AN INDIGENOUS STRATEGY FOR INTENSIFYING SHIFTING CULTIVATION IN SOUTHEAST ASIA: A SHRUB-BASED (*TECOMA STANS*) MANAGED FALLOW IN WEST TIMOR, INDONESIA

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by

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ABSTRACT

This study contributed to a set of case studies designed to investigate farmer-generated strategies for intensifying the fallow phase of shifting cultivation systems in upland Southeast Asia. In this study, I documented an indigenously developed, managed fallow system in West Timor, Indonesia, based on *Tecoma stans L.* (Bignoniaceae), an invasive, fast-growing shrub. Farmers indicated that *T. stans* fallows rejuvenated soils for maize cropping within five years. The fallows also produced fuel wood, light construction material, vegetable stakes, and some fodder for cattle. My findings indicated that the *T. stans* fallow served as both a more effective and a more productive fallow, based on Cairns' typology. In addition, I examined the political, economic, and social contexts of farmers using *T. stans* fallows. I thereby identified ways in which farmers attempted to enter the market system as well as constraints to their efforts. Finally, I reflected on a framework and characterization template created specifically for documenting indigenous strategies for intensifying managed fallows. The framework and template were useful in guiding the study such that it addressed a diversity of biophysical, political, economic, and social factors. It facilitated the development of an integrated representation of the resources and constraints of small farmers so that informed intervention strategies could be developed. Use of the framework also presented the possibility for more thorough comparisons of fallow systems and the broader contexts in which they occurred across sites in Southeast Asia.

BIOGRAPHICAL SKETCH

Ellen McCallie was born in Chattanooga, Tennessee, and raised in Chicago, Illinois, and St. Louis, Missouri. Prior to college, Ellen lived for a year as an AFS exchange student to SMA5, Bogor, Indonesia. She earned a B.A. in biology with a concentration in environmental studies at Grinnell College in Grinnell, Iowa. Following college, Ellen was a Fulbright Scholar in Manaus, Brazil, where she became involved with small-scale agriculture. At Cornell University, Ellen collaborated with CIIFAD (the Cornell International Institute for Food and Agricultural Development), particularly MOIST (Management of Organic Inputs in Soils of the Tropics) and CAWG (Cornell Agroforestry Working Group) which had active interests in fallows in Southeast Asia. Through CIIFAD and ICRAF (the International Center for Research on Agroforestry, also known as the World Agroforestry Center), Ellen was introduced to Politani (the Agricultural Institute), Kupang, West Timor, Indonesia. She collaborated with CIIFAD, ICRAF, and Politani from January 1996 to May 1998 to produce this thesis. Since 1998, Ellen has worked in science education, science communication, and research in a variety of science-based museums and public school districts. In addition, she was a scientist/presenter for five seasons of the BBC/Open University television series Rough Science. She is currently completing a Ph.D. at King's College London, UK, focusing on argumentation among scientists and publics on topics of controversial science-based issues, such as global climate change. In addition, she serves as the director of the Center for Advancement of Informal Science Education (CAISE), funded by the National Science Foundation (NSF) and based in Washington, DC.

Dedicated to the Fallows Working Group at Politani, Kupang, West Timor, Indonesia, to the Managed Fallows Working Group, Cornell University, Ithaca, NY, USA, and to Dean J. Ellen Gainor, Dr. Janice Thies, Dr. Robert Blake, and several others who understood I couldn't give up—so they didn't let me.

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TABLE OF CONTENTS

BIOGRAPHICAL SKETCH iii

DEDICATION iv

ACKNOWLEDGMENTS v

LIST OF FIGURES xii

LIST OF TABLES xiii

CHAPTER ONE: INTRODUCTION 1

- CIIFAD and the workshop series 2
- Southeast Asia workshop: Goals 4
- A rationale for studying the fallow phase of shifting cultivation 6
- Characterizing a shrub-based system in West Timor, Indonesia 7
- Structure of this thesis 7

CHAPTER 2: LITERATURE REVIEW 9

- Defining terms 9
    - Analytical framework 9
    - Subsistence agriculture 9
    - Technology transfer 10
    - Intensification 10
- A review of shifting cultivation 10
    - The conversion phase 11
    - The cropping phase 12
    - The fallow phase 13
- The managed fallow seminar and Southeast Asia workshop 18
    - Outcomes of the managed fallow seminar 18

Outcomes of the Southeast Asia workshop 26
Review of literature on West Timor, Indonesia 27
Climate 27
Topography and geology 29
Soils 29
Soil fertility and suitability for agriculture 33
History of livestock production in West Timor 33
History of vegetation on West Timor 34
History of shifting cultivation in West Timor 35
CHAPTER 3: METHODOLOGY AND METHODS 42
Methodology 42
Rapid Rural Appraisal 42
A case study approach 43
Selecting the agricultural system and the individual farms 44
Methods of data collection 45
The role of the characterization template 45
Data collection 46
Semi-structured interviews 46
Maps, calendars, and photographs 47
Soil samples 47
Vegetation samples 49
Reliability and validity within the research process 49
Data analyses and interpretation 49
Analysis of soil samples 49

Analysis of vegetation samples 50
Interviews 50
Calendars, maps, and photographs 50
Secondary data collection 51
Context 51
Location of the study 51
CHAPTER 4: AN INDIGENOUS STRATEGY FOR INTENSIFYING SHIFTING CULTIVATION 53
Findings: The political, economic, and social context 53
Political structure 53
Economic structure 55
Social structure 63
Findings: A description of the agricultural system 65
Soil classification by farmers 65
Soil analysis results 67
A history of agriculture in the area as reported by farmers 70
Overall vegetation description and land use 70
The agricultural system 70
A brief history of the agricultural systems 71
Livestock production 75
Permanent cultivation 76
Shifting cultivation 77
Maize-T. stans shifting cultivation system 77

CHAPTER 5: ANALYSES, INTERPRETATIONS, AND RECOMMENDATIONS WITH RESPECT TO THE CASE STUDY 85

Soil: Interpreting observations, farmer-derived data, and laboratory analyses 85

Red soils 85

Black soils 87

White soils 87

Analysis and recommendations for agricultural systems 88

Biomass management 88

Weed management 88

Crop residue management 89

Maintaining soil fertility during conversion 89

Present fertilizer applications: Possible rationales 90

Fertilizer recommendations 91

Conclusions 96

CHAPTER 6: REFLECTING ON THE ANALYTICAL FRAMEWORK AND TEMPLATE: REACTIONS AND CONCLUSIONS 98

Reflecting on the theoretical framework: Using fallow systems as an entry point 98

Reflecting on methods: Comments concerning the ease and use of the template . 100

Conclusions 102

APPENDIX A: CHARACTERIZATION TEMPLATE (BLANK) 104

APPENDIX B: REVIEW OF SOILS OF WEST TIMOR 118

Soils of West Timor reported by Monk et al. (1997) 118

Soils of West Timor reported by ISRIC-WISE 122

Soils reported in West Timor based on government sources 123

Soils in West Timor from other sources 124

APPENDIX C: CHARACTERIZATION TEMPLATE FOR *T. STANS* FALLOW SYSTEM 126

APPENDIX D: RAW DATA FROM SOIL ANALYSES OF *T. STANS* FALLOWS ...148

REFERENCES 150

LIST OF FIGURES

Figure 1. Bali cattle from West Timor. 34

Figure 2. The distribution of *T. stans* in fields in relation to large coral rocks and the area cropped with maize. 48

Figure 3. Map of a section of the village of Belo. 57

Figure 4. Map of the village of Fatukoa. 58

Figure 5. Map of the village of Tunfeu. 59

Figure 6. Young *T. stans* fallow on soil with small coralline rocks. 65

Figure 7. *T. stans* fallow resprouting out of large coralline rocks. 66

Figure 8. *T. stans* flower and seed pod. 73

Figure 9. *T. stans* as an ornamental in West Timor. 74

Figure 10. Five year old *T. stans* fallow. 82

Figure 11. Farmers unloading bundles of fuelwood (*T. stans*) for sale. 83

Figure 12. Farmer collecting large coral rocks from fallowed fields. 102

LIST OF TABLES

Table 1: Rainfall data from Kupang weather stations: 1887-1940 28

Table 2. Categories of income generating products that were part of the livelihood of local farmers in this study 60

Table 3. Activities calendar: Women. 63

Table 4. Activities calendar: Men. 64

Table 5. Activities calendar: Children. 64

Table 6. Field crops and products by soil type and use category, excluding home garden products. 68

Table 7. The results of averaging analyses from 11 soil samples from fields in the maize-*T. stans* shifting cultivation system. 69

Table 8. Crop calendar. 78

Table 9. Uses of *T. stans* by season. 79

Table 10. General comparison of fallow species 83

Table 11. Soil analyses of the red calcareous soils 86

Table 12. Constraints to crop production in shifting cultivation. 93

CHAPTER ONE: INTRODUCTION

My primary aim in this study was to characterize and analyze a previously undescribed upland shifting cultivation system that included a novel fallow phase developed by resource-constrained farmers in upland Southeast Asia. The shifting cultivation system documented here occurred in at least three villages in West Timor, Indonesia, where the weedy shrub *Tecoma stans L.* (Bignoniaceae) was the dominant fallow species.

