *C. odorata*), this can create the necessary shade conditions for *Pometia pinnata* growth. Once firmly established, the smooth bark of *P. pinnata* appears to be resistant to climbing vines, with vine growth mounding at the base rather than clambering up the bark (Figure 6.37) although they are still vulnerable to the vine spreading from adjacent trees (Figure 6.38).

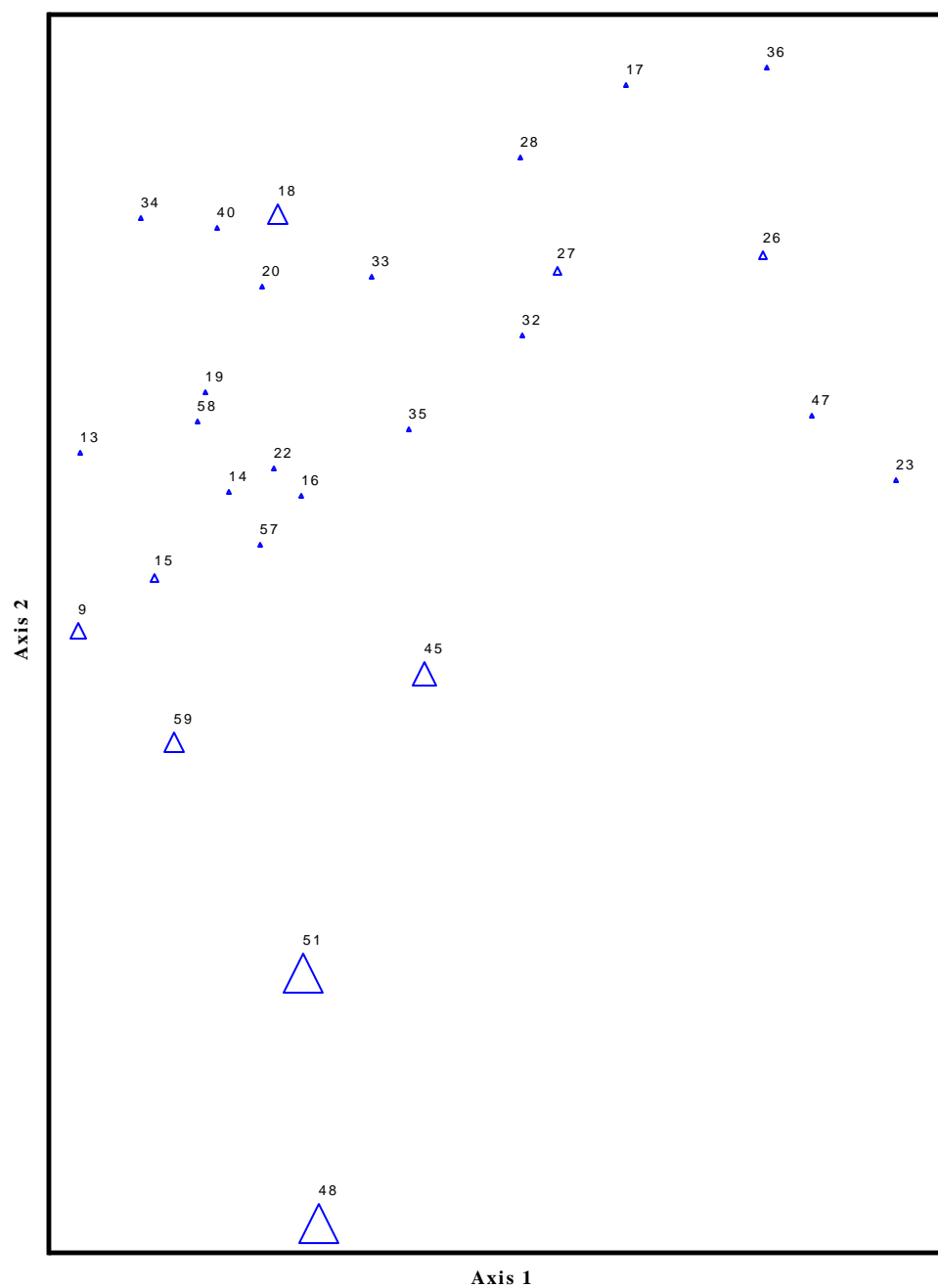


Figure 6.34. *Cananga odorata* on Axes 1 vs. 2

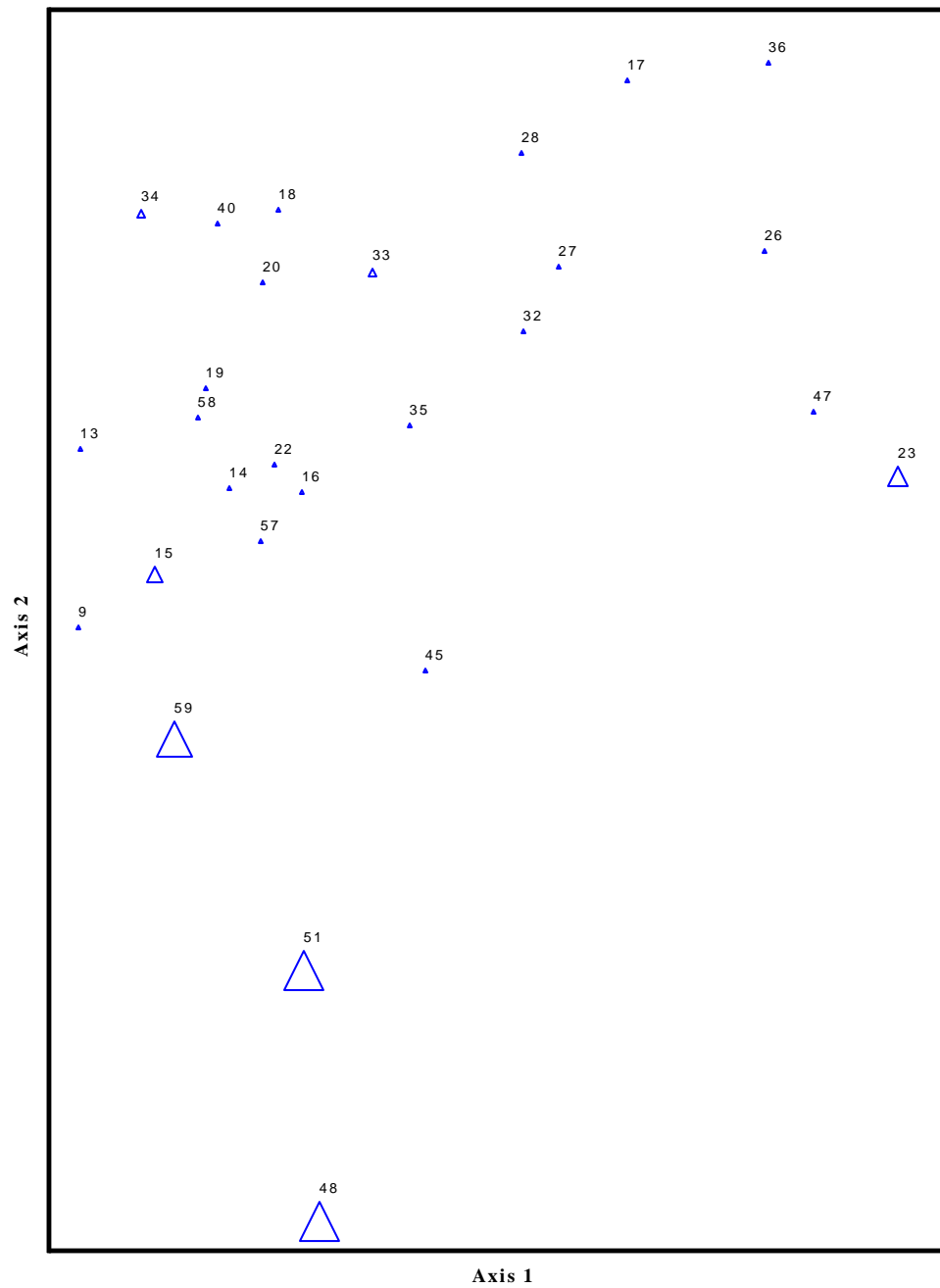


Figure 6.35. *Pometia pinnata* on Axes 1 vs. 2



Figure 6.36. *Cananga odorta* branches emerging beneath *Merremia peltata*. South of Plot 13.



Figure 6.37. Comparison of *Merremia peltata* growth on *Pometia pinnata* and coconuts. The top photo shows three *P. pinnata* trees in a dense vine scrub with little vine growth up their trunks, whereas the bottom two photos show coconut trees in similar environs being smothered.



Figure 6.38. *Merremia peltata* vines spreading on *Pometia pinnata* crown. Southwest of Plot 13.

Furthermore, *P. pinnata* seems to be somewhat resilient to wind damage; typically on the survey landscape, any tree towering over the secondary growth (often smothered in vines), survivors of the hurricanes of the early 1990s, were *P. pinnata* (Figure 6.39). This tree species thus appears to be adapted to both hurricanes and vines. Lowland forests, dominated by *P. pinnata*, appear to be the product of selection by both of these natural forces.

The vegetation survey analyzed here is a synchronic study, presenting the landscape and its vegetation communities at a single point in time. Suggestions of successional patterns are therefore largely inferential. A glimpse into the population ecology of many of the species discussed above is possible through an analysis of stem diameter measurements (diameter at breast height or dbh). Figures 6.40-6.47 exhibit the stem diameters of woody species in each plot, aggregated by the five vegetation categories described above. The early successional species described above (*Macaranga harveyana*, *Kleinhovia hospita*, *Cananga odorata*, and *Pometia pinnata*) are often found in the largest stem classes in the lowland lavaflow forest (Ib) and some of the vine scrub edge plots (Ia) as well as in some of the secondary forest/growth plots (Iib1). By contrast, much of the Group II plots have the earliest successional stages represented by coconuts (planted), *Rhus taitensis*, *Omalanthus nutans*, *Psidium guajava*, *Morinda citrifolia*, and *Flacourtia rukam*. Interestingly, the early species of Group I plots occasionally appear in later stages of Group II. The Iib1a and Iib1c subgroups show a strong mixture of species from both Groups I and II. Where they differ significantly is in the smallest stem diameter classes. The forest



Figure 6.39. *Pometia pinnata* towering above vine scrub.

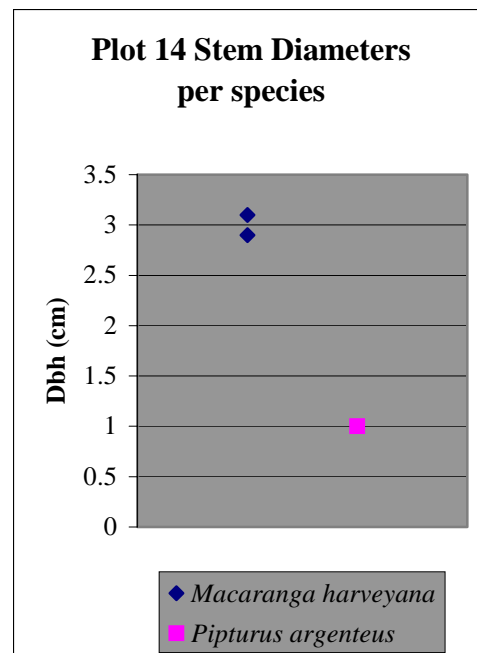
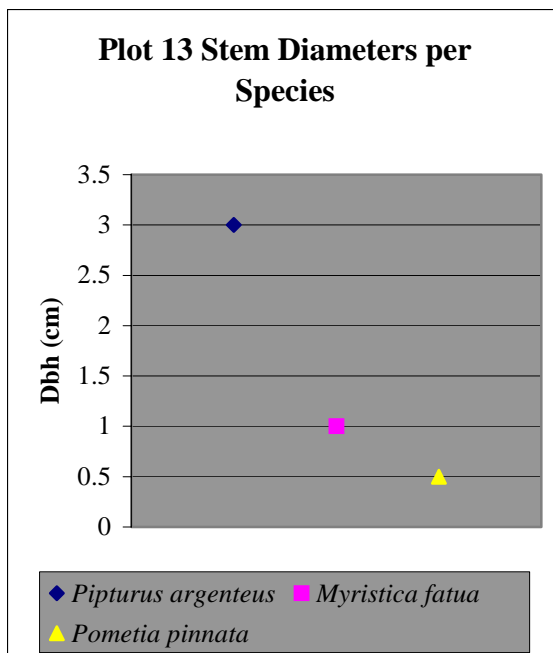
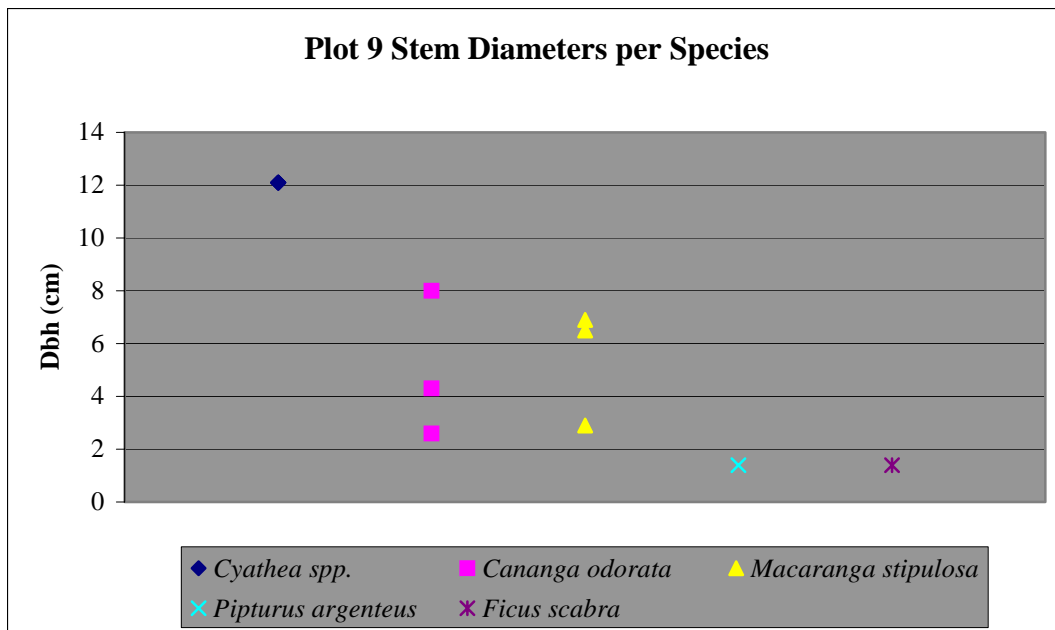


Figure 6.40. Population dynamics of woody species in vine scrub (Ia1). Note: Plots 16, 22 and 57 did not have woody vegetation