This study was part of a larger program of research and development organized by CIIFAD (Cornell International Institute for Food, Agriculture, and Development) to understand and improve the lives and livelihoods of resource-constrained farmers in tropical areas. With CIIFAD funding, this study was conducted in collaboration with Nusa Tenggara Upland Development Consortium (NTUDC) and the Agricultural Polytechnic Institute (Politani), Kupang, West Timor, Indonesia. In addition, it contributed in two ways to a workshop on Indigenous Strategies for Intensification of Shifting Cultivation in Southeast Asia, Bogor, Indonesia, June 23-27, 1997. First, the study's overarching results were presented at the workshop in Bogor, Indonesia and, second, they were later published in an edited volume based on the workshop (Djogo et al., 2007). In this thesis, I expand on the workshop presentation and the publication in several ways. First, I frame the case study in terms of the literature on shifting cultivation, the Southeast Asia workshop, and the study area. Second, I present a more detailed case study and discuss preliminary soil analyses. Finally, I examine the findings from the case study in light of the analytical framework and characterization template that were created as part of a managed fallows seminar and the Southeast Asia workshop in Bogor.

CIIFAD and the workshop series

On-going, on-site research and development efforts by CIIFAD and its collaborators in the mid-1990s indicated that green manures (GM), cover crops (CC), and managed fallows (MF), collectively known as GMCCMF, held particular promise for improving the lives of resource-constrained farmers in the tropics. Acting on these experiences, MOIST (Management of Organic Inputs in Soils of the Tropics of CIIFAD) convened an international meeting at Cornell University in Ithaca, NY, in April, 1996. The meeting defined and mobilized resources for a series of workshops focusing on GMCCMF in Asia, Africa, and Central America. The series aimed to identify strategies to:

1. Facilitate, improve, and expand the use of cover crops and managed fallows, in order to increase the sustainability of tropical farming systems;
2. Improve the livelihood of small scale resource-poor farmers;
3. Identify common issues or system components linking the regions;
4. Strengthen inter-regional linkages; and
5. Identify collaborative opportunities (Fisher, 1998).

By August 1997, one global and four regional meetings had taken place, bringing together agricultural researchers, extension agents, community development workers, representatives from farmer organizations, officials responsible for agricultural policy, and representatives of donor agencies. The meetings included:

1. A Regional Workshop in Central America designed to produce an "Information Kit" on Green Manure/Cover Crop Technologies, Tegucigalpa, Honduras, August, 1996. This workshop drew on experience of farmers,

technicians, and researchers to produce a digest of practices to consider applying elsewhere.

2. A Global Meeting on Green Manure - Cover Crop (GMCC) Systems for Small-holders in Tropical and Subtropical Regions, Chapeco (Santa Catarina), Brazil, April 6-12, 1997. The overall goal of this meeting was to develop strategic agendas to promote research and the use of GMCC systems for smallholders worldwide. These agendas sought to build upon experiences surrounding research, development, evaluation, and adoption practices related to GMCCMF systems by smallholders in different tropical and subtropical regions.

3. A Regional Workshop on Cover Crops in Sustainable Agriculture in West Africa: Constraints and Opportunities, Cotonou, Benin, October 1-4, 1996. By drawing on regional experiences, workshop participants discussed and identified the major opportunities and constraints related to smallholders' use of cover crops in West Africa.

4. The Science and Practice of Short Term Improved Fallows in Humid and Sub-humid Tropics, Lilongwe, Malawi, March 11-15, 1997. This workshop focused on short-term fallows of shrubs, herbaceous species, and trees, whose primary role was to maintain or restore soil fertility.

5. Indigenous Strategies for Intensification of Shifting Cultivation in Southeast Asia, Bogor, Indonesia. June 23-27, 1997. Participants in this workshop presented case studies in which farmers had successfully developed managed fallows. Workshop organizers then identified trends in fallows and the contexts in which they thrived.

An integral part of each meeting was the use of case studies describing the successes, challenges, and contexts of small-scale agriculture in the upland tropics (Fisher, 1998). This focus on cases studies resulted from researchers realizing there was often relatively greater success of indigenously developed innovative strategies as compared with externally introduced agricultural solutions (Cairns, 2007b). For each workshop, numerous individual cases studies were collected or commissioned. The resulting data sets were used to characterize what was occurring in the field and to identify themes for further research and development. The case study described in this thesis was commissioned specifically for the Southeast Asia workshop.

Southeast Asia workshop: Goals

As research, extension, and development workers in Southeast Asia reflected on their experiences with resource-constrained upland farmers in the mid-1990s, they realized that in areas where small-scale agriculture based on shifting cultivation was under stress, farmers were modifying the fallow phase of shifting cultivation. Specifically, farmers managed fallows more intensively as a strategy to increase the productivity of their agricultural systems and to improve their livelihoods in the face of changing circumstances or needs. Based on these observations, the Southeast Asia workshop organizers defined the workshop's goals:

1. Review a series of case studies where farmers successfully developed strategies for intensifying shifting cultivation by modifying how they managed fallows;
2. Synthesize current knowledge on these indigenous systems;
3. Evaluate whether farmer innovations were context-specific or whether they were replicable (transferable) to other stressed agroecosystems in Southeast Asia;

4. Compare and evaluate research methods in order to develop a common research approach for studying the fallow phase of shifting cultivation in the region;
5. Identify and clarify emerging research questions and formulate longer-term research agendas around managed fallows;
6. Establish a collaborative structure to enable a regional research thrust; and
7. Stimulate donor interest in funding further research by highlighting the importance of farmer-generated innovations.

The processes for achieving these goals were multi-fold and included soliciting case studies from all over Southeast Asia. The authors of the case studies represented non-governmental organizations, conservation groups, upland research and development projects, forest managers, indigenous technical knowledge centers, academics, NARS (National Research Centers), CGIAR (Consultative Group International Agriculture Research) Centers, and government policy makers.

CIIFAD contributed to several facets of the Southeast Asia workshop. In addition to providing funds through two of its thematic working groups (MOIST and CAWG (the Cornell Agroforestry Working Group)) and two of its country programs (Indonesia and Philippines), CIIFAD representatives collaborated on several case studies, specifically with the Visayas State College of Agriculture in the Philippines, the Forest Research Center of Vietnam, and the Nusa Tenggara Upland Development Consortium (NTUDC) and the Agricultural Polytechnic Institute (Politani) in Kupang, West Timor, Indonesia. The case study presented in this thesis resulted from the collaboration between NTUDC, Politani, and CIIFAD. In addition, CIIFAD sponsored a seminar working group, henceforth referred to as the managed fallow seminar, at Cornell University specifically around the theme and case studies of this workshop. In the autumn of 1996, an interdisciplinary team of graduate students, faculty, and staff provided:

1. A peer review of the workshop papers;
2. A synthesis of current knowledge on fallow systems;
3. A synthesis of trends in how farmers managed the fallow phase of shifting cultivation;
4. An overview of the biophysical, social, political, and economic components in which fallows were employed; and
5. An analytical framework for research and development efforts with regard to managed fallows.

A rationale for studying the fallow phase of shifting cultivation

Given the three phases of shifting cultivation (the conversion phase, the cropping phase, and the fallow phase), the Southeast Asia workshop, managed fallow seminar, and this study focused on the fallow phase of shifting cultivation for four reasons. First, observations demonstrated that, while the availability of seed, credit, labor, and fertilizer limited resource-constrained farmers in terms of improving the cropping phase of their systems, farmers could still productively innovate within the fallow phase. Second, changes in how farmers managed fallows, such as changes in fallow duration, composition, and management strategy, were likely to indicate the major pressure(s) on the farming community, such as increasing population, decreasing land availability, and access to markets, capital, or inputs. Third, changing fallow management practices was considered an important pathway to either (1) converting a collapsing shifting cultivation system into a sustainable upland agricultural system or (2) transitioning to permanent agriculture or other livelihood practices. By understanding how and why farmers were intensifying their fallows, the managed fallow seminar group reasoned that researchers and development workers could identify critical issues in the context of farmers, points of potential intervention, and the transferability of intensified fallow systems to other locations. The results of these efforts could improve the lives and livelihoods of these and other resource-constrained farmers in upland Southeast Asia.