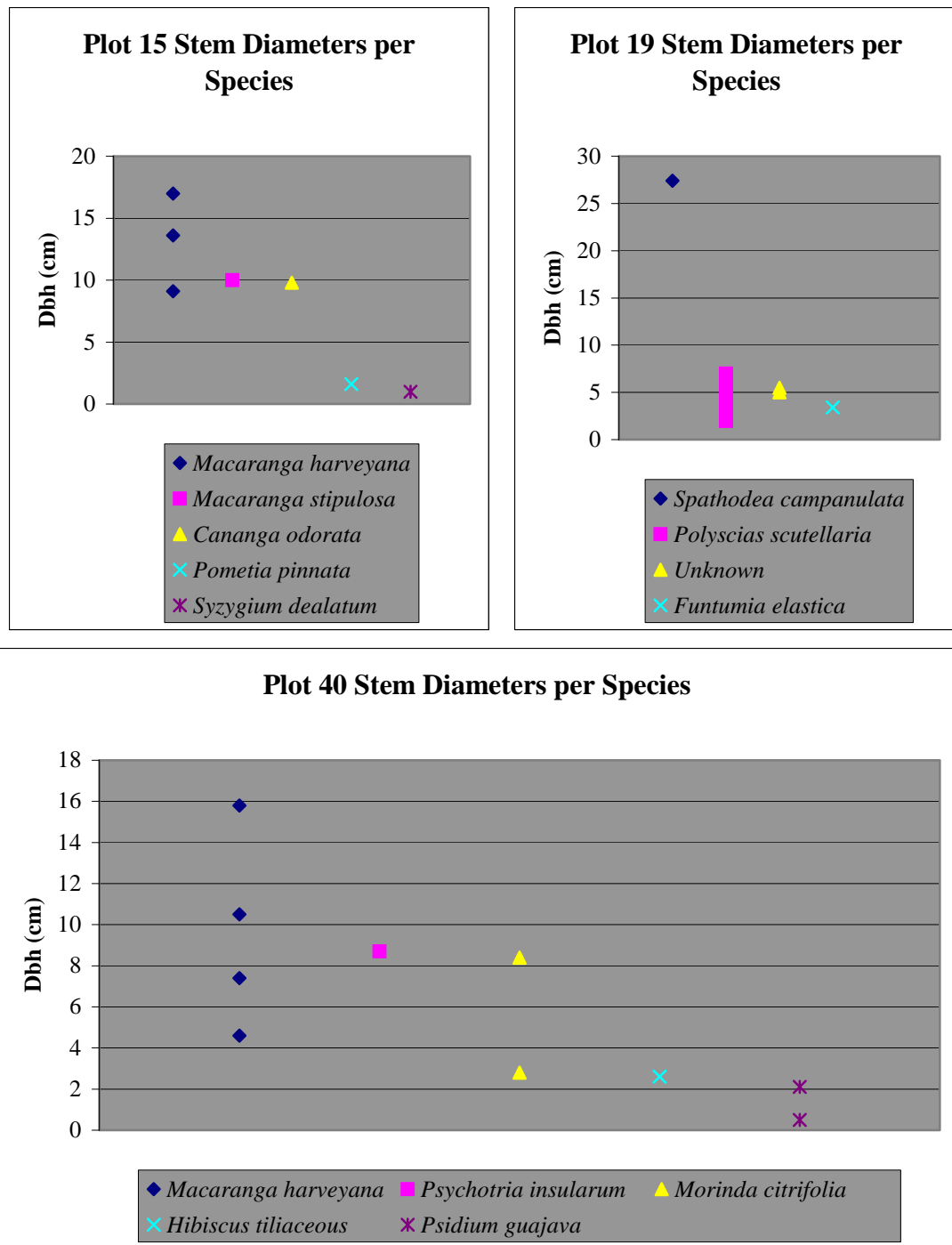


Figure 6.40. Population dynamics of woody species in vine scrub (Ia2). Note: Plot 58 did not have woody vegetation

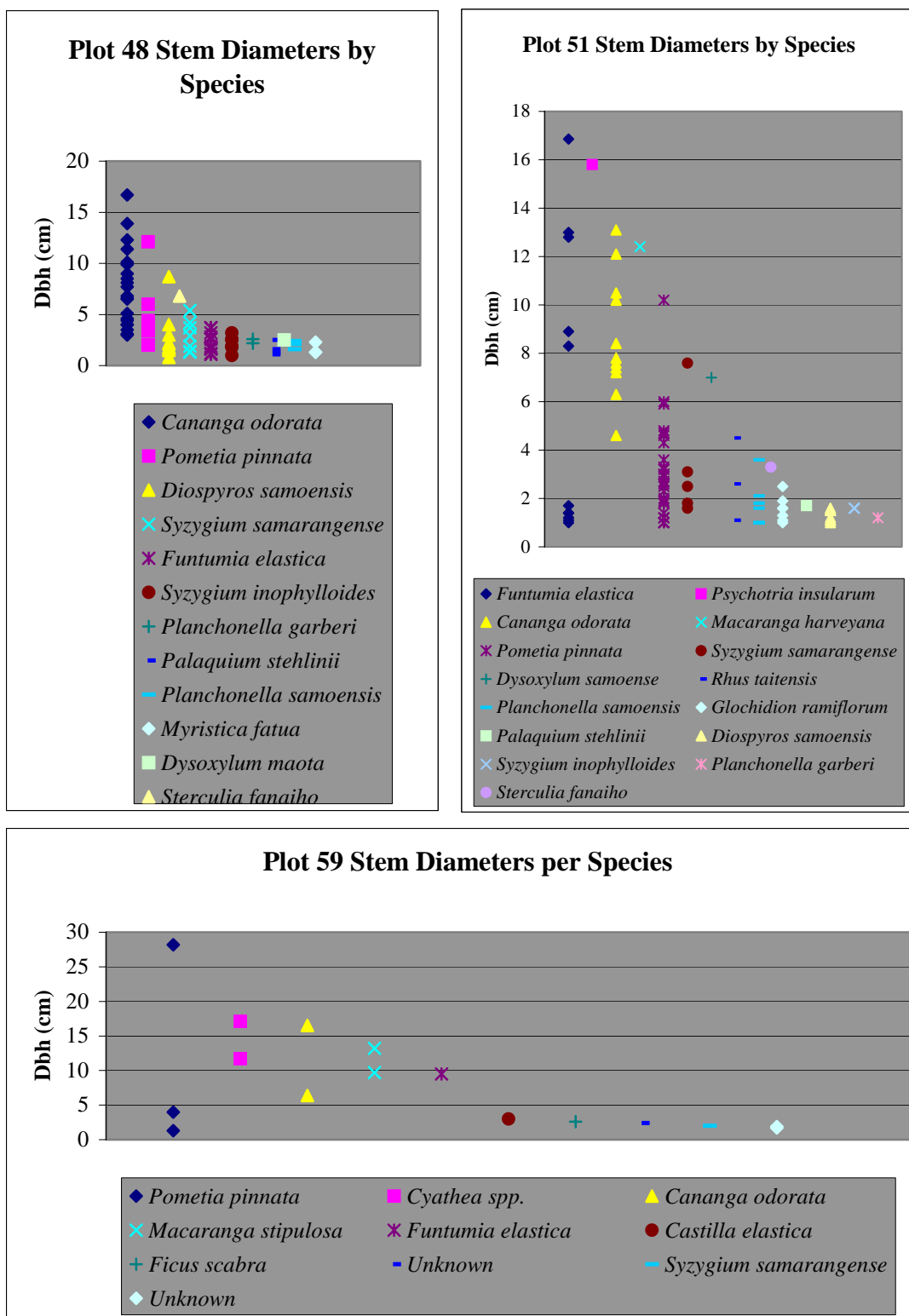


Figure 6.42 Population dynamics of woody species in lowland lavaflow forest (Ib)

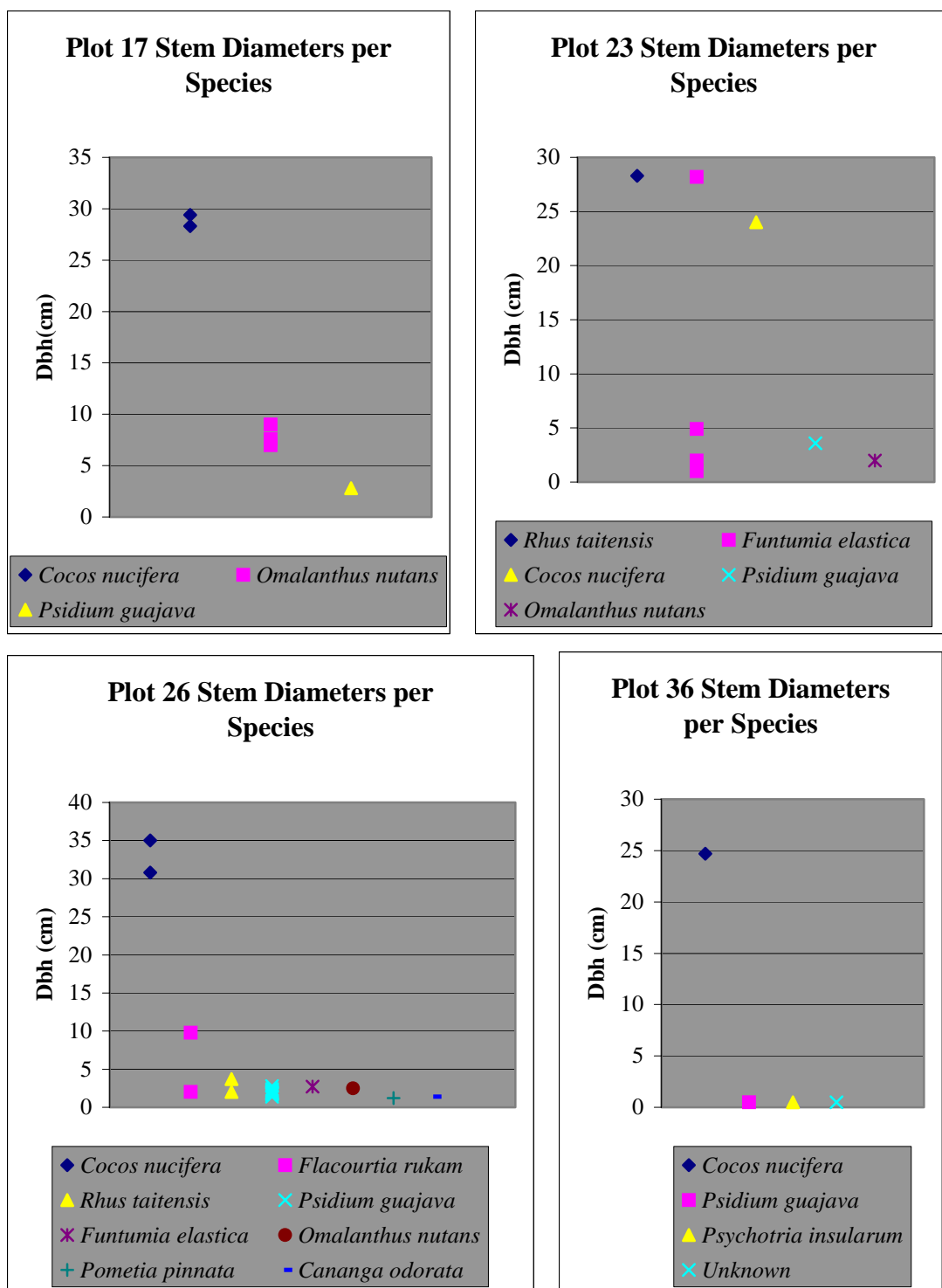


Figure 6.43 Population dynamics of woody species in coconut scrub (IIa)

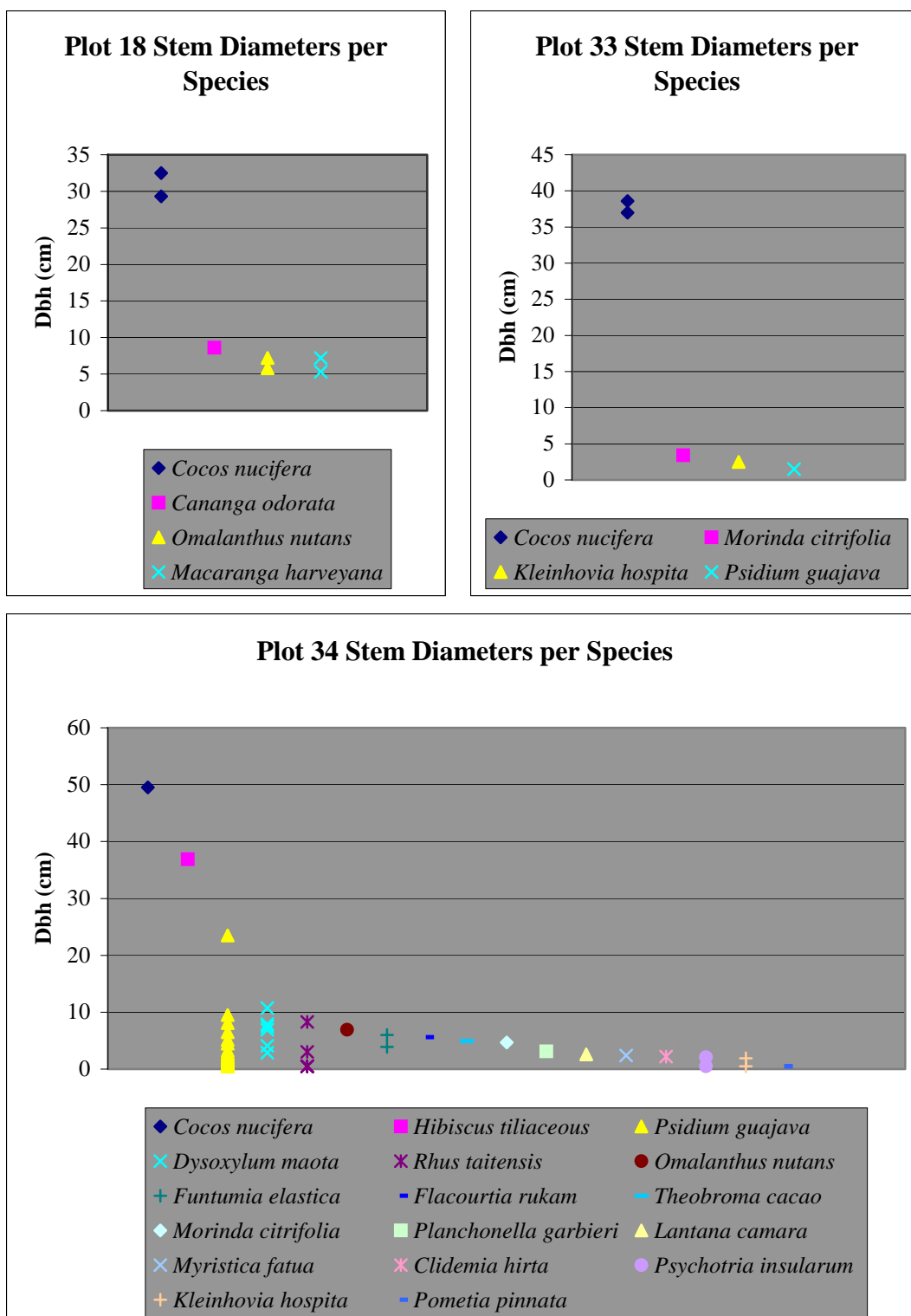


Figure 6.44 Population dynamics for woody species in secondary forest/growth (IIB1a)

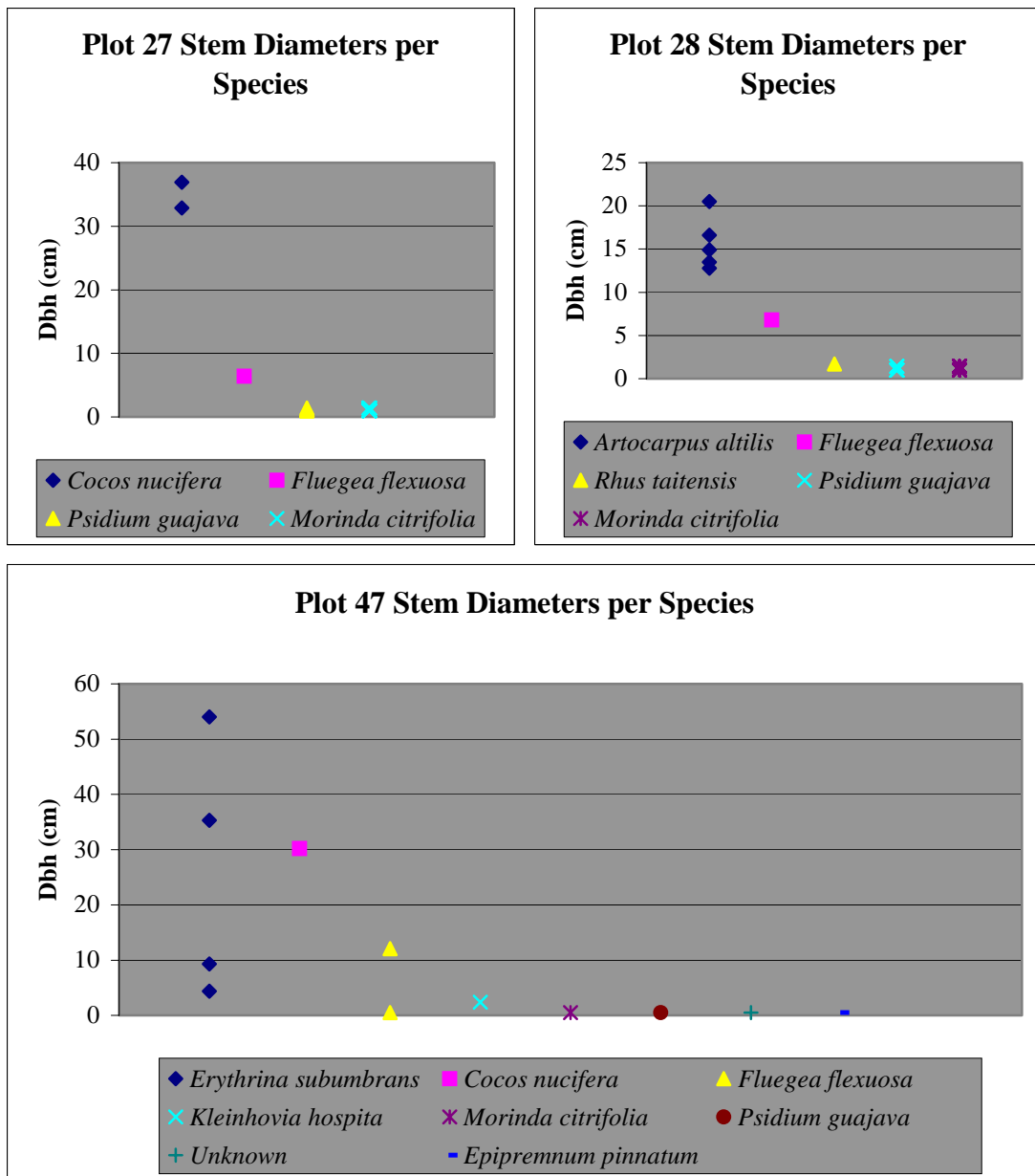


Figure 6.45 Population dynamics for woody species in secondary forest/growth (IIb1b)

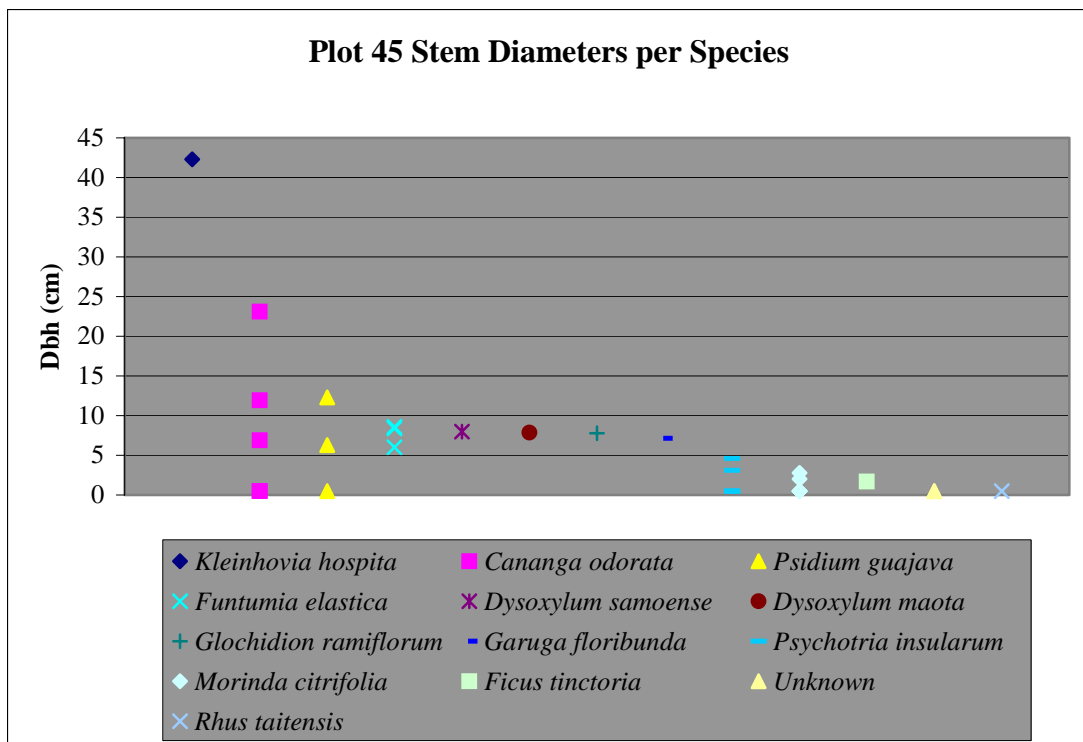
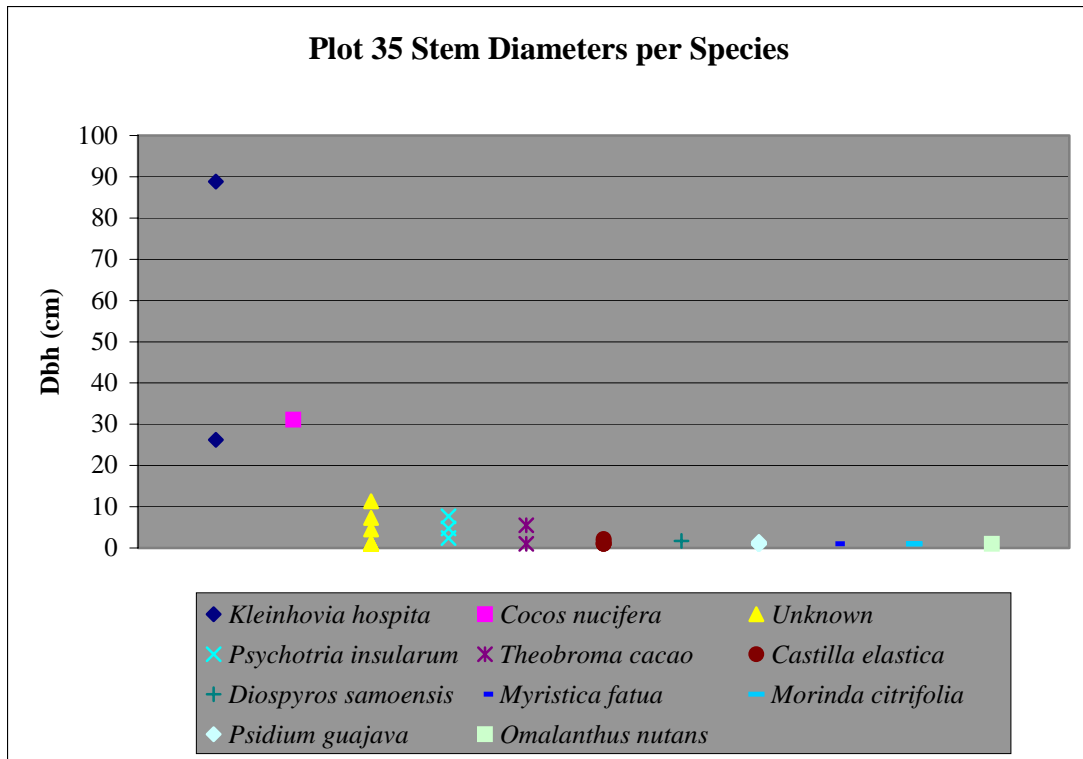


Figure 6.46 Population dynamics for woody species in secondary forest/growth (IIB1c)

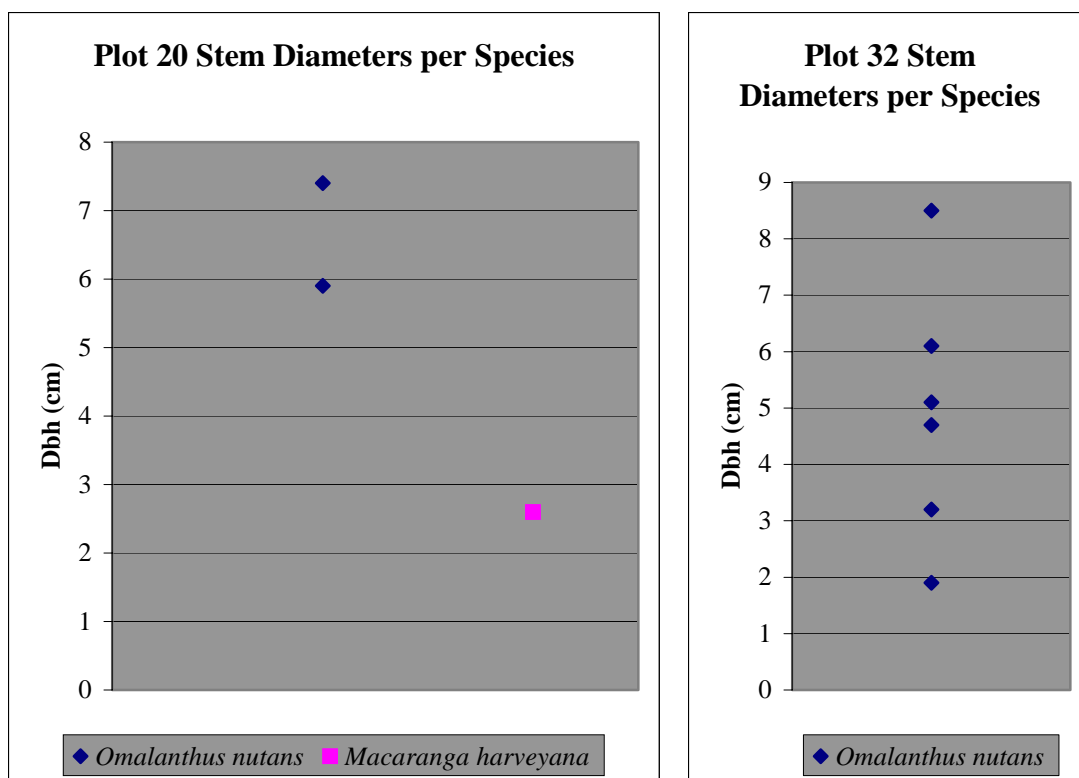


Figure 6.47 Population dynamics for woody species in secondary scrub (Iib2)

plots (Ib) have the most diverse and abundant array of native tree species of any of the plots in the survey.

The Group I and the Group II early pioneer trees do not appear to be mutually exclusive of each other, and often appear in the same plots. It appears that *Merremia peltata* has a tendency to select for those in Group I, while the effects of coconuts on the soil may have some influence on selecting for *Rhus taitensis*, *Omalthus nutans* and *Psidium guajava*. *Merremia peltata* may have the effect of competitively displacing these Group II species as well. *R. taitensis* often appears in Group I plots, but it is often in the later stages of succession (e.g. Plot 51, Figure 6.42). Similarly, *Pometia pinnata* appears in some Group II plots but in later stages of succession (e.g. Plot 26, Figure 6.43). All of these early pioneers are widely dispersing species, and their ability to appear in a variety of plots across the landscape reflects this ability. Sorting into two separate groups is largely a function of the vegetation at that location first, and proximity to individuals of the other species.

Yet Axis 2 indicates a marked contrast between the lowland lavaflow forest and the coconut-based secondary vegetation classes in terms of the native character of the vegetation, with the vast abundance of native species being concentrated in the former category. The distinctive native character of the lowland forest plots is derived from the wide abundance of species comprising the later successional, smaller stem classes. These species are largely absent from the Group II plots. This is not necessarily a direct consequence of coconuts, either by direct competition or indirectly through soil effects. After all, a wide variety of species arise alongside

coconuts that are characteristic of both Groups I and II. Nevertheless, stand composition among coconuts can range from a very diverse mixture of Group II-led succession followed by Group I, including some of the less common late successional species (e.g., Plot 34, Figure 6.44) to very mature stands that contain only early Group II species (e.g., Plot 23, Figure 6.43). Although the species composition of the early successional stages is a product of initial conditions (vegetation, soils and disturbance) and the surrounding landscape (dispersal), the vegetation in later stages of succession may be more dependent on the presence of seeds in the soil seed bank.

Disturbance, then, may play a greater role in shaping the outcomes of community composition than the plants themselves. At some hypothetical point in time, all of the land of the survey landscape was under lowland rainforest cover, and all of it has been subjected to some kind of disturbance, whether cyclones, logging, shifting cultivation, grazing or conversion into coconut plantations. The greatest loss of native species has come on lands occupied by coconuts, but the above discussion indicates that a variety of successional outcomes, including those with native forest species are possible under coconuts (as well as *Merremia peltata*). The depletion of late successional native species is most likely due to the repeated and prolonged disturbance of these coconut plantations which had the dual effect of depleting the species abundance of the soil seed banks and also by preventing the seed banks from being replenished, since the late successional species are apparently not wide-dispersers (otherwise they would be more representative of the early successional vegetation) and would need mature individuals of their species in close proximity to

produce more seed. Over time, then, these areas under coconuts would become more susceptible to, and the communities more represented by, plant species with widely dispersing habits.

This latter trend would then seem to be the main mechanism by which these island environments become more susceptible to invasive plant species. The mortality of the native species is disturbance driven, whereby frequency of disturbance occurs on a smaller time scale than the period of time required for a particular species to reach reproductive maturity, and not necessarily through direct competition with exotics. Non-native plant invasion can thus be seen as a process that is concomitant with recovery from disturbance, whereby each disturbance alters the species composition of the community and thus alters the successional pathways. Factors that become relevant for modeling and predicting invasions would thus focus on the reproductive habits of specific species, as well as the frequency at which disturbances occur. The invasives, being wide-dispersers, would then be expected to be present across a wide range of disturbance-and-recovery gradients. Some contemporary woody non-native invasives that are present in both early and late successional environments, displaying this tendency, include *Funtumia elastica*, *Lantana camara*, *Clidemia hirta*, *Castilla elastica*.