Characterizing a shrub-based system in West Timor, Indonesia

The backbone of the managed fallow seminar and the Southeast Asia workshop was specific case studies. In this context, I represented CIIFAD and helped a Politani research team characterize the *T. stans* managed fallow system, a previously undocumented, but locally developed, managed fallow system near south Kupang, West Timor, Indonesia. This was one of over sixty case studies focusing on how resource-constrained, upland farmers intensified their shifting cultivation systems that contributed to the Southeast Asia workshop.

Structure of this thesis

This thesis consists of six chapters. In Chapter 1, I set out my aims for the thesis and the context in which the study occurred. In Chapter 2, I provide a review of shifting cultivation, managed fallows, and the particular area in which I undertook the case study. This chapter draws from the published literature as well as the outcomes of the managed fallow seminar and Southeast Asia workshop. In Chapter 3, I describe the methodology and methods used in the case study. In Chapter 4, I characterize a shifting cultivation and livelihood system from West Timor, Indonesia, which included a *T. stans* fallow. I provide analyses and recommendations with respect to the case study in Chapter 5. In Chapter 6, I conclude the thesis by reflecting on the case study with respect to the managed fallow seminar and the Southeast Asia workshop, specifically focusing on the characterization template and the larger context of shifting cultivation by resource-constrained upland farmers.

CHAPTER 2: LITERATURE REVIEW

This chapter is organized into four sections. In the first section, I define terms relevant to the thesis. In the second section, I review relevant literature on shifting cultivation. In the third, I present the processes and outcomes of the managed fallow seminar and the Southeast Asia workshop with respect to managed fallows, shifting cultivation, and their contexts. I conclude the chapter by reviewing literature on the region in which the case study occurred.

Defining terms

Analytical framework

An analytical framework provides a context and a structure within which to conduct research and evaluate findings. An analytical framework is also inherently value-laden and goal-oriented. The analytical framework used in this study was based on the goals set for the Southeast Asia workshop and the assumptions and lessons-learned from the managed fallow seminar. The framework was also used to develop a tool, the characterization template, to facilitate organizing information and for subsequent decision-making.

Subsistence agriculture

In the context of this thesis, subsistence agricultural practices are those that result in food being grown by farmers for home consumption. In most cases with resource-constrained farmers, farmers produce the vast majority of the food they consume. In some cases, even though it would be less expensive to buy certain food, cultural practices or the lack of cash resources prompt farmers to produce their own. Subsistence agriculture is often complemented by growing cash crops, which farmers sell, rather than consume. The shifting cultivation system described in this thesis was a subsistence agricultural system. Its primary product, maize, provided the dietary staple of the farming family.

Technology transfer

Technology transfer is defined as introducing a practice or method of agricultural production into a new community. The transfer may or may not be accompanied by significantly adapting the technology to the new locale.

Intensification

Intensification, in terms of fallows, means that farmers increase their management or intervention in time and/or space within their shifting cultivation system. Inherent in the farmers' practices is the intent to increase overall land output or land output efficiency based on labor.

A review of shifting cultivation

Shifting cultivation is an agricultural system in which fields are rotated between supporting subsistence annual crops and rejuvenating them as fallows (Nye & Greenland, 1960). The premise is that, after a few years of cultivation, annual crop yields decline. This decline is the impetus for abandoning annual crop production in those fields. The subsequent fallow period functions to recuperate the agronomic characteristics of the field. Specifically, fields are fallowed until the soil fertility and soil structure have rejuvenated such that the field, once again, produces acceptable crop yields. The fallowed field is then converted to produce crops, typically via slashing and burning. A successful shifting cultivation system is one in which the system can be "prolonged for many cycles without noticeable erosion of the soil, a change in the type of fallow, or a marked decline in yields among cycles" (Nye & Greenland, 1960, p. 127).

Although the soils of the tropics in regions inhabited by resource-constrained farmers tend to be chemically and physically challenging environments for crops, generations of small-holder farming communities have successfully negotiated these biophysical constraints and have produced crops by employing shifting cultivation. Traditionally, the cropping phase of shifting cultivation lasts 1 to 3 years, while the fallow phase lasts at least 20 years (Styger & Fernandes, 2006). This long fallow phase is historically dominated by secondary forest plant species and successional processes.

With an increasing human population, restricted land access, and changes in cultural practices, however, many traditional shifting cultivation systems are biophysically ineffective at producing sufficiently high and sustained crop yields to meet farmers' needs. In response, farmers have modified their agricultural practices in each stage of shifting cultivation: the conversion phase, the cropping phase, and the fallow phase.

The conversion phase

The conversion phase between the fallow and cropping phase should create the system's optimal growing conditions for annual crops. Conversion by slashing and burning vegetation releases nutrients from fallows into three pools. The first pool is the atmosphere to where nutrients (primarily carbon (C) and nitrogen (N)) volatize and are lost from the immediate system (Kauffman,et al., 1995). The second nutrient pool consists of ash that remains on the soil surface. The ash is relatively high in phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca) (Kauffman et al., 1995). The ash, which forms an immediate nutrient source for plants, is generally highly susceptible to wind and water erosion and can easily be lost from the system (Kauffman et al., 1993). The third pool is the incompletely burned biomass, primarily in the form of tree trunks and large branches that are left in fields. These form a long-term, slow-release source of nutrients (Nye & Greenland, 1960; Sanchez, 1976).

Properly managing the conversion phase (1) opens the canopy, providing a high light environment for crops, (2) temporarily sets back the growth of potentially competitive plants from both root stocks and seeds, (3) converts nutrients bound in fallow vegetation into a flush of plant-available nutrients, and (4) maintains or improves physical and chemical properties of soil (Nye and Greenland, 1960; Sanchez, 1976).

Intensification within the conversion phase generally means moving from slashing and burning to slashing and mulching using green manures or cover crops. These latter alternatives were examined in the workshops held in Honduras, Brazil, and Benin.

The cropping phase

Crop yields typically drive overall management and decision-making in shifting cultivation systems. Crops in shifting cultivation systems are usually subsistence-based annual crops, typically those high in starch, which provide the calorie base for the resource-constrained farmer.

Planting, crop growth, and harvesting during the cropping phase generally depend on natural rainfall in resource-constrained areas. Crops are planted one to three times a year, depending on rainfall patterns and/or irrigation. Crop yields generally decline after one to three years of cropping. Factors leading to declining crop yields include (Nye & Greenland, 1960; Sanchez, 1976):

1. Deteriorating soil nutrient status due to crop nutrient uptake and crop harvesting, weed nutrient uptake, and wind and water erosion;

2. Increasing weed density and/or diversity, which compete with crops for resources;
3. Increasing pest damage and diseases due to mono-cropping and/or increased time for them to invade and establish; and
4. Deteriorating physical components of the soil and its associated flora and fauna.

Since the late 1970s, researchers and development workers have explored extending the cropping cycle and increasing yields with varying degrees of success (see Smyth and Cassel, 1995, for a thorough review). These efforts often require tremendous amounts of inputs—mechanized cropping systems, increased labor and fertilizer, improved seed, and/or irrigating fields—none of which are typically feasible for the resource-constrained farmer. In the context of the overall workshop series, the Southeast Asia workshop, and this case study in particular, it was assumed that the cropping phase of shifting cultivation was at its maximum productive capacity, given farmers' resources. For this reason, farmers living under stressed conditions looked to innovate using GMCCMF, for the fallow phase of shifting cultivation.

The fallow phase

In shifting cultivation systems, farmers eventually decide not to plant annual crops in a field and instead fallow the land. While most of the constraints to crop production faced by small farmers were identified in studies of shifting cultivation in the 1950s and 1960s (Nye and Greenland 1960), more recently scientists have focused their efforts on understanding the fallow phase (Cairns, 2007c; Sanchez, 1976; Styger & Fernandes, 2006). The basic principles are that fallows rejuvenate soil fertility that is depleted by the annual crops and that fallows improve soil physical properties (ICRAF, 1997a, 1997b; Sanchez, 1976). In addition, fallows can provide products and services, such as fuel wood, fruit crops, or grazing land for livestock (Styger and Fernandes, 2006).

In historical shifting cultivation systems, farmers fallow land and allow it to proceed through secondary growth and plant succession toward mature forest. Vegetation establishment and successional patterns are well described (Buschbacher et al., 1988). Major influences on fallow vegetation and regeneration rates are (1) the length of cropping prior to fallowing and how the crops are managed, (2) the nature of the seed bank and seed influx, and (3) the type of roots and stumps that regenerate (Nye and Greenland, 1960; Sanchez, 1976). Typically, shifting cultivators judge the readiness of a piece of land for cropping by the vegetation composition and soil properties of the fallow. While these properties often correlate closely with the length of time land has been fallowed, it is not the age of the fallow that triggers its conversion to cropland. Specifically, vegetation and soil characteristics of fallows serve as indicators for the farmer as to whether or not good annual crop yields are likely.

In historical systems, typical fallows are of 20 or more years, followed by one or two years of cropping (Styger and Fernandes, 2006). More recently, fallow lengths have decreased. The ability of fallows to overcome biophysical constraints to cropping depends on environmental and climate factors as well as on fallow management (ICRAF, 1997b). As less and less land is available to shifting cultivators, and as less and less mature forest remains, fewer fallows are composed of secondary forest vegetation. Instead, farmers shorten the length of their fallows and intensify how they manage these fallows. The most common way farmers alter their fallows is by shortening the fallow length. While shortened fallow length can lead to (1) less mature fallows at slash and burn, (2) lower soil nutrient stocks, (3) more weedy vegetation, and (4) viable seed banks which compete with planted crops, some farmers overcome these constraints through intensifying fallow management using herbaceous plants, shrubs, or fast-growing trees (Cairns, 2007a, 1997; Nye & Greenland, 1960; Styger & Fernandes, 2006). These changes in fallow management have triggered greater interest in fallows and a desire to understand the ways in which farmers operate them successfully (Garrity, 2007; Sanchez, 1999).

With increased management, the primary purpose of the fallow phase often changes from one of slowly rejuvenating land for future cropping phases to one of two generalized paths of farmer innovations: (1) more *effective* fallows which accelerate the biophysical efficiency of fallows to restore soil fertility and (2) more *productive* fallows in which farmers add value to the fallow by introducing economically valuable perennial species. When combined, these two trends result in both biophysical and economic benefits (Cairns, 2007a; Conklin, 1961; Garrity & Lai, 2001; Styger & Fernandes, 2006).

Van Noordwijk (1996) suggests that an inverse relationship exists between more effective and more productive fallows. For example, on one hand, more effective fallows enhance the agronomic functions of the fallow phase of shifting cultivation. They rehabilitate the chemical, physical, and biological functions of the soil. They control erosion and limit weed and pest invasion. In most cases, more effective fallows decrease the time a piece of land is fallowed while still rejuvenating the soil for the cropping phase. In many instances, farmers achieve more effective fallows by using specific management practices, including preferentially cultivating certain fallow species. At the extreme end of the continuum of more effective fallows are ones in which soil properties are rejuvenated in a year or two, allowing for almost annual cropping over an extended period of time. On the other hand, more productive fallows increase the amount or diversity of harvestable products from the fallow phase of shifting cultivation. For example, more productive fallows provide household needs, such as fuel wood or cash crops, such as fruit. Managing land for more productive fallows results in the intentional planting of particular species. In some cases, more productive fallows also require longer fallowing times in order to produce harvestable products. In fact, the phase of re-opening fields and cultivating annuals may eventually be foregone altogether as farmers protect perennial vegetation, allowing it to develop into semi-permanent or permanent agroforests. Permanent agroforestry systems may be thought of as the extreme end of the continuum of more productive fallows as the fallow vegetation becomes the cropping system.

More effective or accelerated fallows often provide an intermediate step in the process of transitioning to permanent cultivation of annual crops. More productive fallow species may produce high value products, such as timber or fruit, and provide subsistence goods, such as fuel wood, while still effectively rejuvenating the land for sufficient subsequent crop yield.

For the purpose of the managed fallow seminar, the Southeast Asia workshop, and this case study, managed fallows are defined as those fallows that farmers intentionally manipulate for the purposes of achieving enhanced ecological efficiency (more effective fallows), economic productivity (more productive fallows), or some combination of these two benefits (Cairns, 2007a). Either or both practices constitute intensified land use management.

Cairns (2007a, 1997) developed a typology for fallows in the 1990s, which was used to advise the Southeast Asia workshop. It includes six types of fallows based on fallow length and fallow attributes. The typology ranges from semi-permanent, mixed-species plantings to short-lived monocultures. Within each fallow type, naturally invading species and farmer planted species can be differentiated (Styger and Fernandes, 2006).

The Cairns types include (Cairns, 2007a, 1997):

1. Agroforests in which mixed species produce a variety of products over the course of the forest's lifetime, from 5-200 years;
2. Perennial-annual crop rotations in which perennial crops, such as timber species growing for up to 30 years, are cycled with annual crops;
3. Dispersed tree fallows in which nitrogen-fixing legumes or non-legume trees are cultivated for forage, timber, fuel wood and other products from 3 to 20 years;
4. Preferred voluntary species in which the species that voluntarily invade fallows are retained or promoted, such that farmers reap economic and/or ecological benefits from their presence within 5 to 20 years;
5. Shrub-based accelerated fallows in which fast-growing species, including nitrogen-fixing species, improve biophysical field components and also provide economic products within 1-4 years; and
6. Herbaceous species in which seasonal fallows, such as herbaceous legumes and grasses, are grown for up to 3 years.

One contribution of Cairns' (2007a, 1997) typology is that he recognizes fallow systems in which preferred volunteer species are retained or promoted. Such an approach in Southeast Asia includes farmers who base their fallow intensification on what are typically considered nuisance weedy species. Traditionally, farmers approach weedy fallow species as they approach most weeds: they try to eradicate them or they wait until a fallow naturally suppresses them through the processes of succession. Weedy fallows often occur, however, when locally-acting factors allow a species or species complex to invade or dominate an area. For example, a prolonged cropping cycle may depress the typical means of fallow recovery by secondary species: seed banks, stump sprouting, and recruitment via introduced seeds. Weedy species often thrive in such degraded soils or deforested areas. Without a quickly recovering canopy produced by secondary species, some weedy species gain a competitive edge, allowing them to retard further succession.

Paradoxically, the cases studies from the Southeast Asia workshop (as well as from the Malawi workshop) document that some farmers find weedy fallows to facilitate more frequent cropping and shorter fallow times (more effective fallows) due to their rapid natural regeneration and growth, competitive ability, and self-seeding and/or fire tolerance (ICRAF, 1997a, 1997b). Therefore, instead of trying to control weeds, farmers are exploiting them, particularly when the farmers' contexts do not allow the extended fallow time needed for decreasing weed species and weed seed banks thorough successional processes. Thus, plant species traditionally considered detrimental to the fallow phase are being embraced and exploited by farmers in managed fallows. In the case study presented in this thesis, I characterized one of these weedy fallows, that of *T. stans*.

The managed fallow seminar and Southeast Asia workshop

Outcomes of the managed fallow seminar

Through a process of iterative discussions based on reviewing the case studies prior to presenting them at the Southeast Asia workshop, the managed fallow seminar participants identified the following themes regarding shifting cultivation and fallow management in Southeast Asia.

First, agricultural knowledge and problems were not the root cause of poverty or stress for resource-poor farmers. Instead, the political, economic, and social milieus of the resource-poor farmer were the causal issues. However, short of local, regional, and international overhaul of the political, economic, and social systems, resource-constrained farmers' hopes for the near future depended on modifying their agricultural practices. By intensifying the fallow stage of their shifting cultivation systems, farmers were taking a very rational and promising approach to improving their lives.

Second, technology transfer did not provide simple solutions for farmers. These farmers were not isolated or technologically limited and the challenges they faced were not solely agricultural. The political, economic, and social context of their lives and agricultural systems prevented an agricultural fix-all recipe. This position was somewhat in contrast to past research programs and development initiatives, in which it was assumed that farmers were striving for a specific, end-goal type of production system and that if prescriptive steps were taken, farmers would reach their goal(s). In case studies from the Southeast Asia workshop (ICRAF, 1997a), participating researchers and development workers recognized that farmers were generating and/or modifying the fallow phase of shifting cultivation in ways that addressed more than the biophysical aspects of the cropping system. These farmers innovated and altered their agricultural system in order to address the changing context of their shifting cultivation systems, including their values, goals, perceived opportunities, and constraints. In addition, there were patterns in the stresses that resource-constrained upland farmers in Southeast Asia faced.