For the landscape surveyed in this study, the most non-native character of the vegetation is associated with coconuts. A littoral species, coconuts have been widely dispersed into the lowland regions by human agency. The changes to the native character of the vegetation are most likely not due to the direct action of the coconuts

themselves, but due to the frequent and sustained use of these plots by people. The social forces necessitating this use relate to the time period when export agriculture was the predominant income generating activity for the country, ranging in time from the early 1900s until the taro blight of 1993. The emphasis on coconuts, and the massive inland expansion of coconut plantations was most intense during the colonial period (1900-1962). Indeed, the vast majority of the non-native species that are currently identified as invasive and that on this survey show signs of becoming established in more native-community areas date to the colonial period, and have been in the country for roughly a century, at least (Table 6.3). For *Merremia peltata*, this species seems more associated with the native vegetation, and its dominance on the landscape is most likely the result of the relaxation of agricultural pressure on the landscape following the collapse of taro exports due to the taro blight, and simply represents the earliest stages of succession for the “Group I” type of communities. Whether this pattern of succession occurs or not is also relative to the dispersal rates of the other species of this complex, and its long term sustainability may be threatened by increasing cyclone frequency, whereby late successional species numbers are worn down before individuals can reach reproductive maturity and community composition becomes increasingly biased toward rapid and wide-ranging dispersers, including non-natives.

Table 6.3. Contemporary non-native invasives with dates of introduction

| Species | Date | Group I Cover | Group II Cover |
|-------------------------------------|---------------------|---------------|----------------|
| <i>Mikania micrantha</i> | 1906 | 25 | 18 |
| <i>Eriochloa procera</i> | 1944 | 1 | 10 |
| <i>Blechum pyramidatum</i> | 1929 | 1 | 8 |
| <i>Hyptis rhomboidea</i> | 1970 (1979) | 2 | 7 |
| <i>Ruellia prostrata</i> | 1944 | 0 | 8 |
| <i>Paspalum conjugatum</i> | 1840 | 2 | 4 |
| <i>Funtumia elastica</i> | (Early 1900s) | 2 | 3 |
| <i>Erythrina subumbrans</i> | Modern (post WWII) | 0 | 3 |
| <i>Flueggea flexuosa</i> | (Late 1800s) | 0 | 2 |
| <i>Psidium guajava</i> | Early 1800s | 0 | 2 |
| <i>Stachytarpheta urticifolia</i> | 1893 | 0 | 2 |
| <i>Synedrella nodiflora</i> | 1905 | 0 | 2 |
| <i>Brachiaria mutica</i> | 1877 | 0 | 1 |
| <i>Lantana camara</i> | 1858 | 0 | 1 |
| <i>Mimosa pudica</i> | 1839 | 0 | 1 |
| <i>Desmodium heterophyllum</i> | 1864 | 0 | 1 |
| <i>Castilla elastica</i> | Modern Introduction | 1 | 0 |
| <i>Passiflora foetida</i> | 1916 | 0 | 0 |
| <i>Pseudelephantopus spicatus</i> | 1945 | 0 | 0 |
| <i>Clidemia hirta</i> | 1905 | 0 | 0 |
| <i>Desmodium triflorum</i> | 1864 | 0 | 0 |
| <i>Kyllinga polyphylla</i> | 1942 | 0 | 0 |
| <i>Senna tora</i> | 1839 | 0 | 0 |
| <i>Hyptis pectinata</i> | 1819 | 0 | 0 |
| <i>Phyllanthus amarus</i> | 1847 | 0 | 0 |
| <i>Digitaria radicata</i> | 1909 | 0 | 0 |
| <i>Polygala paniculata</i> | 1905 | 0 | 0 |
| <i>Ageratum conyzoides</i> | 1871 | 0 | 0 |
| <i>Crassocephalum crepidioides</i> | 1929 | 0 | 0 |
| <i>Paspalum paniculatum</i> | 1920 | 0 | 0 |
| <i>Solenostemon scutellarioides</i> | Modern Introduction | 0 | 0 |
| <i>Spermacoce assurgens</i> | 1929 | 0 | 0 |

Source: Whistler 1995.

Summary

In general, *Merremia peltata* is a dominant species on the landscape in question and exerts considerable influence on the community structure. Although cited as an invasive species of environmental concern, *M. peltata* is most strongly associated with native lowland forest. Although the entire landscape has been disturbed, areas of *M. peltata* dominance are more commonly associated with areas of infrequent disturbance, represented either by lowland rainforest having at least ten years of recovery from cyclones, or the areas of vine scrub that are more recent disturbances due to either shifting cultivation or logging. In contrast, areas dominated primarily by coconuts are areas of frequent disturbance and show a greater tendency toward the inclusion of non-native plant species in their communities. *M. peltata* also exhibits the ability to displace other non-native species with some notable exceptions listed above.

Insights into successional pathways are less conclusive and largely inferential. It appears likely that *M. peltata* influences the pathways that succession can take. Although the vast majority of wide-dispersing early pioneer species occur together in many plots, *M. peltata* dominated areas appear to be led by *Macaranga harveyana*, *Cananga odorata*, and *Kleinhovia hospita*, with *Pometia pinnata*, the dominant species in lavaflow forests, following closely, and a wide variety of later successional species following these. Areas dominated by coconuts are often led by *Rhus taitensis*, although the other species common in *Merremia peltata* dominated areas may be present in later stages as well. Whether this is an indication that *Merremia*

peltata helps to select and ultimately speed succession toward a *Pometia pinnata* dominated forest, or whether the vine only influences the composition of early successional stages while disturbance influences later succession through its role in altering the composition of the soil seed bank, is uncertain. Successional questions can ultimately only be answered through long-term experimental studies. Additionally, the question of whether *Merremia peltata* groundcover acts to deplete the soil seed bank of late successional species cannot be answered from this study. It is not clear whether these seeds sprout immediately after disturbance, in which case vine cover would act to deplete the seed bank, or if these seeds only sprout after certain microclimatic conditions are met, which seems to be the case with the lowland lavaflow forest in this survey, in which case *M. peltata* may actually speed the regeneration process by closing gaps in the canopy and quickly establishing the necessary conditions. Once again, long-term experimental studies are necessary to answer this question.

By examining the landscape as a whole, crossing a gradient of mixed anthropogenic and natural disturbance, this methodological approach has helped elucidate the important role that both disturbance and recovery play in the invasion process. Neither strictly a matter of plant ability, environmental niches, or disturbance alone, all processes appear to be in play simultaneously. Furthermore, the disturbance factors appear to be in direct play in terms of affecting plant mortality and creating opportunities for non-native establishment. Furthermore, the expansion of coconut plantations appears to be the most dramatic and prolonged disturbance on

this landscape, and thus is highly social in nature, and crosses several social and spatial scales.

Chapter 7

The Social Life of Weeds

Overview

Merremia peltata is gaining some recognition as an invasive species of environmental concern. The field of “invasion biology” is grounded in an environmental narrative extolling the importance of protecting native species, however, in which scientific ecology is intermingled with nationalist sentiment (Dunland 1999), and whereby the science itself is subject to the cultural values held by the scientists (Barbour 1996). Being just one form of environmental narrative, it can be expected that implementation of this discourse into policy could create conflict with those who have an opposing view of nature (Proctor 1996). Indeed, even under a single dominant environmental discourse, a plurality of value-laden natures proliferates (Latour 1993, Cronon 1996). Others caution against the excesses of postmodern deconstructionism (Soulé and Lease 1995), warning that a real nature exists independent of discourse (Shepard 1995) and that although different natural world-views should be viewed equally, these worldviews nevertheless do not value nature equally (Kellert 1995). A plurality of *Merremia peltatas* is thus to be expected, each view imbued with value-laden ideas. Furthermore, the contestation of these ideas will occur at (indeed, construct) a particular social scale (Swyngedouw 1997).

The title of this chapter is derived from Appadurai's (1986) edited volume, *The social life of things: commodities in cultural perspective*. He argues that objects can be said to have a "social life" because their value arises through the ways that people control the social networks that access these objects; that is, through politics. Value, then, can be seen as a product of social linkages, not simply set by those who have, but also validated by those who have not, through participation in the social networks in which the objects are exchanged. Appadurai presents his theory of commoditization from the perspective of socially constructed demand, as opposed to the Marxian perspective of production, and hence indicated that his theory is not predicated on the material context in which the objects arise, but rather leaves this topic open as an opportunity for ecologists to explore. Similarly, complexity theory in the social sciences emphasizes these social linkages. Norms, and, by extension, culture and cultural change, evolve through interaction (broadly cast as either cooperative or competitive) between people (Axelrod 1997). People's values, and the way they value things, such as nature or a particular species, are colored by the way that individuals or groups interact, and this can cross several social (and spatial) scales.

This chapter, then, explores the perspectives of the various social actors that are stakeholders in the *Merremia peltata* invasion. Broad categorizations of groups include village level actors, local/government/urban sector professionals (employees of government departments, NGOs or local organizations based out of the capital, Apia), and regional level experts (whose organizations serve several countries in the

region). Each group espouses a variety of opinions in regard to *Merremia peltata*, and the ways they interact with the other groups reveal more about the social structure of Pacific Island societies in a global community than about *Merremia peltata*, per se. Indeed, it will be seen that lingering power structures from the colonial and development periods lend momentum to a national discourse, in which the interests of protecting the environments of the cosmopolitan countries of the region (Australia, New Zealand and the United States) at the expense of Pacific Island environments becomes possible, by silencing the views of local ecologists more directly familiar with the species and ignoring the perspectives of village level actors.

Village Level Surveys

The results from structured village level interviews are divulged both in terms of overall trends and also in specific reference to *Merremia peltata*. First, the general findings from the assessment of plant valuation are discussed, examining the various criteria used in their descriptions. Next, these criteria are discussed with specific reference to *M. peltata*. Finally, the results from the less formal section of the interview are discussed in light of what the responses reveal about the social “nature” of invasive species and *M. peltata* specifically.

Table 7.1 summarizes the criteria reported by interview participants. Every participant identified plants with medicinal properties as beneficial species. In part, this may be a result of the prominence of ethnobotany, ethnopharmacology, and general bioprospecting in Samoan society. Several researchers have published work

Table 7.1. Criteria cited for valuing plants

| Criteria | Total Responses | Criteria applied to <i>Merremia peltata</i> | Men | Women |
|----------------------------|----------------------------|--|------------|--------------|
| Medicinal use | 12 | 0 | 7 | 5 |
| Ease of control | 10 | 5 | 7 | 3 |
| Palatable to cattle | 9 | 1 | 6 | 3 |
| Competitiveness with crops | 8 | 1 | 5 | 3 |
| Useful/not useful | 8 | 3 | 4 | 4 |
| Edible | 8 | 0 | 5 | 3 |
| Shading/cooling the soil | 6 | 6 | 5 | 1 |
| Hazardous | 6 | 0 | 4 | 2 |
| Low vs. tall growth | 5 | 0 | 5 | 1 |
| Spreading growth (sosolo) | 4 | 0 | 2 | 2 |
| Impact on soil quality | 4 | 1 | 3 | 1 |
| Improving taro yield | 2 | 1 | 2 | 0 |
| Suppression of other weeds | 2 | 2 | 2 | 0 |
| Aesthetics | 2 | 0 | 0 | 2 |

on local medicinal plants and practices, including Macpherson and Macpherson (1990), Whistler (1996), and most prominently, Cox (1997, Cox and Banack 1991). With regard to the latter, Cox is well known to the village of Fa'ala, and is known exclusively by his *matai* title Nafanua, bestowed upon him by the village of Falealupo, and several people believed that I was conducting similar research due to my interest in plants. Indeed, the success of Cox in finding pharmacologically active plants (such as *Omalanthus nutans*) through working with *taulesea* (older women skilled in traditional medicine) is well known throughout Samoan society, and I was frequently offered advice by people as to which plants I “should take back and show them” once they found out my research interests. I was also admonished by officials in both the Environment and Forestry Departments against performing any clandestine biopiracy. Indeed, there is a widespread consciousness of the interest that the cosmopolitan pharmaceutical industry takes in indigenous knowledge, and this appears to have shaped people's perceptions of my work (one subject was very intent and insistent on my recording her *Mikania micrantha* remedy for toothache, for instance). Although this may account for the high number of responses where medicinal properties were cited as criteria for valuing plants, such knowledge is nevertheless widespread in Samoan society and its prevalence in the survey is likely to be accurate. The importance of indigenous knowledge to the cosmopolitan core may indeed be a factor in building up a sense of identity around this knowledge.

Since most of the plants in the survey were weeds, many of the criteria listed were of a more agricultural nature. The most frequently cited criteria here relates to

the difficulty in controlling the weed, whether it is easy to control or more difficult. Whether the plant is competitive with crops or whether it provided good cattle forage were both traits that were frequently identified as judgment criteria. Less frequently cited but fairly common criteria described specific traits of plants. The ability of plants to shade and cool the soil or crops was frequently identified as a positive trait, and applied almost exclusively to *Merremia peltata* and *Mikania micrantha* (but more commonly the former). The ability of a plant to spread along and cover the ground (*sosolo*) was used as a criterion, but it was identified as a negative trait as frequently as it was identified as a positive trait (indeed, one plant, *Desmodium heterophyllum*, was alternately identified as either a beneficial or detrimental species, but always because of its *sosolo* properties). A low growth habit was typically considered to be a better quality in a weed than one with a taller growth habit. Soil impact (whether the plant improved or degraded the soil), improving yield of taro, and suppressing other weeds (the latter said exclusively of *Merremia peltata*) were less frequently used as criteria.

Other miscellaneous criteria include a general assessment of usefulness of the plant, edibility, hazardousness of the plant, and aesthetic qualities. The term *aoga tele* (extremely useful) was often employed when a subject cataloged several benefits for a plant, and conversely the phrase *le aoga* (not useful) was used if there were no benefits from it, revealing a utilitarian disposition toward valuing plants. Edibility was used exclusively in descriptions of *Passiflora foetida*, where it was typically cited as being beneficial because children eat its fruit. Hazards typically referred to

the thorniness of *Mimosa pudica* and *Mimosa invisa*, and to the remnant stems of cut *Nephrolepis hirsutula*. Although the more herbaceous *M. pudica* is often regarded more as a nuisance, several people indicated that the shrubbier *M. invisa* posed more of a hazard since people could become rather painfully wounded if entangled in the plant. For *Nephrolepis hirsutula*, several subjects indicated that after a field of the ferns were cut, the cluster of dried stems that remained could skewer people's feet if one were not careful. Finally, two informants used aesthetic criteria in describing plants. One cited the ability to use the "seeds" from *Nephrolepis hirsutula* for decorations, and another cited some weeds as being undesirable because they were unattractive (in terms of maintaining the appearance of the household).