Trends in the stresses faced by resource-constrained farmers

Management changes in shifting cultivation systems were often the result of other changes or constraints experienced by farmers. These constraints were not necessarily agricultural, but may have to do with any aspect of a farmers' livelihood. In general, changes in the farmers' political, economic, and social contexts produced prolonged stresses, while environmental anomalies led to unusual production years. Most of the scientific literature emphasizes biophysically based stresses (ICRAF, 1997a; Nye & Greenland, 1960; Sanchez, 1976; Smyth & Cassel, 1995). It was critical, however, to recognize that political, economic, and social forces also affected how farmers managed their fallows, which in turn altered the biophysical processes themselves.

Through the managed fallow seminar, five major trends were identified in the contexts of resource-constrained shifting cultivators' lives that led to changes in their agricultural practices.

The first trend was population increase. Population increase was the most commonly cited reason for the deterioration of shifting cultivation systems (ICRAF, 1997a). With population growth, changes in land management and tenure patterns occurred. Two types of population growth affected farmers: (1) area-wide density increases, which included in-migration and urban sprawl, and (2) familial population increases (more individuals living to adulthood), such that land holdings had to support larger numbers of people.

The second trend was a change in land tenure (ICRAF, 1997a). Increased commerce and land speculation, usually from outside the rural community, gave land a monetary value and spurred changes in land tenure patterns. Changes in tenure patterns were due to:

1. Establishment, regulation, and/or enforcement of government-owned land;
2. Establishment or increased prevalence of privately owned land; and
3. Overall breakdown of communal (or no-ownership) land patterns.

Examples of changing land tenure patterns included: selling parcels of land for temporary purchasing power and/or the need to demonstrate land use in order to obtain or maintain land ownership. Land tenure status of farmers (and/or the perception of their land tenure status) greatly affected farmers' management decisions. This was especially applicable in areas where land was not privately owned or was known to have been taken over by the state.

The third trend was greater influence exerted by a centralized government (ICRAF, 1997a). Increased and/or more centralized government systems were exercising authority over previously isolated areas and were mandating changes in livelihood patterns through taxation or by requiring tax payments in currency.

The fourth trend was the influence of wage labor and a cash-based economy (ICRAF, 1997a). Families met mandatory or desired cash flow by working for money both in and away from home communities, even though this removed or limited some family members' participation in the agricultural labor force. Nye and Greenland (1960) predicted this trend. Wage labor and non-farm income generation often competed with shifting cultivation for time and labor resources. In addition, children were often sent away to school or to work in towns, further depleting the labor supply for subsistence agriculture.

The fifth and final trend was the rapid and sustained state of fluctuations that resource-constrained farmers experienced. The milieu of the small farmer was constantly changing. Scientists often study technology transfer in model systems, but due to the complex and dynamic nature of many farming systems (and lack of functional extension systems), it remains difficult to implement a given system. Recommended practices soon lost their usefulness or needed to be constantly adapted to changing contexts.

An examination of the contexts in which resource-constrained shifting cultivators operated suggested that intensifying shifting cultivation did not alleviate poverty or all of its causes because agricultural systems were not the root of poverty for many people. The managed fallow seminar participants concluded that the majority of shifting cultivation farmers was moving into the mainstream, cash-based, market economy. Increased infrastructure allowed outsiders and mass communication into previously isolated areas. With greater exposure and potential access to things outside their immediate communities, shifting cultivators' worldviews, values, and goals often changed in relation to their changing context. This was documented in terms of farmers' efforts and desires to enter the cash-based market economy and their willingness to move toward permanent agriculture and/or other forms of livelihood. Shifting cultivation was not a system that was proving likely to allow farmers to move into the cash-based, market economy—permanent agriculture and other means of livelihood were more likely to do so and/or were more desirable. Intensified fallows were, however, a potential transitional bridge from subsistence agriculture to permanent agriculture or other means of livelihood. This is because agriculture was one major area in which farmers had a significant degree of control.

Many participants in the managed fallow seminar were not initially convinced that managed fallows held the most promise for moving resource-constrained farmers out of poverty. By the end of the seminar, however, the group firmly believed that there was sufficient evidence to support the argument that by intensifying the fallow phase of the shifting cultivation system, farmers were taking a very rational and promising approach to improving their lives and livelihoods.

Finally, the participants in the managed fallow seminar summarized the immediate conditions under which resource-constrained farmers operated and the larger trends in their livelihoods. First, resource-constrained farmers:

1. Had access to or owned only marginally fertile land (not prime agriculture land);
2. Had little or no access to fertilizer inputs (via gift or purchase);
3. Had insufficient land or were restricted by policy to have long fallows;

4. Had insufficient labor during at least the critical production periods to have highly managed systems; and
5. Had little access to extension services or improved seed/technologies.

Second, the major trends occurring in these systems included that:

1. Shifting cultivation systems in Southeast Asia were subsistence systems, not systems likely to allow farmers to move into the cash-based, market economy. Permanent agriculture and other means of livelihood were more likely to do so and/or were more desirable;
2. Farmers typically wanted to move into the mainstream, cash-based, market economy. Specifically, if resources were available, shifting cultivators would move from shifting cultivation to permanent cultivation or would change their means of livelihood;
3. Of the aspects within the control of the resource-constrained farmer, intensifying the fallow phase of shifting cultivation provided the greatest opportunity, using the least amount of resources to improve shifting cultivators' lives and livelihoods as they attempted to transition to other livelihoods;
4. Intensification strategies tended to be transitional and dynamic. They should be viewed as coping mechanisms or bridges into the market economy, not end goals;
5. Intensifying shifting cultivation did not alleviate poverty or its causes in relation to resource-constrained farmers in upland Southeast Asia. In other words, agricultural systems were not the root of poverty for many people; and
6. Technological changes and "Cinderella" species did not necessarily address the central production constraints of upland farmers, though they may have improved their immediate situation.

Analytical framework

These findings guided the managed fallow seminar participants in creating an analytical framework for studying the strategies farmers used to intensify shifting cultivation. Specifically, instead of viewing managed fallows as isolated biophysical and management processes, the framework placed shifting cultivation and managed fallows in the social, political, and economic contexts of the resource-constrained upland farmer. In essence, socio-cultural factors were considered as essential local contexts, as opposed to barriers to opportunities and innovations.

A characterization template

In its simplest form, a fallow is characterized by describing the composition, management and nutrient cycling, and products and/or benefits achieved by a farmer on a piece of land between cycles of growing annual crops. However, this type of characterization was insufficient to guide development based on the findings from the managed fallow seminar. Thus, in order to actualize the analytical framework, the participants in the managed fallow seminar developed a characterization template which outlined an idealized minimum dataset necessary for understanding, as well as comparing, the agricultural systems and contexts in which farmers operated. The template (Appendix A) was based on (1) the analytical framework established by the managed fallow seminar participants, (2) the original outline proposed by the Southeast Asia workshop organizers (Garrity, Fisher, & Cairns, 1996) and Conklin's (1961) topical outline. This minimum data set included agronomic, socio-economic, environmental, and policy information.

The managed fallow seminar group argued that from a solid characterization one should be able to:

1. Identify the key issues/components of a farmer's livelihood;

2. Identify decision-making processes used by farmers;
3. Compare systems and practices;
4. Identify knowledge gaps;
5. Generate lessons learned;
6. Identify effective strategies/practices that may be of use elsewhere;
7. Understand how alterations within some aspects of the farmer's life will affect other aspects; and
8. Provide a basis for selecting and implementing fallow-related interventions designed to improve the lives of farmers, their communities, and the surrounding environment.

Recommendations

Participants of the managed fallow seminar then recommended that research and development practices should focus on:

1. Using the characterization template to guide collecting and analyzing data;
2. Managed fallows, not as a set of biophysical typologies, but as a set of transitional livelihood strategies based on the social, economic, and political contexts of farmers, which increase fallow productivity, effectiveness, or a combination of the two;
3. Managed fallows as transitional stages or bridges leading out of shifting cultivation toward permanent agriculture or other means of livelihood. As such, these systems should be sufficiently dynamic to meet the changing contexts and/or needs of farmers; and

4. Determining the effectiveness of technology transfer among systems with similar contextual stresses versus solely similar biophysical aspects. However, case-specificity should always be given prime focus.

The managed fallow seminar group presented its findings at the Southeast Asia workshop (Hafner & McCallie, 1997). From these findings, the presentation of case studies, and working sessions conducted within the overall workshop, several notable products from the Southeast Asia workshop resulted.