For *Merremia peltata*, although opinions on the plant varied, the majority of land managers viewed the species as beneficial. The term "land manager" is referring to those individuals responsible for maintaining their families' agricultural land. These people are typically male, but the term "land manager" is being used to emphasize that the valuation of *M. peltata* appears to be closely related to experience with agriculture, especially taro cultivation. Table 7.2 shows the opinions given on three of the four dominant species on the landscape, *Merremia peltata*, *Mikania micrantha* and *Nephrolepis hirsutula*. The fourth species, coconut, was not included in the interview since it was a crop whose distribution on the survey landscape is almost entirely the result of deliberate human planting. Table 7.2 indicates people's perceptions of these dominant species, expressed as a simple good/bad value

Table 7.2. Valuation of some dominant plant species.

| Species | Value | | Notes |
|------------------------------|----------|-----------|---|
| | Judgment | Men Women | |
| <i>Merremia peltata</i> | Good | 6 0.5 | The half point is due to one participant qualifying that it is good in fallows but not active fields |
| | Bad | 1 4.5 | |
| <i>Mikania micrantha</i> | Good | 7 (5) | Parentheses indicate that the plant was only considered as beneficial medicinally, and detrimental otherwise |
| | Bad | 0 4 | |
| <i>Nephrolepis hirsutula</i> | Good | 0 1 | The one positive evaluation was based on an aesthetic criterion without any further opinion being given on the plant. |
| | Bad | 7 4 | |

judgment, with responses disaggregated by gender. With *Merremia peltata*, a sharp distinction between men's and women's opinions on the plant is apparent. With one exception every male informant, whether a participant in the interview or encountered in the field during the survey and informally questioned, gave consistent opinions. The one male dissenter in the formal interview was not familiar with *M. peltata*, and gave no firm opinion on the plant other than to dismiss it as generally useless, which was recorded as a negative opinion, since he frequently used "usefulness" as a criterion. The two properties most commonly cited as making the species beneficial (Table 7.1) were its ability to shade and cool (*fa'amalu*) the soil and the ease with which it can be controlled. The ability of this species to suppress other weeds was cited by two participants in the formal interview, and additionally by another in a field encounter, and this criterion was only used in reference to *Merremia peltata*. One participant also indicated that he believed that this species improved the soil by making it soft and, he added as an afterthought, that it probably added "minerals" to the soil as well. This same informant also stated that it was desirable to leave the roots of *M. peltata* when clearing it so that it would re-sprout later. Indeed, this participant indicated that people preferred to make their taro plantations on land covered in *M. peltata*, because of all the benefits described above.

Interestingly, some of the results from the vegetation analysis corroborate the viewpoint elaborated by the men in the survey. The ability of *M. peltata* to suppress other plants is axiomatic, given its agency in creating the perception of its invasiveness, but it also appears to displace many of the more noxious weeds of

agricultural plots (Chapter 6). The analysis also indicated that *M. peltata* may be an efficient cyclor of phosphorus. For cooling the soil, the evidence from the vegetation analysis is less indicative. While the soil temperature difference in plots under *M. peltata* varied somewhat, their values did not extend to either extreme, and under NMS analysis, the vegetation on one axis, representing the non-*Merremia peltata* dominated plots, had a relatively high correlation to the daily variation in soil temperature, whereas vegetation under vine cover was largely unaffected by this soil temperature difference. Nevertheless, these corroborations between land manager perception and empirical data merit more targeted study.

The women in the survey, by and large, regarded *M. peltata* as a detrimental species. The criteria used to describe this species were largely the same criteria used to describe any agricultural weed. In Table 7.2, for instance, a strong consensus along gender lines exists for each of the three species present, and that although men typically cited agricultural benefits for *Merremia peltata* and *Mikania micrantha*, women generally regarded these as agricultural pests. Women distinguished between medicinal and agricultural value, however, in that the medicinal value of *Mikania micrantha* was frequently cited as being a positive feature, despite their opinions otherwise of its agricultural merits. Despite these differences in valuation, women often demonstrated a similar ecological understanding of the plants as the men. One woman indicated that although she considered *Merremia peltata* negatively, that it was a beneficial plant in fallowed fields. Two other women, when asked during the informal part of the interview why they thought that this species was so dominant on

the landscape, replied citing the plant's ability to shade and cool the soil. This difference of opinion despite similar ecological knowledge merits further study.

Although it was not the explicit purpose of this research to explain gendered environmental perceptions, one observed event may give some indication as to why this difference has arisen. On a mapping expedition early in the field season, part of the process of establishing the stratified random field sample in the GIS, a couple was observed clearing a field of *Merremia peltata* and planting *tiapula* (taro shoots). Interestingly, it was the woman clearing the vines while the man followed closely behind planting the *tiapula* (Figure 7.1). While it is problematic to draw any conclusions from this single anecdote, information from previous studies can provide insight into this question. Agriculture is typically a male domain, with all of a family's land invested under a *matai* title (traditionally), where the *matai* is typically (but not exclusively) male. The men of a household, that is, the *matai*, his sons and son-in-laws, form the bulk of the day-to-day agricultural labor force (O'Meara 1990). Women's participation in agricultural labor often occurs due to high labor demands, such as occurred during the peak of the taro exports (Paulson and Rogers 1997). Additionally, during the current field season, the *matai* of the family I was staying with mustered his family, children and all adults of both sexes, for plantation work on only one day during the field season, and for the purpose of extensive weeding of the plantation. For the women of this family, their involvement was very sporadic throughout the course of the year, and arising at times of high labor demand. This demand for household labor can also be mitigated by the circumstances of the



Figure 7.1. Couple clearing a taro plantation in *Merremia peltata* scrub. Images captured from video.

household in question, such as whether an older man has acquired a sufficiently prestigious title to command a large labor force, including his adult sons, son-in-laws and anyone performing service to him, at one extreme, or whether the couple is younger, such that the children are too young to help in the fields and a man's spouse may be the only other adult available to help, at the other (Kirkham1999).

In general then, women are largely marginalized on the agricultural landscape, and act on this landscape during periods when labor demand is high, such as in the initial clearing of plots. The difference in opinion over the plants may simply derive from the fact that men, by being engaged in the maintenance of plots throughout the course of the year, are more selective weeders, whereas women tend to view all of the non-crop plants as detrimental because their interaction with the plants occurs at times when all the weeds are removed. The difference of opinion over the plants, then, may be colored more by the interplay between social relations and the agricultural cycle than by specific knowledge of the plants themselves.

Similarly, discussion of the nativity of the plants in the survey elicited responses that were more informative of social relations than knowledge of the plants. For each plant in the survey, each participant was asked whether the plant were native (*O se la'au Samoa*, literally, a "Samoa plant") or non-native (*O se la'au mai fafo*, literally, a "plant from outside," or foreign plant). By and large, the respondents classified virtually all of the plants as native, often using phrases such as "*Ua ola nei Samoa*," that is, "it lives in Samoa now." This stands in stark contrast to the view from Western science, in which nearly all of the species in the survey are neither

native to Samoa or the Pacific region. Only nine individual assessments of plants as being non-native were made, and some consistency was apparent in the responses. Plants that were identified as non-native include the two *Mimosa* spp. (4 assessments), *Hyptis pectinata* (2), *Stachytarpheta urticifolia* (1), *Cenchrus ciliaris* (1) and *Pueraria lobata* (1). For *Mimosa* spp. and *S. urticifolia*, identification of these plants as non-native was often based on the suffix “palagi” (European) applied to the local names for the plant. *Vaofefe palagi* is most appropriately applied to *Mimosa invisa*, as distinguished from *vaofefe* (*Mimosa pudica*), and accounts for three of the four assessments, while one informant identified *S. urticifolia* as *mautofu palagi*. Two informants indicated that the “palagi” suffix was something somewhat of a “give-away,” although they neglected to identify *Mikania micrantha* (*fue saina*, “Chinese creeper”) as non-native on these same grounds. *Hyptis pectinata* and *Cenchrus ciliaris* were identified as being non-native because the participants regarded them as “new” plants to Samoa. One person indicated that *C. ciliaris* was a recent introduction that arrived with cattle. One person identified *Pueraria lobata* as non-native (although it is considered to be an ancient Polynesian introduction and has been in the country for several hundred years, Whistler 1995), because the government was encouraging people to use it as cattle fodder. Several participants also associated *H. pectinata* with cattle, although they indicated that the plant was toxic to cattle. The association of cattle with “the outside” no doubt arises from the fact that most of the original cattle had been imported from overseas during recent

memory (Maiava 2001). The association of the government with “the outside” is noteworthy as well.

Some generalizations can be made from these findings. One somewhat obvious conclusion is that people in the villages do not view the environment the same way as Western ecologists do. Indeed, the language of “Samoa plants” and “foreign plants” does not reflect local understanding of plant species. More importantly, the landscape is seen as being almost completely Samoan. When the participants were presented with a question that was phrased in nationalistic terms, the answers they gave were grounded in terms of identity. This has implications for any national or regional attempt to control invasive species, since a program phrased in these nationalistic terms might engender resistance, as it might be interpreted as an attempt to alienate an inherently Samoan landscape.

State Level Actors

State level actors represent a diverse category. The term “state level” here includes not only the local government, but also NGOs, private business interests, and any individual or organization that is based in the capital Apia. Actors at this level often have membership in multiple social spheres in the country, and include Samoans with varying levels of education and ties to rural villages, expatriates from the various cosmopolitan centers from around the Pacific that have mostly cut their ties with their home countries and reside primarily in Samoa, and people of various international origin that work for the multitude of international and regional aid

organizations (the latter will be discussed under the section on international and regional factors). This sector of Samoan society is very dynamic, since all of the social networks within Samoa and tying Samoa to the outside world converge here, if for no other reason than the government having direct control over the ports and airports.

A variety of opinions on *Merremia peltata* exist in this sector. The conventional wisdom, told in both MAFFM (Ministry of Agriculture, Forestry, Fisheries and Meteorology) and the DLSE (Department of Lands, Surveys and Environment, recently reorganized into the Ministry of Natural Resources and Environment, MNRE), states that while *Merremia peltata* had been in the country for quite some time, it had never become so dominant on the landscape as currently, and that it was likely the aftermath of the cyclones of the early 1990s that had thinned out the canopy of the forest that allowed the vine to become so dominant. From here, different perspectives are evident. The forestry division first expressed their interest to me in research on this species, because they were interested in finding some means of controlling the species. The department had begun some preliminary research on the effects of managing this vine on forest regeneration (Woods and Pouli 1995), but preliminary results indicated no difference in trunk diameter, although plots without the vine showed some signs of improved crown development. Pouli (personal communication) also indicated that some difficulties had arisen with the long term study, due to work crews clearing both the treatment and control plots of vines (department supervisors had apparently been delayed in arriving at the site due to

miscommunication in the vehicle pool). Final results for that project were undergoing analysis at the close of this study season. Hence, it was not entirely clear that *Merremia peltata* posed a threat to forestry at the beginning of this research, although it was widely assumed to be.

The Division of Natural Resource Management of the DLSE had recently conducted a survey in seven villages in Savai'i, where both *Merremia peltata* and *Mikania micrantha* had been identified as the greatest environmental problem faced by the villages. Its findings seemed to contradict the information I had been hearing in the Fa'ala, in which neither of these species was considered to pose a problem. As the vegetation analysis (Chapter 6) suggests, these two species are predominant on the landscape, however. It is not clear to me how the "seven village survey" was conducted or what the exact wording of questions was (I requested to see some documentation but never received any), but a likely reconciliation of this apparent discrepancy may be that villagers communicated the most dominant plants on their landscape, and the interpretation of this as a "problem" may have been imposed by the analysts. Alternatively, the views of the people from Fa'ala toward this species may be dramatically different from the other villages, which may be more vested in economic activity for which these species are a pest. I do not think the latter interpretation is likely, however, as the medicinal benefits of *Mikania micrantha* are widely known throughout Samoa, for instance, and it is not regarded as a problem or a threat. The source of this discrepancy merits further investigation.

One government official expressed frustration over foreign intervention in the management of *Merremia peltata*, stating that the overseas experts would simply see the vine's dominance on the landscape and pressure Samoa's government to take action. This official expressed further dissatisfaction with an Australian volunteer placed in charge of developing Samoa's invasive species management plan, because she "only repeated what other people have said," and he expressed the importance of having someone on the ground actually investigating the plant scientifically. One private individual active in environmental affairs in the country expressed similar concerns over foreign involvement, citing an Australian speaker at a Rotary Club meeting who advocated the control of the vine through aerial spraying of herbicide, a plan which this person felt would do more harm than good, especially to people's health. One individual with environmental experience both in the local government and abroad expressed frustration over trying to convince some people working on this species in Fiji that the problem would resolve itself in time, but that his views were ignored. Another official also expressed his opinion that although *Merremia peltata* was currently dominant on the landscape, it would be succeeded; he did not view it as a threat. The discrepancy between the skepticism of many Samoan officials working on the *Merremia peltata* problem and the officially espoused view that it is a threat raises some serious questions as to the nature of this particular invasion phenomenon.

People at the state level demonstrated knowledge of both modernist scientific discourse as well as the view from the village. One topic that state level officials often broached whenever I articulated the village view of *Merremia peltata*, was the

question of whether I had investigated the belief that the plant was a legume. The question is easily settled, since this vine is in the family Convolvulaceae and is not, by definition, a legume (in which case it would be in the family Fabaceae, formerly Leguminosae). This topic was broached by officials in both MAFFM and DLSE, and also by an American Samoan official working with the USDA. This reveals several important issues. One is that it demonstrates that these officials were familiar with the rural belief that the species is agriculturally beneficial. From my interviews, however, planters expressed their approval of *Merremia peltata* primarily on the basis of its superior qualities as a cover crop, rather than for improving the nutrient content of the soil. One interviewee associated improved yield with *M. peltata*, which only indirectly points to soil improvement, while another participant specified his belief that the vine added nutrients more as an afterthought, after cataloging the other more prominent benefits of the vine. Furthermore, no one in the interviews associated any of the leguminous plants (*Mimosa pudica*, *Mimosa invisa*, *Vigna marina*, and *Pueraria lobata*) with improved agricultural performance, although admittedly the legumes in the sample were not chosen for the purpose of testing these perceptions. Indeed the *Mimosa spp.* are considered to be notoriously difficult weeds, and *Vigna marina* is largely confined to littoral areas, where little agriculture is done. Nevertheless, *Pueraria lobata* was added to the survey after one regional official indicated that he considered this species to be worthy of encouragement over other weeds (like *Mikania micrantha* and *Merremia peltata*). Interestingly, only the villagers with cattle considered *Pueraria lobata* to be beneficial (and only as fodder),

while those strictly invested in farming spoke of that vine in extremely negative terms, with one person describing it as being the “worst” and being worse even than *soi* (*Dioscorea bulbifera*, bitter yam, that has the reputation of being nearly impossible to eradicate). It does not seem clear from the village survey that there is a belief that *Merremia peltata* is a legume, or that people are even considering nitrogen fixation at all. That the state level officials are conflating the views of rural people that this vine is an agriculturally beneficial species with a belief that the vine is a legume no doubt arises from the perspective of reductionist science that focuses on the intake of basic elements and chemical compounds as the source of plant health, and thus fostering the view that the only way that a plant can improve the soil is through adding these elements, specifically by fixing nitrogen. Indeed, after returning from the field, people often ask whether the plant is a legume when I relate the perspective of the village planters toward this vine; science has conditioned people into this fixation.

The theme of nitrogen fixation and vine cover cropped up in another invasive species venue, this time concerning rhinoceros beetle, *Oryctes rhinoceros*. This large beetle first appeared in Samoa during the German colonial period of the first decade of the 20th century, apparently an accidental introduction, that became a serious pest of coconuts. At the time of this study’s field season, rhinoceros beetle numbers were increasing, and local and regional authorities were working to bring them back under control. A newspaper article cited that Samoa’s government had encouraged people to allow vines such as *Mikania micrantha* to grow over fallen

coconut trees (potential nesting sites) to control their numbers (Samoa Observer, 23 January 2003). Subsequent inquiries into the regional and government offices working on this problem, first yielded the result referred to above, whereby an official from the regional program in Fiji simply stated that their organization did not advocate growing weeds, but rather encouraged the growth of leguminous vines, such as *Pueraria spp.* In an interview with the head officer of Samoa's rhinoceros beetle project, the officer confirmed that the department had been encouraging people to allow the vines to smother the coconut logs after first restating the same disclaimer the Fijian official used, but then confided that in practice, any vine would work, as long as it covered the coconut logs, and, when directly asked, confirmed that both *Mikania micrantha* and *Merremia peltata* would work. Here, by the scientific discourse acting in the international sphere, the factor that separates weedy vines from beneficial ones is nitrogen fixation; also, the state level officials balance out the international perspective with the realities on the ground.