Outcomes of the Southeast Asia workshop

In addition to the 826 page volume composed of the collected case studies (Cairns, 2007c), several other publications resulted from the Southeast Asia workshop. For example, Cairns and Garrity (1999) developed a framework for research and development of farmer-developed fallows. Their framework outlines six stages in two phases - the research phase and the development phase. In the research phase, participants seek to (1) identify promising systems, (2) characterize the systems, and (3) validate their functionality based on field samples and trials. In the development phase, participants then (1) identify areas with potential for successful transferability, (2) establish and evaluate trials of a transferred system, and (3) develop strategies and methods for appropriate expansion of the system.

As part of these processes, Garrity (2007) asserts that several critical factors should be considered:

1. The actual increase in output in relation to any given increase in labor input;
2. Costs and benefits of a system across the livelihood activities of the farmers as well as over time in the system cycle;
3. Soil sampling and analysis across years and/or across laboratories that may confound the results of soil analyses; and

4. Invalid comparisons that may result from comparing between fields (controls and treatments) without taking land use history and other factors into account.

In addition, Garrity (2007) identifies four major hurdles that need to be overcome in order to further develop and extend any fallow system that is identified, characterized, and validated. The major hurdles to extension include:

1. Poorly developed transportation and market infrastructure;
2. Under-staffed and over-stretched extension agents, as well as limited geographical work areas;
3. Ambiguous, ignored, or transitioning land-tenure processes; and
4. The fact that the livelihoods of farmers using fallows tend to be in transition.

Review of literature on West Timor, Indonesia

Climate

The Nusa Tenggara Timur region, in which West Timor is situated, is the driest region in Indonesia. It has a prolonged dry season of 7-9 months, followed by 3-5 months of intense rains. Mean annual rainfall is between 1000 and 1500 mm; however, its distribution, even within the wet season, is unpredictable (Metzner, 1977, 1983). Rainless spells of up to several weeks during the rainy season are not unusual, nor are days with rain showers releasing over 100 mm of rain. From a Kupang weather station, the average rainfall from 1887-1940 was 1403 mm with a dry season of greater than five months (Soares, 1947). In addition, rain fell an average of 80 days per year during this period (1887-1940). The overarching rainfall pattern, as well as the irregularity of rains based on the 1887-1940 data (Soares, 1947), along with one year of more recent data (Adnyana et al., 1994) are given in Table 1. The moisture regime qualifies as ustic or even aridic, with a unimodal rainy season (Soil Survey Staff, 1994).

The ITCZ (inter-tropical convergence zone) and Timor's geographic location account for Timor's rainfall pattern. From May to September the ITCZ lies north of Timor such that warm continental trade winds blow in from the central Australian deserts (bringing dry air). Relative humidity is often <50%. Once the ITCZ crosses the equator, the summer solstice season of November to April brings wet northwesterly winds from across the sea, but the northwest monsoon releases most of its moisture over western Indonesia before reaching Timor (Monk et al., 1997). These monsoonal patterns result in two distinct seasons.

During the dry season, Timor is frequently subjected to 36-44 km h^{-1} winds (6 on the Beaufort scale) (Ormeling, 1956). The average annual temperature is 25^{o}C with average maximum daily temperatures in the dry season from 33 to 36^{o}C (McKinnell & Harisetijono, 1991), making the temperature regime iso-hyperthermic (Soil Survey Staff, 1994). Rivers in West Timor are seasonal, being absent in the dry season and rushing following downpours in the wet season (Ormeling, 1956).

Table 1: Rainfall data by month from Kupang weather stations: 1887-1940 (adapted from Adnyana et al., 1994, p. 91 and Soares, 1947, Table XI).

	J	F	M	A	M	J	J	A	S	O	N	D
Average rainfall (mm), 1887-1940	388	367	222	64	28	10	5	3	2	18	90	246
Average number of days of rain, 1887-1940	18	16	12	5	3	1	1	0	0	1	7	15
Rainfall (mm) in 1992	213	489	57	176	20	2	0	3	12	5	54	97

Topography and geology

The majority of the island of Timor is composed of marine sediments, specifically limestone and marl, varying in age from the Permian to the Quaternary. Areas of Timor were folded during the Tertiary and then later uplifted, resulting in the current landscape which ranges in altitude from sea level to 600 m (Ormeling 1956). The topography is rugged with craggy plateaus (Jones, 1983) and slopes of up to 45 degrees. Igneous rocks from the pre-Tertiary and Tertiary, as well crystalline schist, are scattered throughout Timor, occurring in isolated patches as well as composing the north coast and the mountains in central and east Timor (Ormeling 1956). Igneous rocks were not found in the area of this study. There are also a few lowlands as well as several extensive plains (the South Belu plain, the Bena plain, and the Oesau-Pariti plain, consisting of 30,000, 15,000, and 10,000 ha, respectively) formed from alluvial deposits (Ormeling 1956).

According to Ormeling (1956), although extensive mapping of Indonesia and Timor has not taken place, 60% of the land may be rugged, sloped and inappropriate for agriculture without terracing.

Soils

An extensive search for literature on the soils of West Timor resulted in only a few maps and descriptions. These vary in scope, detail, and consistency of findings. A commonly expressed sentiment in the literature is that while the geology of Timor is reasonably well-described, the soils are poorly known (see, for example, Metzner 1977 and Ormeling 1956). In addition, of the soil studies that have been conducted, at least three different classification schemes have been used, including the USDA Soil Survey, FAO-UNESCO, and an Indonesia-specific system (Monk, et al., 1997). The soils that are reported to occur in the study area or that closely resemble those in the study area are discussed here. A more thorough review of the soils in West Timor is given in Appendix B.

Soils of West Timor reported by Monk et al. (1997)

Monk et al. (1997) report 15 soil types in four soil orders as occurring in West Timor. Only a subset of these soils is reported to occur near the location of this study, however. These are Inceptisols: Eutropepts and Ustropepts; Mollisols: Calciustolls and Rendolls; an Alfisol: Rhousdtalfs; and an unidentified soil.

Inceptisols are in the transitional stage between Entisols and mature soils. They are defined by their stage of development. Typically, their cambic horizons bear identifiable remains of the parent material and have textures finer than fine sand (Van Wambeke, 1992). Van Wambeke (1992) describes three major processes evident in Inceptisols:

1. The removal of carbonates (brown soils overlying white materials coated in lime);
2. The release of iron oxides (high chroma and red soils); and
3. The reduction and removal of iron oxides in aquic conditions (grey soils).

Eutropepts generally form from limestone (mafic and sedimentary rocks), have high base saturation (Ca and Mg), weatherable minerals, and good drainage. They are more silty than heavy clays. These properties generally result in "satisfactory water supply and adequate nutrient content" (Van Wambeke, 1992, p. 242). These can be shallow or deep soils.

Ustropepts are similar in nutrient availability to Eutropepts, except that moisture regimes severely limit agricultural production on these soils (Van Wambeke, 1992). Monk et al. (1997, p. 119) describe Ustropepts as having "soft powdery lime concentrations following evaporation of lime-rich ground water."

Two Mollisols are described from West Timor: (1) Calciustolls from the suborder Ustolls and (2) a soil attributed to the suborder Rendolls (Monk et al., 1997). Mollisols are characterized by a surface soil layer that is dark and thick, with high base saturation (>50% at pH 7), low phosphorus (< 10 mg P kg^{-1} soil, soluble in 0.05 M citric acid), and saturated in "bivalent cations" (Van Wambeke, 1992, p. 279). These soils have relatively high organic C (> 5.8 g kg^{-1} soil) and are not hard when dry (Van Wambeke, 1992).

Monk et al. (1997) describe the Calciustolls as shallow, well-drained, stony soils situated directly on coral reef, hard limestone, or marls. They occur in small areas of Timor and are dark in color, well-drained, and weakly acid or neutral. In terms of vegetation, Monk et al. (1997) state that they typically support grassland or savanna. These soils tend to be K deficient, have moderately high cation exchange capacity (CEC), and are saturated with Ca, which "causes gross imbalances in magnesium in particular" (Monk et al., 1997, p. 120).

The Rendolls are described less specifically than Calciustolls. They are shallow, stony, fine-textured, well-drained soils on limestone and coral reefs (Monk et al., 1997).

Alfisols are generally high base saturated soils formed from limestone or mafic rock in ustic moisture regimes (Van Wambeke, 1992). They have low CEC and demonstrate clay accumulation in their horizons (Van Wambeke, 1992). If they are light-textured (<40% clay) on the surface layer, Alfisols tend to harden under dry conditions. Alfisols may contain rocks in up to half of their volume (Van Wambeke, 1992). Rhodustalfs are well-drained, weathered soils on coral reefs and older alluvial fans. Their surface is composed of friable clayey soils with finer textures below.