Samoa's Rhinoceros Beetle Ordinance 1954 (originally enacted during the New Zealand colonial administration), explicitly states the steps that all citizens of the country must take to control rhinoceros beetle, but this vine-smothering technique is not included in the law. When this was pointed out to the official, he indicated that this was indeed true, but that their technique had proven effective in controlling beetle numbers and that the conditions of the law were too strenuous for the people to comply with, and the government did not have the resources or personnel to enforce it. Following up on this discussion, when the participants in the village-level survey

were asked about Rhinoceros beetle control during the informal part of the interview, eight respondents indicated that they considered rhinoceros beetle to be a problem (although one indicated that it was a problem, but not locally in Fa'ala). When asked about what they did to control rhinoceros beetle, only four gave answers that demonstrated some knowledge of the Ordinance, and none mentioned allowing vines to grow over the rotting coconut logs. So while a majority knew that the government considered rhinoceros beetle to be a problem, few were aware of the requirements of the law or the government's preferred technique for dealing with it.

This situation illustrates an apparent disconnect in the social networks between the state level and village level actors. It also illustrates an apparent sense of powerlessness to affect change at the village level by the state level actors involved with this problem, as they were apparently relying on the agency of the vines to take care of the problem without further human involvement (this fact, too should be taken notice of in terms of the synergistic ways that these vines, native and non-native alike, act to control another invasive species¹). It further illustrates the degree to which villagers have control over their own lands and affairs.

Several events that arose in southeastern Savai'i during the field season further emphasize the relatively high level of autonomy that villagers have over their lands and affairs. Laws exist that both empower the government and that empower the villages, and these laws often come into conflict. Two such laws that have

¹ It was observed during the vegetation survey that plots with moderate to high stocking levels of cattle had lower levels of vine coverage, especially of *Mikania micrantha*. Given that cattle are largely being stocked in coconut plantations, and that the rise in cattle numbers roughly corresponds to the period of increasing rhinoceros beetle numbers, the question of how the stocking rate of cattle may affect beetle populations merits focused research.

currently come into play in the interaction between the government and villages are the Taking of Lands Act and the Village Fono Act of 1990. The former stipulates that the government of Samoa can appropriate customary land in the villages for the purpose of building infrastructure. This law gives the government some sweeping powers and has come into play in recent events surrounding the development of the Salelologa Township. The Village Fono Act of 1990 on the other hand, gives sweeping power of authority over village affairs and property to the village councils, especially over matters effecting health and economic development, according to the customs and usage of the village. These two laws provide each group with considerable negotiating power.

Currently, a single diesel-powered electrical generator in Salelologa provides electricity for all of Savai'i. For the development of the Salelologa Township, the government wants to build a hydroelectric plant in the village of Sili as a more environment-friendly alternative to diesel generation. One informant from the village has indicated that the government has been trying to develop this project in Sili off-and-on over the last thirty years, and the village has consistently turned the government down, fearing damage to its rivers. For the township, the government has threatened to use the Taking of Land Act, reluctantly they say, because the project was being funded through the World Bank and their rules stipulate that the land for the project must belong to the government, and not simply be leased from the villages. Having brought the village council into negotiations, the village got promises of concessions from the government, and the government has acquired

alternative means of funding through the Asian Development Bank. This does not necessarily represent a unilateral victory for the government, as another informant from Sili stated that not all of the chiefs in the council were opposed to the project, as benefits would accrue to the village. Another informant, opposed to the project, suggested that the demands made by the village were too great for the government to meet, and ultimately the project would not go through. Thus, while decisions by village councils are reached through consensus, such a decision does not necessarily represent uniformity of opinion nor necessarily end the matter. This increases pressure on the government, since a perception that the government is not following through on its promises could shift council opinion against the project, and the village council always has the option to invoke its powers under the Village Fono Act to influence the process.

Just such an incident occurred in the village of Vailoa concurrently with the events in Sili. Vailoa is the site of a water treatment plant that was recently completed. Prior to completion, the village council, feeling that the government had not honored their previous arrangements, blocked access to the site, effectively halting work. Although this action would be illegal if undertaken by an individual or group other than the village council, it was legal under the Village Fono Act, and they were able to bring the government back into negotiations. Once agreements were reached, the project was allowed to finish.

The Village Fono Act was an attempt to define a traditional institution in terms of modernistic law. In terms of village-government relations, traditional

institutions and government institutions are avenues of exercising power, capable of being manipulated by actors on both sides. Within Salelologa itself, the development of the township has a long contested history. The signing of the Tafua Rainforest Preserve agreement by Salelologa interfered with government plans for developing a township there. This village is already the main service center on Savai'i, and the government wants to develop it into a service center on par with the capital, Apia. The government entered into negotiations with the village to buy land for the township, and Salelologa sold the government all of its forest land in the Tafua peninsula, thus effectively ending its participation in the preserve agreement. The government, through negotiation with the village council, paid the agreed amount of four million SAT. Late in 2002, other actors in the village took the government to court, alleging that the agreed amount was inadequate compensation and that the village council's decision did not reflect village opinion. The judge has reserved his opinion on the case, and at time of writing no formal decision has been made. The DLSE has since announced development plans for an environmentally-sensitive township whereby 100 acres are set aside for concentrated, high-rising township development and the rest of the forest land to become a national park with a 200 acre buffer, and construction has commenced with support of the village council. These divisions between "traditional" and "modern" institutions represent unresolved tensions from the division of power during the colonial period and add complexity to the negotiations between government and local interests.

The zone of contention over invasive species appears to be occurring at the state level, however. Although the official stance of the government departments falls in line with the standard scientific discourse over invasive species, many officials expressed some skepticism toward this view in as much as it regarded *Merremia peltata*. These officials are familiar with the scientific view and have firsthand experience with Samoa's environment. Although many have ties to the rural villages, many were not familiar with the planters' views toward this species; their view is largely based on their first-hand experience of Samoa's environment. It appears then, that the greatest zone of contention over this species lies not necessarily between modernist scientific discourse abutting traditional knowledge (although what is basically under contention are landscapes managed under the village perspective not conforming to a scientific perception of an ecologically healthy landscape), but rather is represented by nationalistic discourse that charges the social networks through which the variety of social agents act.

These perspectives are crucial to the implementation of control efforts. Space and Flynn (2002), for instance, state that because of the prevalence of land outside of government control, that is freehold and village customary land, that it is imperative that invasive species control efforts have the weight of law and to be enforced. It is not clear from the examples described above, however, whether these hypothetical laws would have any real force due to lack of resources to monitor and enforce them, or whether people in the village would want to participate, especially given the nationalistic discourse inherent in the native/non-native dichotomy.

Regional and International Factors

The social networks connecting the various Pacific Island Countries (PICs) to each other and to the cosmopolitan core countries of the Pacific Rim provide the primary setting in which the scientific discourse over invasive species occurs. Indeed these links are critical to the arguments, as the political boundaries between these political entities are all oceans, and tend to form natural barriers against invasive species transmission. Ironically, these barriers also contribute to the vulnerability of these island states through the isolation of their ecosystems. Control efforts thus focus on transportation networks, that hasten the movement of organisms between these otherwise isolated areas. Coordinated efforts at control and management of invasive species in this region thus involve multilateral organizations and agreements.

The South Pacific Regional Environment Program (SPREP, part of the UNDP) established a comprehensive plan for identifying and combating invasive species in the Pacific (Sherley 2000) that includes establishing a definition of invasive species that excludes both native species and species whose distribution is aided mainly by disturbance (Meyer 2000), both factors that are applicable to *Merremia peltata*. Smith (1991) and Whistler (2002) both indicate that the species is indeed native, although both indicate the ability of the species to smother growth. Although this apparent discrepancy provides an opportunity to gain a more nuanced understanding of the invasion process, most researchers in these networks seem to disbelieve its nativity and simply treat it as they would any other exotic invasive. Space and Flynn (2002) for instance, offer up the possibility that it might not be

native, but indicate that they treat it as native. Meyer (2000) simply ignores the nativity issue for this species and lists it with other exotics despite his own definitions. Several officials, both international and state-level, expressed disbelief at this species' nativity, often theorizing that it might have been an ancient Polynesian introduction, but could offer no compelling reason for this belief other than the tautology that it must be non-native because no native species could become so dominant on the landscape. One regional official directly involved in formulating a management plan to combat *Merremia peltata*, and strongly advocates finding a biotic control (a fact that essentially aligns these officials with those in the Forestry Department), after expressing her disbelief in its nativity, and after I pre-empted the tautological explanation, offered the idea that it has very small seeds that could be easily transported. This idea is derived from studies that identifies this as a property that some invasive species have (Bazazz 1986), although Bacon (1982) observed a low seed viability rate in this particular species, a fact that makes this particular line of reasoning suspect. The startling, and ironic, point to be seen from these discrepancies is that although scientific knowledge is employed as the power discourse in these networks, very little science is actually being done in regard to this species, despite the fact that its nativity raises several concerns of merit. Although science is used to justify environmental intervention, the right questions are not being asked or investigated regarding *Merremia peltata*, despite evidence that this species does not quite fit the conventional mold.

Another highly prominent domain in which invasive species discourse drives policy is the agricultural quarantine program. Early in the field season, a program coordinated between New Zealand's Ministry of Agriculture and Forestry (MAF) and Samoa's MAFFM was implemented to educate the traveling public, that is Samoans traveling to New Zealand to visit their relatives, on how to avoid being fined by New Zealand's quarantine officials. During the Christmas holiday season, the number of Samoans visiting their overseas relations rises dramatically, and these visitors bring with them a considerable amount of Samoan foods, typically cooked in the *umu* (stone ovens) that are not available overseas (and certainly not cooked in this manner). MAF, however, feels threatened by this sharp rise in foreign foodstuffs crossing its border, and often bans breadfruit (*Artocarpus altilis*), even if cooked, as it transports fruit fly larvae. Although presented as a cooperative program, whereby each nation in the region would ensure the mutual protection of all member nations by rigorously enforcing their quarantine standards, it became clear that the program was more about protecting New Zealand by targeting Pacific Islander travelers. For instance, the topic of what to do about tourists, a potential problem to both countries, was never broached in the program. Also, MAFFM officially stated that its official response to New Zealand's measures would be to target high-profile New Zealand officials that frequently traveled between the two countries, a statement that belied the tensions inherent in the otherwise mutually friendly program. These nationalistic interests were further revealed in the words of a member of the Pacific Island community in New Zealand, part of MAF's entourage, who stated that "when you

protect New Zealand, you are protecting the Pacific.” In this instance, the invasive species discourse was being invoked to serve nationalist interests, with the New Zealand government acting through its social networks with the Samoan government to affect change in the social networks tying Samoan families to their overseas relatives.

The clout that the cosmopolitan countries on the rim, especially New Zealand and Australia, have within Pacific Island governments stems from the agreements attached to development aid. With the difficulty many island states face in developing economies of scale under conventional primary-export oriented development models, some researchers have suggested that Pacific Island states are better described as following a “MIRAB” (migration, remittances, aid and bureaucracy; Bertram and Watters 1985) model of development. Although this model of development is criticized for apparently advocating that PICs essentially live off of aid, Poirine (1998) indicates that this aid is often traded for strategic concessions, especially in the context of the Cold War, and that aid typically furthers the interests of the donor more so than the recipient. Indeed, during the field season Australia required PIC governments to place Australian personnel in strategic government positions as a requirement of receiving its aid, and the person in charge of making Samoa’s invasive species management plan and the person investigating the control of *Merremia peltata* at SPREP were both Australian. The perspective towards invasives in general and *M. peltata* in particular are thus going to be colored by the Australian experience with and perspectives toward invasive species; control

of the social networks linking the Samoan government to Australia is an attempt to ensure that this will happen.

Indeed, this control of the social network can be seen as a means of constructing the value of Australian environmental expertise, much in the same way that restricted access to objects commodifies them (Appadurai 1986). Appadurai further explains that one aspect of creating the value of a commodity is not simply to restrict access to the object in question, but also to restrict access to knowledge of the commodity as well; such restricted access occurs with environmental knowledge as well. At the Fifth Annual National Environment Forum (November 2003) held at the National University of Samoa, one paper presented efforts to create a database of locally conducted environmental research (Bentin and Duffy 2004). During the question and answer session, several audiences expressed concern over the possibility that intellectual property rights would be infringed upon as a result. Afterwards, one person familiar with the project indicated that people were often unwilling to share their research and that quite often the only way such research could be entered into the database would be to have the author's contact information. This was contrasted to an expression of extreme frustration of having to balance these concerns with those of international organizations that were very demanding to have local research turned over to them, although without reciprocating any information in return. This informant was further frustrated by fearing to speak out from concern that much needed aid money would be lost as a result. Within the PICs, the legal and other infrastructural mechanisms to insure the protection of intellectual property and to

disseminate local research do not currently exist, while the power structures of the international social networks appears to be somewhat extractive of information. These power inequalities have the effect of suppressing local expertise, and cosmopolitan expertise builds at the expense of the local.

Every actor involved in the debate over the *Merremia peltata* invasion, however, is working to the best of their abilities and knowledge. Invasive species are an issue of special significance to PICs, and the promotion of strategies whereby invasives are controlled where they exist does help to protect the entire region. What is dubious, however, is the willingness of the various actors, broadly divided along the international interface, to ignore several indications that *Merremia peltata* does not fit the conventional pattern of invasive species, and to try and control it as such. Evidence from this study suggests that *M. peltata* functions as part of the native vegetation and that control efforts should focus on mediating the effects of disturbance. From this perspective, combating this species as a non-native risks ecological harm to local ecosystems, and considering that this species is already present throughout the Pacific islands, the only areas that would be protected through containment are the cosmopolitan countries on the Pacific Rim. Whether multilateral containment policies work toward the common good or result in environmental (and social) injustice thus hinges on whether the species in question are non-native to the entire region in question (Oceania as a whole, here). It is not my contention here that any of the actors involved are deliberately trying to reproduce a colonial power structure. I do contend, however, that the power structures are such that they create a

social momentum that serves the cosmopolitan interests, regardless of the intent or perspectives of the individual actors involved. Indeed, inasmuch as environmental science is used to justify these nationalist agendas, there needs to be a greater emphasis on making sure the proper science is being done, the appropriate questions are being asked, and that local perspectives are actively sought and taken seriously.

Summary

Merremia peltata is many things to many people. This case study illustrates the principle that nature is both “real” and also socially constructed, and that for any given phenomenon, a plurality of perspectives on this nature exist (including the “perspective” of the non-human species that are going to behave in their own way regardless of the various narratives invoked by people). Indeed, within the realm of scientific discourse, different narratives over this species exist. Given that *Merremia peltata* landscapes are plural natures, control methods that are based on the concept of a single natural truth (in this case that *Merremia peltata* is an inherently detrimental species), such as biotic control that would adversely affect farmers as well as alter the forest recovery dynamics (quite possibly for the worse), are undesirable and irresponsible.

From a political ecology perspective, this case study illustrates that scientific ecology can play an activist role. Here, the greatest zone of contention over the species lies at the interface of the state-level and regional and international spheres, with the potential for both environmental and social injustice arising from certain

scientific facts about this species being overlooked, and subsequent questions not being asked, even though discrepancies between this species and the conventional knowledge over invasives are at odds. With scientific discourse being used to justify national biosecurity agendas, using empirical science to expose where scientific discourse glosses over power inequities should be considered a viable and legitimate tool in the activists' toolbox.