They tend to be acidic to neutral and have high CEC and high base (Ca) saturation (Monk et al., 1997).

Soils of West Timor Reported by ISRIC-WISE

Another set of soil data for West Timor comes from the ISRIC-WISE data bank (Batjes, 2006). The soil map includes six soils for West Timor based on derived data. Based on the resolution of the GIS map, two types of Chromic Luvisols are present in the study area (Batjes, 2006). Both Chromic Luvisols are mildly acidic (pH 5.5-6.5) with high base saturation, medium levels of organic matter and a heavy texture (Batjes, 2006). Luvisols generally have good drainage. The Chromic attribute indicates high color saturation.

Soils reported in West Timor based on Government Sources

Two soil maps at the scale of 1:5,000,000 depict the soils of West Timor. Both were produced by sections of the Indonesian government (Lembaga Penelitian Tanah Bogor, 1974/1980; Pusat Penelitian dan Pengembangan Tanaman Pangan, 1991). On one map (Pusat Penelitian dan Pengembangan Tanaman Pangan, 1991) the soils in the study region are shown as primarily Mediterranean, with some possibility of Regosols and soil complexes. The second map (Lembaga Penelitian Tanah Bogor, 1974/1980) indicates that there are Mediterranean and Litosols in the study area.

Additional government sources (Yayasan Bhakti Wawasan Nusantara, 1992) state that Grumusols account for 1.33% of the Kabupaten Kupang region and that Alluvial soils and Mediterranean/Renzina/Litosol complexes are in the general area.

Soils in West Timor from other sources

Ormeling (1956, p. 53) describes the soil types under grasslands as composed of “rock-hard clods.” Ormeling (1956) also states that most Timorese prefer to cultivate the hills because of their loose, fertile soils and compatibility with a digging stick and dibble. Metzner (1977), however, reports that in areas used for shifting cultivation, rock fragments compose over 40% of the soil volume in the top 30 cm and that the C horizon is less than 50 cm from the soil surface. Conceptually, this suggests soils consist of a craggy coral surface with soil filling the cavities in and among the rocks. Metzner (1977) also includes soil analysis data from a study conducted in eastern East Timor (Garcia et al., 1963). The soil data that most closely resemble that of the study area are reproduced in Chapter 4.

Soil fertility and suitability for agriculture

The majority of soils described in West Timor have high base saturation and high levels of calcium carbonate. These properties suggest neutral to alkaline pH, which may limit P and micronutrient availability as these bind to Ca under high pH conditions. The presence of shallow soils, rocky soils, and soils that harden on the surface suggests difficulty tilling. The alluvial deposits and areas with accumulated clays are the most promising for agriculture as long as the soil structure is good and water is available. Overall soil organic matter is expected to be low given the moisture and temperature regimes.

History of livestock production in West Timor

Livestock production, particularly cattle, has been a large part of West Timor's agricultural system since Europeans and European-Australians introduced them to the island in the early 1900s (Ormeling, 1956). Farmers prefer Bali cattle, derived from wild Banteng (*Bos banteng*) to Australian cattle, because of their more rapid growth and comparative ease of care (Monk et al., 1997; Ormeling, 1956). Figure 1 shows Bali cattle from West Timor.

Agricultural and livestock production have had a contentious relationship in West Timor, however. The soil used for cropping is too rocky to till, so cattle are of no use in preparing fields. In addition, cattle trample crops unless strong fences are constructed, and they require large areas for grazing as pasture quality tends to be poor (Ormeling, 1956.) Regulations with respect to cattle have changed over the years.

Figure 1. Bali cattle from West Timor.

During times in which cattle were free-grazing, farmers spent as much as a quarter of their time keeping cattle out of their fields (Ormeling, 1956). At other times, cattle were required to be tethered and were fed through cut-and-carry systems using species such as *Leucaena* sp. (Ormeling, 1956). In addition, when unpalatable or poisonous plant species became dominant in the countryside, such as *Lantana camara*, cattle numbers dropped due to decreased quantities of palatable forage (Monk et al., 1997).

History of vegetation on West Timor

Prior to extensive agricultural production, the vegetation on the island is presumed to have been dense monsoon forest (Ormeling, 1956). Timber harvesting and agricultural expansion are thought to have resulted in forest decline. For example, sandalwood (*Santalum album L.*: Santalaceae) was sought after for incense, particularly by the Chinese and Hindus, as early as the 10th century and possibly 200 BC (Ormeling, 1956). Over-exploitation occurred by 1790. In addition, fire and trampling by cattle prevented sandalwood forests from regenerating (Ormeling, 1956).

European traders from the 1600s onwards report brush, scattered forest, and open savanna as Timor's dominant vegetation types. Ormeling (1956) reported that the predominant vegetation below 1000 m was four types of low savanna in a mosaic with unimproved open grasslands. The four savanna types were (1) palm; (2) *Eucalyptus;* (3) *Acacia*; and (4) tjemara (*Casuarina junghuhniana* Miq.). Ormeling (1956) suggested that soil variation determined the type of savanna in a given area. The palm savannas occurred on alluvial plains and low hills. They survived long dry periods, high ground-water, and fire. The *Eucalyptus* savannas also survived fire, but they were limited to dry, lime-poor soils in hilly regions up to 1000 m elevation. *Acacia* savannas occurred with other species and were found on margalitic and black limestone soils. The tjemara savannas made up the smallest area of land, including barren, poor soil and sandy river beds. They did not regenerate well following fire.

By the mid-1980s, most of the island was a mosaic of shifting agriculture, unimproved pasture, weedy and shrub savanna and, occasionally, attempts at high input plantation cropping by wealthy individuals originally from other islands (Metzner, 1983). Monk et al. (1997) report that mixed savanna covered 1,786 km^2 (11.38%) and grassland covered 2,140 km^2 (13.63%) of West Timor, Semau, and Roti. They list the dominant savanna types in Timor as palm savanna, *Eucalyptus alba*, and *Casuarina*.

History of shifting cultivation in West Timor

Prior to the introduction of maize by the Dutch just after 1672 (Fox, 1988), roots and tubers were the primary crops and staple foods for people in the region

(Ormeling, 1956). Maize quickly replaced tubers as the staple food, with upland rice and sorghum supplementing maize (Ormeling, 1956).

Conversion phase

As part of hillside shifting cultivation on loose fertile soils, Ormeling (1956) reported that secondary growth was felled in August. Farmers cut bushes and shrubs to about ground level, while they only cut branches off trees, leaving standing trunks. The felled vegetation dried until October or November when it was burned. Ashes were strewn on the fields as fertilizer. A major issue was protecting ash from wind and water erosion, which was nearly impossible due to the intense rains and winds prevailing during the cropping season. The fields were fenced to keep out livestock and wild animals (Ormeling, 1956). Monk et al. (1997) describe coral rock fences as relatively permanent structures built from stones from the fields. It is uncertain if both Ormeling (1956) and Monk et al. (1997) are referring to the same land type with respect to shifting cultivation.

Cropping phase

Ormeling (1956) reports that maize, beans, and squash were planted together using a dibble. Dry rice was planted as well, but it is unclear if it was planted with the other crops. Farmers lived in huts in their fields during the cropping season.

Ormeling (1956) also reports that farmers weeded maize once or twice per season with a short-handled tool. Farmers planted part of the field with early maturing varieties of corn, which were harvested green in February or March, while later varieties were allowed to mature in the field into May. Maize was dried several days in the field before storing at the top of beehive shaped huts. Low fires were kept burning for an unspecified amount of time to prevent beetle damage to the stored crop. Pest damage to crops was considered a serious problem. In addition, rainfall limited farmers to a single cropping season, and crop failure was always a risk due to long dry spells within the wet season and no irrigation systems (Ormeling, 1956).

Writing 40 years later, Monk et al. (1997) report that farmers in West Timor planted maize, pigeon pea (*Cajanus cajan*), and squash (*Curcurbita spp.)* in a single hole. The beans reduced weed growth, while maize stalks served as climbing poles for the beans. Monk et al. (1997) note that traditional maize-bean mixtures took three hours to cook, placing great demand on fuel wood resources.

In terms of maize yields, Ormeling (1956) reports that a one ha field produced 1000 kg of maize, approximately 10,000 ears, but that this amounted to less than seven ears per person per day for a family of four.