Samoa is a society where an indigenous people have made great strides in constructing their own modernities. With ethnic Samoans being in the majority and having control over their government, understanding Samoan political ecologies in terms of contention between modernizing discourses conflicting with indigenous knowledge or rights is highly problematic, given the high degree of control that rural populations have over their own landscapes which are the result of the laws that these same people enacted through their government. The cosmopolitan countries of the Pacific Rim have no direct access over any of the Samoan landscape so try to influence outcomes on the landscape by acting through the Samoan government, NGOs and various other international donor and aid agencies. This provides outside actors with one degree of separation from government owned lands such as the National Parks, but with a second degree of separation from village lands which comprise that majority of the Samoan landscape. The state-level sector serves as both point of entry for external influences as well as a buffer zone to the landscape. Furthermore cosmopolitan countries also try to protect their borders from non-native species entering their country through quarantine measures; the example of New

Zealand's quarantine program essentially targets the network linking Samoan village population to the overseas Pacific Island community by acting through Samoa's government.

Contention over landscape processes tends to occur in the state-level sector then, where modernistic discourse is the common currency. Many environmental initiatives tend to contrast development in terms of ecological science reaching out to traditional (that is, non-western) practitioners. What is obscured is that there is, in fact, a local modernity, itself a body of knowledge and experience, that becomes silenced, ignored and bypassed. Political ecologists then need to also study the tensions between local and international modernities. Ignoring this interface while emphasizing the modern/traditional interface risks reproducing colonial divisions of power.

Chapter 8

Conclusions and Recommendations

Overview

This research project presents a socially self-reflective biogeographic study, examining the social context in which the concern over *Merremia peltata* research has arisen by examining discrepancies between the biogeographic results with the claims that phrased the research issue, and ultimately investigating how the predominant research agenda was constructed, given that other avenues of approach were readily pursuable. Specifically, given that *M. peltata* is considered to be native to the Pacific, why were management efforts directed toward controlling the species as an alien invasive (Meyer 2000)?

Biogeographic results that indicate the invasion of *Merremia peltata* is more likely an example of forest recovery than invasion by a non-native emphasize the importance of understanding how the rush towards management failed to ask relevant questions concerning this species' role in the functioning of the native ecosystems. Indeed, these results indicate that the greatest threat to the preservation of native and endemic species derives from frequent and sustained disturbance that increases the rate of mortality and reduces the presence of these species' seeds in the soil seed bank at a rate greater than these species can replenish themselves. From a biodiversity perspective, management efforts should be directed toward fostering the process of forest recovery and propagating species with lower rates and range of dispersal.

The focus on *M. peltata* as an invasive threat to biodiversity arises from the social context in which the question arose. A complex tension exists between concerns for biodiversity and biosecurity. This tension plays out through international social linkages that are still redressing the power inequalities of the colonial era, including, but not limited to, economic disparity and aid dependency, infrastructural lag in developing local ecological expertise and information sharing resources, articulation of a global capitalist economy with pre-capitalist modes of production, and ultimately with the extent of prolonged, repeated disturbance on the landscape. These power inequalities create momentum in which biosecurity efforts can potentially override biodiversity concerns, such that, in the case of *M. peltata*, the cosmopolitan core countries risk potentially harming native ecosystems in the Pacific Islands for the sake of protecting their own biodiversity. Although the dominance of *M. peltata* on the landscape does indicate a disruption of ecosystem processes, centering the debate in terms of invasion ecology places too much scrutiny on the plant itself as the problem rather than examining the issue in an entire landscape context, seeking to manage disturbance, dispersion and recovery of the various other species of conservation interest. Furthermore, recent efforts by international ecological organizations emphasize the importance of ensuring the compliance of customary landholders to management practices through the legal mechanisms of the state (Space and Flynn 2002). Investigations reveal that the success of development efforts channeled through state and non-governmental institutions ultimately lies with the cooperation of the customary landholders themselves, owing to the empowerment

of village councils, and are threatened by lack of accountability (providing opportunity for intrigue) at several levels.

The results from this research suggest means of managing the situation that has allowed for the dominance of *M. peltata*. Conservation efforts need to focus on the entire landscape itself and concentrate on restoring the abundance of less dispersible species. The management plan must address social differences at several levels, for instance making sure that the biosecurity self-interests of powerful countries do not override those of the less powerful countries, and that the customary landholders are willing to participate because their needs and concerns are adequately addressed. The question of finding shared values must be addressed in formulating biodiversity conservation strategies.

Merremia peltata and the Threat to Biodiversity

A landscape smothered under a dominant cover of *M. peltata* alarms the sensibilities of the ecologically sensitive observer. Results from this research indicate that although this species appears to behave in a manner consistent with that of a non-native invasive species, that it remains part of the native vegetation, and appears to be indicative of recovery from recent, infrequent disturbance to lowland forest. A sequence of succession from *M. peltata* dominant groundcover to native forest appears likely given that several widely dispersing tree species, characteristic of the earliest stages of forest regeneration, are able to compete with the vines. Whether forest regeneration continues past this later stage depends on a variety of factors, such

as the disturbance history of a particular site, and the proximity of other tree species that can disperse into these areas of recovery.

Although indicative of a disturbed native ecosystem, the dominance of this species is best understood as resulting from a shifting pattern of disturbing forces interacting with the reproductive and dispersal habits of individual plant species on the landscape. These disturbances are both anthropogenic (primarily agricultural) and natural (primarily tropical cyclones) in origin. In terms of invasive species on the landscape, the colonial period and the subsequent period of agricultural commodity export-led development saw the most extensive and enduring disturbance on the landscape, primarily for the production of coconut products. As coconut-based commodities declined, a brief period of lucrative banana and cocoa exports arose and collapsed, followed by a rise in taro production in conjunction with increased migration of Samoans and other Pacific Islanders to the cosmopolitan core countries. This last major agricultural export led to the greatest extent of forest clearing in the past fifty years at least, and was aided by the tropical cyclones Ofa and Val during the early 1990s. The subsequent extensive monocropping of taro permitted a fungal blight to wipe out the taro crop, causing this recently cleared land to become fallowed, in part because other Pacific Islands were able to continue supplying taro to the core regions, leaving Samoan planters without a lucrative cash crop. These two periods of disturbance, the colonial era coconut production and the post-colonial taro production differ primarily in the duration and frequency of disturbance to vegetation and soils, and have differential effects on the native character of the vegetation.

In general, the greatest numbers of non-native species occur on lands that have been subjected to prolonged and repeated disturbance, and are associated with the coconut production of the colonial period, whereas the areas dominated by *Merremia peltata* appear to be more closely associated with areas of less frequent and less prolonged disturbance, and is characteristic of land recovering from hurricane disturbance and shifting cultivation, as typified in the post-colonial era of migration and taro exports. These findings have important ramifications for biodiversity conservation, which views invasive species as threat to biodiversity almost on par with habitat loss, and with islands being especially vulnerable due to their high rates of endemism, amongst other reasons. Although widely dispersing tree species, including a mixture of native and non-native species, were found to be established in both areas of infrequent and frequent disturbance, less dispersible species, including most endemics, were represented for the most part in the forested plots (areas of infrequent disturbance), and were largely absent from the parts of the landscape that had been subjected to sustained and repeated disturbance. Prolonged and repeated disturbance represents a greater threat to Samoa's biodiversity than *Merremia peltata* dominance.

This threat to biodiversity can come from disturbance that acts directly on the individual plant species themselves, increasing the mortality of trees and reducing the available stock for replenishment, such as logging, clearing forest for swidden plots, or through the impact of tropical cyclones. Additionally, any action that disturbs the soil or otherwise removes seeds from the seed bank causes the resulting recovery

vegetation to be represented more by species that easily disperse into the plot, such as non-native invasive species, as the less dispersible species depend more heavily on the seed bank for rapid reestablishment. At question then, are frequency and duration of disturbance relative to dispersal ability of the plant species in question, such as number of seeds produced, range and method of dispersal. The structure of the landscape thus factors into this disturbance-dispersal model, with the location and spacing of remnant stands of vegetation factoring into the question of whether certain species' seeds will be present at a particular recovery site at any given time. In terms of biodiversity conservation, the invasive species issue appears to be closely tied to the question of habitat loss.

Given the importance of anthropogenic disturbance to the invasion process, and that conservation efforts involve international agents, a variety of actors at the national level, both inside and outside of government, and rural land managers, the invasives question is produced by and reproduces the power inequalities present in the post-colonial Oceanic region.

Biosecurity and Biodiversity in the Post-Colonial South Pacific

The subject of invasive species management drives both biosecurity initiatives and biodiversity conservation, and the two topics are often viewed as being fundamentally interconnected. Biodiversity conservation tends to be primarily a concern of environmental integrity, focusing on quantity, abundance, and quality (that is, the relative abundance of native species compared to non-natives), whereas

biosecurity is largely a matter of enforcing national concerns, with the aim of protecting the national economy and environment, with the prevention of movement of species across borders being its primary goal. Although political borders often do not coincide with ecotones, in the case of the Oceania and the South Pacific, borders are typically the Pacific Ocean. The vastness of these ocean borders is somewhat advantageous to biosecurity efforts, given that the transport of organisms typically occurs through transportation routes, and control efforts can be focused at the limited number of ports and airports that exist. In the Pacific case, the transport of invasive species occurs through networks that are highly socially and politically regulated. Current biosecurity and biodiversity conservation efforts in the Pacific emphasize the importance of control and management of invasive species where they currently exist (a biodiversity conservation concern) in order to reduce the possibility of transport (a biosecurity concern). Although theoretically sound, some ecological and social injustices may still occur due to lingering power inequalities from colonial times between the cosmopolitan core countries and the less developed Pacific Island countries, as the case of the *Merremia peltata* invasion in Samoa illustrates.

These inequalities create social momentum that favors the interests of the core over the developing island nations. Samoa, as are other island nations, is heavily dependent on development aid. Australia requires countries that receive its aid to place Australian personnel in strategic positions in their governments, allowing Australian perspectives to operate in these governments. In the case of *Merremia peltata* control, officials developing control strategies in both the Ministry of Natural

Resources and Environment as well as the South Pacific Regional Environment Program are Australian personnel, so this international arrangement has direct bearing on the *Merremia peltata* invasion. Samoan Government personnel are restrained from expressing their viewpoints, often counter to those of the expatriate officials, for fear of jeopardizing receipt of aid. Trained Pacific Island personnel are often lost to jobs in the core countries, and local information-sharing resources, including the protection of intellectual property rights, are underdeveloped. Local experts, often with considerable experience working in the local environments, lack access to the accumulated research knowledge of the core institutions. These inequalities favor the expertise of core professionals over local personnel, despite the lack of experience in Pacific Island environments these professionals have.

Thus, instead of asking appropriate questions as to why a native species behaves such as this one does, whether it has any ecological role to play in native ecosystems, and pursuing the appropriate research to answer these questions, many prefer to deny this species' nativity and target the plant for control, including biotic control, despite the belief of local professionals that the species may not pose as much of a threat. Decreasing *Merremia peltata* cover in highly disturbed areas will likely increase the abundance of non-native species, however, as these would rapidly disperse into these newly disturbed areas; a reckless course of control could potentially harm Samoa's environment, although it would decrease the likelihood that it would spread beyond Samoa. However, given that this species is already largely spread throughout the Pacific Islands, the only countries that benefit are those of the

core. The inequalities between the core and developing island states allows biosecurity concerns to dominate over biodiversity conservation, even to the point of harming other ecosystems in the interest of protecting core environments and economies.

Further Research

Although a sequence of vegetation change appears possible from *Merremia peltata* cover to early pioneer tree species to mature native lowland forest, this sequence has been inferred from a synchronic analysis across all of the plots in various stages of recovery, and not on direct evidence of a sequence of change occurring over time on any given single plot. Two important relevant questions arise that the current methodology cannot address.

First, areas that are dominated by *Merremia peltata* groundcover are in such early stages of succession, that direct connections to later stages cannot be directly inferred. One finding of this project indicates that frequent disturbance has played a role in reducing the abundance of less-dispersible tree species. A pertinent question then is whether *Merremia peltata* groundcover acts in a similar fashion, smothering the sprouts of trees that may germinate under the mat and thereby reduce the abundance of these species in a manner similar to weeding. This question requires targeted study to answer, such as by examining seed bank content, although in cases where plots have also been farmed it may be difficult to attribute the absence of seeds to farming or to vine cover.

Similarly, the ability of forest cover to succeed directly from vine scrub cover needs further investigation. Although there appears to be a successional sequence apparent across the landscape, this sequence has been reconstructed across several plots at a single moment in time. An important question relates to the initial conditions that each of the plots experienced prior to the commencement of regeneration. A sequence commencing with vine scrub and ending in lowland rainforest appears possible, but it is not clear if the plots in later stages of regeneration began as vine scrub, or if the high proportion of *Merremia peltata* is a result of the plot being invaded at a later stage. Another important question, especially in regard to management, is how the dominance of *Merremia peltata* affects species composition, especially in regard to the number and abundance of native species. For instance, does succession commencing with vine scrub convey any advantages to biodiversity management? Does *M. peltata* dominance increase, decrease or have no effect upon the native character of community composition? Areas under *M. peltata* often show a higher number and abundance of native species (especially in later successional stages) than those without it (the coconut dominated plots), but this may be explained better in terms of the frequency and duration of disturbance. The disturbance question would be highly relevant to the number of native species in the seed bank, but *Merremia peltata* ground cover may have an added benefit of suppressing colonization from non-natives. Both of these questions raised here require long-term observation and experimentation to answer.

Additionally, this research has studied the species in a single location, and the ability to generalize these results to other locations, especially different island chains is highly problematic. Some of the species that are capable of competing with *Merremia peltata* in Samoa, such as *Macaranga harveyana* and *Pometia pinnata*, are not as common in Fiji as they are in Samoa (Smith 1991). Different island groups have unique biogeochemical and cultural histories. The circumstances of geological origin and age of the islands, island area and elevation, and isolation from other islands create unique floral and faunal assemblages for each island that may respond differently to the introduction of new species, even if those species are native to islands themselves. Geographical location on the globe means that these assemblages are subject to a different frequency of disturbance from tropical cyclones. Additionally, unique cultural histories, in terms of original colonization and cultural modification of and adaptation to local environments, colonial experience and post-colonial development have created unique land use history and patterns of disturbance as well. Thus, although this vine may not be a significant hindrance to lowland rainforest recovery in Samoa, it may present significant problems in other island environments.

Regional studies could be conducted, both synchronically and diachronically, at the regional level. Synchronic studies would perform research similar to this study in other island locations. This could include other locations in Samoa, with differing population and land-use pressures as well as locations in other island countries, to examine the interaction between human-induced disturbance and the spread of this

plant species. A hypothesis that could be tested is that *Merremia peltata* has become dominant in large part because of the various dynamics associated with the production of taro for export overseas, in terms of the extent of disturbance and recovery on the landscape. Fiji, after all, picked up a large part of the market share that Samoa lost, which should increase the amount of land being cleared for dry-field taro cultivation. Another aspect of the hypothesis would assert that the integration of pre-capitalist modes of production (shifting cultivation) into a global capitalist market acts to maximize disturbance on the landscape. Investigation should also include studies of migration, food choice and maintaining island identities in the cosmopolitan centers (both within island communities and with the dominant society as well) to give a broader perspective on the problem, and not simply reduce the invasion to a question of agricultural practices or market dynamics.

Diachronically, the study of *Merremia peltata* could shed light on both island biogeography and Pacific cultural ecology. The relationship between *Merremia peltata* and *Pometia pinnata* forest appears to be subject to, and is adapted to, hurricane disturbance. Given that the western South Pacific is subject to a higher frequency of tropical cyclones than the eastern part, early Polynesian settlers may have been able to maintain a prolonged presence in the western region in part because the ecosystems were somewhat resilient to disturbance in general, such that shifting cultivation may have been more sustainable in the western islands (such as Samoa where it has persisted as the dominant mode of taro cultivation throughout most of its history), but unsustainable in the eastern islands, such as Hawai'i, where wide scale

ecological collapse has been recorded in relation to deforestation, and where terracing of taro plots became a more standardized practice. Indeed, many of the crops that are indicative of transported Polynesian landscapes, such as *Pometia pinnata*, which has been distributed as far east as Hawai'i, may have been done in part because of these species' adaptation to disturbance. Ancient Polynesians may have been actively involved in stabilizing their environments by transporting these species, and not solely for the purpose of utilizing them economically. Furthermore, the question of tropical cyclone frequency needs to be examined both in terms of past frequency and its effects on the island biota as well in the contemporary context of global climate change. If trends in increasing air and ocean water temperature continue to rise, the frequency of tropical cyclones would likely rise as well, and the increased frequency of disturbance to island ecosystems would be as potentially threatening to the native biodiversity as any human-induced disturbance, and also impact all of the island's ecosystems simultaneously.

Merremia peltata may, in fact, have been a part of these transported landscapes. It is possible that its seeds could have been accidentally transported in soil with deliberately transported species, although the apparent low viability of its seeds (Bacon 1982) lowers the odds of this possibility. Alternatively, the species may have been transported deliberately because of its labor reducing potential in dry-field taro production. Although *Pometia pinnata* is likely dispersed naturally throughout the western islands (Samoa, Fiji, Tonga) due to these islands being within the flying range of the native fruit bats (Smith 1991), it is highly unlikely that *Merremia peltata*

could have been dispersed naturally between the islands, given that it is not known whether the species is dispersed by animals. Although the ancient Polynesians are often depicted as having been actively destructive to native island habitats, they may also have been actively engaged in stabilizing their habitats against disturbance through the species that they transported.

The possible agricultural benefits of *Merremia peltata* need further investigation as well. Ethnographic evidence indicates that there is a perception *Merremia peltata* is beneficial to taro production in particular. The predominant reasons cited by farmers relate to providing cover and ease of control of this species, which points to reduced labor inputs as being the likely reason for this belief. Other reasons for this species' benefits cited by farmers included the suppression of other weeds, and possible improvements to the soil. Evidence from the biogeographic phase of this research demonstrates that areas under *M. peltata* vine cover are lacking in nearly all of the other weedy species that are common in disturbed areas without vine scrub cover. As for soil improvement, soils under vine scrub cover appear to have a higher nutrient content than soils without this cover. Whether this is a direct effect of this plant itself, whether the higher nutrient levels are the result of input from vegetation smothered by *Merremia peltata*, or whether this species simply needs more fertile soils to become established, are not firmly established. The latter case appears unlikely, as *Merremia peltata* vine scrub has been observed on several soil types, from rocky *soata* soils to areas with greater accumulation of colloidal material.

The question of whether this species directly contributes to changed soil conditions can only be tested experimentally.

Experimentation could be conducted on several treatment and control plots. Plots should have varying starting conditions, for instance, some starting under conditions of vine scrub and others under secondary scrub. An assessment of initial conditions would be made, including vegetation cover, soil nutrients, and seed bank composition. Three different treatments would be applied, representing the most common techniques in practice, including manual weeding and planting in vine scrub, manual weeding and planting in secondary scrub, and herbicide spraying, burning and planting in secondary scrub. Labor and capital inputs would be measured for each treatment. The mass of taro harvested would be measured. In addition, treatments of undisturbed vine and secondary scrub would be maintained. Additionally, another control could be maintained whereby vine and secondary scrub are removed, and no further action is taken on the plots. Periodically, the vegetation cover and soil nutrient levels would be reassessed. The resultant vegetation community would be compared to initial communities and to initial seed bank composition. In this manner, the stated perceived benefits of *Merremia peltata* cover could be assessed, as well as the differential impact between human disturbance and intratrophic competition between *M. peltata* and other species.

The structured interview was one means of assessing the ways that planters valued *Merremia peltata*, but it does not assess the ways in which villagers value biodiversity in general. The interview mainly presented weedy plants that are

common in disturbed areas, and therefore these results may not be applicable to native biodiversity in general. Most responses were given relative to their value to the household, either through medicinal value or utility in agriculture. Additionally, the respondents did not divide plant species into “native” and “non-native” categories, which suggests a fundamentally different understanding of biodiversity than ecologists promote, but does not provide enough detail to explicate an entire ethnoecology of the islands’ native species, or how people’s values contribute to the fluctuating number and abundance of these species. Although, several studies of Samoan ethnobotany already exist (MacPherson and MacPherson 1990, Whistler 1996, 2000), these studies tend to focus on people’s economic engagement with biodiversity, limiting the discussion of valuing biodiversity to questions of utility. An important question then, for ecologists seeking to preserve native biodiversity, is to understand the ways in which those native species that are not utilized are affected by local institutions, which themselves are contemporary products of pre-capitalist institutions and Western-style social, economic and political institutions interpenetrating each other.

If economic utility is the only reason that Samoans value their inherited biodiversity, then it can be hypothesized that as Samoa becomes more economically developed, and as people come to rely more on commercially available substitutions for those produced from forest products, that the cultural impetus for preserving native biodiversity will decline. Additionally, other institutions, such as land tenure, may feed into the declining valuation of local biodiversity; that is, as questions of

ownership of land between villages or households, the presence of forest (and the biodiversity therein) become more of a liability. Projects that are designed to preserve biodiversity need to take these other factors into account, and consider that culture is dynamic and extends beyond local practice. Instead of focusing on reproducing extant economic uses of local biodiversity, preservation interests should seek to construct new ways of valuing biodiversity through engaging local producers as land managers. Project design must be informed of the reasons why biodiversity is not valued, however, in order to avoid reproducing these pitfalls. The alternative risks reproducing poverty as the best means of preserving biodiversity, rather than seeking means of reducing land-use pressure, and engaging land managers to more carefully manage the rehabilitation of forest recovery.

Recommendations

Although *Merremia peltata* groundcover may not be an impediment to rainforest recovery, its dominance on the landscape is indicative of the extent of disturbance to Samoa's lowland rainforest ecosystem, and merits management considerations. Several possible strategies for management are presented below and are based on principles derived from the findings of this study, namely that the overall biodiversity turnover is primarily disturbance-driven, that immediate succession from *Merremia peltata* groundcover is possible, and that *M. peltata* groundcover helps suppress other invasive woody species, and tempered against remaining uncertainties, specifically that initiation of succession from *M. peltata*

groundcover does not guarantee a desirable outcome, and that these outcomes are contingent upon the species composition (number and abundance) of propagule pressure from outside the management area but also by the presence (and absence) of these propagules in the soil seed bank. Some amount of human labor and intervention into the natural process is necessary to balance the strengths apparent in observed near-term succession with the uncertainties of differential successional vectors in the long term. Although natural forces could be expected to turn over species composition from *Merremia peltata* dominance on the landscape, human management is necessary to guide succession in a more desirable direction in terms of native biodiversity.

The most obvious approach would be to have no human intervention into the ecosystem processes at all, and to let succession proceed naturally. Although this approach requires no capital or labor inputs, it is highly subject to the uncertainties of the long term vectors that succession might take, and there is no guarantee that the resulting composition of species would have an acceptable number and abundance of native species. The resulting community would likely be lacking representation by those species that are poor dispersers, including endemics, because this strategy relies on natural dispersion to build up numbers. Given that these less dispersible species are at the greatest risk of extinction, this strategy is not desirable from the standpoint of biodiversity conservation. Additionally, it is also uncertain how quickly forest regeneration would take place, and thus may be undesirable from the point of view of

restoring ecological services, such as maintaining the water budgets in deforested watersheds.

A second strategy involves targeting the *Merremia peltata* groundcover directly. The species is not shade tolerant, so it may be possible to shade the species out. An area targeted for management would first need to be delimited, and *Merremia peltata* cleared from the edges, for the dual purpose of limiting its spread into neighboring areas and to create a buffer in which trees could be planted along these edges. The trees thus planted, when mature and forming a closed canopy along the margins, would serve as a barrier to their spread. Successive trees could be planted along the new margins to gradually shade out the entire area. Alternatively, trees could be planted in a low-density pattern, such that when they mature, they do not necessarily form a closed canopy but cast sufficient shadows on the ground throughout the course of a day that sunlight is insufficient for *Merremia peltata* to be viable. Drawbacks to this strategy involve the high amount of labor and capital that need to be invested, even in a small plot. Enough native tree saplings need to be on hand at the outset of implementing this strategy and would thus require a large capital outlay before implementation began as existing nurseries would need to be expanded or new ones constructed, as well as taking time to build up genetic stock. The exact species to be planted would need to be determined beforehand as well. These plots would also require constant attention, given the rapid rate at which *Merremia peltata* could overtake the newly planted saplings. With limited labor, only a few recovering plots could be managed at a time, and no new plots could be established until the

saplings were mature. Additionally, since this method requires that no vine veil be formed by *Merremia peltata* with the surrounding vegetation, the likelihood of non-native species such as the wind dispersed *Funtumia elastica* becoming established is higher as well. This strategy seeks to control *Merremia peltata* by directly confronting its rapid growth and smothering potential, a fact that results in tremendous energy and resources being applied in what is likely a futile effort to stop its growth and spread.

A third, and more likely viable strategy is to manage *Merremia peltata* in situ by assisting the successional process along. Edge containment would be necessary, but the trees to be planted on the edges would include those species that are capable of competing with *Merremia peltata*, including *Macaranga harveyana* and *Kleinhovia hospita*. Being fairly common on the landscape already, these could be planted vegetatively on the edges of the management area and be allowed to intermingle with the vine cover. As these trees mature and lift the vine cover from the ground, more of these competitive species could be planted at these new edges, and shade tolerant tree species could be planted under the shade of these first cohort competitors. As these secondary cohort trees mature and shade out the *M. harveyana* and *K. hospita*, these primary competitive tree species could be selectively thinned out, to allow for more native tree species to be planted. This strategy's advantages include its ability to be implemented quickly, given the ready supply of wild *M. harveyana* and *K. hospita* stock, and would unfold gradually, allowing time for the accumulation of less common tree stock in the nurseries. Since a vine veil would be

maintained, better control of species composition could be accomplished. The spread of the vine would still need to be made along the edges of control areas, but would require considerably less effort and frequency than if the vines had to be kept off young saplings as well. More control areas could be implemented at one time as a result of these factors.

With any of these three strategies, there will need to be human intervention into the dispersion of some tree species, especially endemics. These species appear more vulnerable to loss through disturbance due to their poorer ability to replenish their numbers. With disturbance having occurred to the lowland rainforest ecosystem to the extent that it has, it is unlikely that their numbers will recover sufficiently and in a timely manner unaided by people. It is critical then, that the integrity of existing forest preserves be maintained as a source for these less dispersible species. Logging should be discouraged at all costs, and the Forestry Act should be amended such that the fines and penalties imposed on violators acts as a sufficient deterrent.

Ultimately, a combination of all of these strategies could be employed. For instance, shade-brakes could be established along the edges of the management area in addition to planting competitive species within the vine cover. Over time, then, the edge control of vine spread would become self-sustaining. Alternatively, management design could take into account already existing natural shade-brakes. Stone walls of sufficient height and thickness could be employed to contain the spread of vines as ground cover. Several instances of walls acting as breaks were observed in the field, although in one case, a *Merremia peltata* runner managed to

penetrate through the gaps between the stones. Additionally, it may be desirable to limit the vertical growth of *Macaranga harveyana* or *Kleinhovia hospita* that are planted along the edges of control areas, to prevent the lifted vines from spreading into the canopy of neighboring areas. A variety of techniques should be attempted, to achieve the goals of containing vine spread, lifting the vine cover from the ground, and hastening the rate of turnover by manually dispersing the seeds of trees that are desirable for preservation.

The use of biotic controls to control *Merremia peltata* is to be discouraged. The use of this technique would likely result in an increased abundance of non-native, wind-dispersed species, such as *Funtumia elastica*, in areas undergoing regeneration. Management efforts should instead try to take advantage of *Merremia peltata*'s ability to suppress the growth of other species and aid the succession process. Additionally, biotic controls would have an impact on village agriculture, although more research needs to be done to ascertain exactly what those impacts would be. It is also unclear whether those control organisms would remain specific to *Merremia peltata* once it was brought under control. Aiding the regeneration process by ushering it along is a more prudent strategy than assuming the species is universally detrimental and imposing the same solution on everyone.

Summary

Biodiversity conservation is concerned with staving off the extinction of species, with habitat loss and invasive species being cited as the primary causes of

extinction. The invasion of *Merremia peltata* in the Pacific has been identified as a problem of biodiversity conservation, despite the fact that it is native to the Pacific. This research indicates that both the *Merremia peltata* invasion and the greatest threat to native biodiversity are a function of shifting patterns of disturbance on the landscape, which have both created the opportunity for the spread of *Merremia peltata* and reduced the number and abundance of poorly dispersing plant species, such as endemics. The threat to biodiversity seems to be a question of disturbance, and the path to recovery lies in aiding the natural succession process as well as intervening in the dispersal of threatened species. The dominance of *Merremia peltata* on the landscape indicates severe trauma to the lowland ecosystem, but attacking this species as the problem and removing it as the solution, that is, by treating it as a non-native invasive, fails to address the root cause of the problem, and does not conceive of the problem adequately in terms of biodiversity conservation.

The social phenomenon of this biotic invasion, both in terms of the biogeographical and anthropogenic processes contributing to its domination on the landscape and the ways in which this invasion is conceived of as a problem and how it should be approached for a solution, are intimately tied into the historic, economic and political linkages between Samoa and the cosmopolitan centers of the South Pacific region. Economic ties during the colonial and post colonial periods established the pattern on the landscape that resulted first in prolonged and frequent disturbance on the landscape reducing the presence of rarer plant species in the regenerating communities during the colonial period due to the planting of various

tree crops (coconuts especially) and later to an expansion of shifting cultivation that created the preconditions for the *Merremia peltata* invasion. These factors have involved the integration of pre-capitalist modes of production, shifting cultivation and the *matai* system of land tenure, into the global capitalist market. The characteristics of these economic linkages have changed over time, as the Samoan economy has become characterized less by the export of agricultural commodities and more by immigration abroad and the resulting remittances flowing back to the country. The export of taro occurred in direct connection with the growth of the Pacific Island Community in the cosmopolitan core countries, and the loss of the taro export market following the taro blight is the most immediate cause of the dominance of *Merremia peltata* on the landscape. The movement of Pacific Islanders between the Pacific Island countries and the cosmopolitan core countries is a target of biosecurity measures by those countries. These measures advocate the control of invasive species in the countries where they occur as a means of preventing their spread. *Merremia peltata* has been thus targeted for control, a fact that raises the possibility that Samoa's native ecosystems could be harmed for the sake of protecting the ecosystems of the core countries. Biosecurity concerns appear to dominate biodiversity preservation efforts in the Pacific.

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This dissertation was typed by the author.