In the mid-1960s, Massey et al. (1964) report that Indonesia planted 3 million ha of maize, with an average yield of 0.8 t ha^{-1}. The low yield was attributed to "short maturity low yield varieties, inadequate fertilizer use and inadequate cultural practices" (Massey et al., 1964, p. 869). Experimental trials on the Latisols of Java and Madura using high yielding varieties and fertilizer were extrapolated, indicating potential production rates of 6 t ha^{-1} (Massey et al., 1966).

In the mid-1980s to the early 1990s, maize yields ranged from 0.3-0.9 t ha^{-1} (Monk et al., 1997). In Timor and the nearby islands, three experimental trials reported on maize yields (Gunarto, 1992; Gunarto et al., 1985; Jones, 1983). Two used chemical fertilizers to determine maximum maize yields (Gunarto, 1992; Gunarto et al., 1985), while one focused on legumes (Jones, 1983). Yields in all cases were less than 1.0 t ha^{-1} without inputs and from 2.5 to 4.3 t ha^{-1} with inputs and management. In 1992, official reports from the Kupang region indicated 34,685 t of corn were produced on 16,740 ha, or about 2.1 t ha^{-1} (Adnyana et al., 1994). Rainfall and/or record keeping practices may explain the wide discrepancies in yields among years.

Fallow phase

By the mid 1950s, Ormeling (1956) notes that, in order to feed the growing population, strategies were needed to shorten the length of the fallow period, while still rejuvenating soil fertility. Specifically, Ormeling (1956) argues that based on the practices at that time, fallows of well over 12 years were required to rejuvenate soil fertility. With only half (7,000 km^2) of Timor's land surface appropriate for shifting cultivation, a 12 year fallow was not feasible due to: (1) population pressures (population was about 450,000 in the mid-1950s), (2) increases in livestock populations, and (3) the creation of forest reserves (1,600 km^2) (Ormeling, 1956). Ormeling (1956) notes that there were several effective short fallows being practiced on the island. There were bush fallows on the coast of Timor lasting 3-7 years, following three years of cultivation, as well as shorter fallows in other areas.

Monk et al. (1997), assuming 15 year fallows, calculate that families in the region needed 9 ha of fallows in order to crop 1.5 ha for three years before fallowing them again. They also describe Timor as having too many fields, resulting in a loss of seed sources for regenerating fallows.

In addition to secondary forest fallows, West Timor experienced a number of invasive weedy shrub species (*Lantana camara L.*: Verbenaceae. and *Chromolaena odorata L.*: Asteraceae.) and one intentionally planted nitrogen-fixing, fast-growing tree (*Leucaena leucocephala Lam.*: Leguminosae). A brief history of these species illustrates how such species take hold in West Timor. This is followed by a short introduction to *T. stans*, which was, prior to Djogo et al. (2007), unreported in the literature as a fallow species on Timor.

Lantana camara

Lantana camara, a fast-growing, thorny, branched, 4 m tall, ornamental shrub, entered Timor by 1915 and quickly invaded the savannas and countryside (Ormeling, 1956). It was imported to Java as an ornamental and possibly a fast-growing hedge. It escaped cultivation and naturalized in the region as birds and other animals dispersed its seeds (Ormeling, 1956). *Lantana camara* grew well on well-drained soils, including high-lime soils. It did less well on margalitic, heavy clay, and high ground water soils. *Lantana camara* did not burn easily without cutting and drying for an extended time, but it re-grew quickly (Ormeling, 1956). Because of its aggressive, thick regeneration and ability to rejuvenate soil structure and organic matter in five or six years, shifting cultivators preferred it to secondary forest fallows (Dove, 1984; Monk et al., 1997). Metzner (1983) reports that regenerating *L. camara* helped to protect soils from erosion, allowed for annual cropping after only 3-5 years, and decreased the need for weeding during cropping. *Lantana camara* is poisonous to cattle, however, and thus decreased the availability of palatable forage as it colonized the island and out-competed native plant species (Monk et al., 1997).

Leucaena leucocephala

In an attempt to control the spread of *L. camara* as well as to both increase soil fertility and fodder for cattle, *L. leucocephala*, a fast-growing, nitrogen-fixing legume with a deep taproot, was intentionally introduced to West Timor by the 1950s (Djogo, 1994; Ormeling, 1956). A variety of government and local programs sought to promote it. In the Amarasi region, it was compulsory to plant *L. leucocephala* in hedgerows when fallowing cropland. This practice thereby established the Amarasi system, which is well-documented as a successful system for resource-constrained farmers (Djogo, 1994; Jones, 1983; Lobach, 1951; Metzner, 1981; Surata, 1993). Through its fast growth and nitrogen-fixation, *L. leucocephala* improves soil fertility and shortens fallow length (Jones, 1983; Shelton et al., 2000). It is also coppiced for cut-and-carry cattle fodder, cut for fuel wood, and used for light construction material, soil stabilization, and shade for tree crops (Jones, 1983; Shelton et al., 2000). This system partially collapsed in the late 1980s, with the introduction of a psyllid insect (*Heteropsylla cubana*) that decreased *L. leucocephala* stands between 25-50% (Piggin & Parera, 1987). The decline in *L. leucocephala* was said to be responsible for the 11% drop in cattle production from 1986 to 1987 (Piggin & Parera, 1987). Since then, however, *Leucaena* hybrids and other legumes that are resistant to or tolerant of the psyllid have been introduced to Timor (Djogo, 1994; Shelton et al., 2000).

Chromolaena odorata

The most recent species reported in the literature to invade Timor is *C. odorata,* a weedy shrub that regenerates easily after cutting. It has small wind-dispersed seeds, which are also reported to be dispersed inadvertently by livestock (Monk et al., 1997). *Chromolaena odorata* is reported to have very high nitrate contents (Sajise et al., 1974).

By 1991, *C. odorata* had invaded high-grade pastures in West Timor (Tjitrosoedirdjo et al., 1991). Based on reports from East Timor in 2003-2004, *C. odorata* continued to spread east and was considered a major weed, particularly for farmers trying to move from subsistence agriculture into a market economy. In addition, by 2004, *C. odorata* was sufficiently widespread that control using herbicides was considered impractical, though bio-control options were being considered (Soil Management Collaborative Research Support Program, 2004).

Tecoma stans

Native to the Andes of South America, *T. stans* is a highly drought resistant species that grows in dry climates throughout the world, having been intentionally or accidentally transported by human activity (Tipton, 1994). While often reported as a medicinal plant in Central America, only three studies report on its use in agricultural systems (Aguirre et al., 2002; Clarke & Thaman, 1993; Jiménez-Ferrer et al., 2007). In a study of uses of trees and shrubs in livestock production in Chiapas, Mexico, Jiménez-Ferrer et al. (2007) report that farmers use *T. stans* for fire wood and construction material as well medicine. Farm trials rank *T. stans* as having medium quality in terms of palatability and propagation ease but low ability to fatten cattle. Laboratory analyses indicate that *T. stans* is composed of 16% crude protein and over 22% fiber. Its digestibility is 56%, while it provides almost 4 Mcal kg^{-1} of energy. In terms of secondary products, its total phenols are 7.1% (tannic acid equivalents), and it has moderate levels of alkaloids. Farmers report, however, that *T. stans* is in decline in the Chiapas area (Jiménez-Ferrer et al., 2007).

In a study of recuperating degraded pastures with forest species in El Salvador (Aguirre et al., 2002), *T. stans* attains both the greatest height (3.8 m) and the largest diameter (9 cm dbh) of the species tested in the 36 month trial of planting forest species with the legume *Canavalia ensiformis.* Notably, it grows substantially better with the legume present than without (Aguirre et al., 2002).

While *T. stans* is considered a "serious invader of disturbed areas in Tonga and French Polynesia" (Space & Flynn, 2002), it is also listed as a support plant for vanilla in intercropping systems in French Polynesia (Clarke & Thaman, 1993).

Following this review of the literature on shifting cultivation in general and on West Timor in particular, the methodology and methods used in this study are described in the next chapter.

CHAPTER 3: METHODOLOGY AND METHODS

Methodology

In this study, I combined two approaches, rapid rural appraisal (RRA) and case studies, to understand the agricultural and livelihood systems of resource poor farmers in three villages in Timor, Indonesia.

Rapid Rural Appraisal

Traditional agricultural research tends to focus on formal, structured, and experimental studies, requiring long time frames, generous funding, and large sample sizes (Crawford, 1997). RRA differs from traditional agricultural research in that it responds to a need for inexpensive, timely, multidisciplinary, and flexible research on complex systems, particularly in rural development and agriculture. RRA emphasizes iterative, informal, yet systematic methods of data collection for use in natural settings. RRA is often used to describe and generate inferences about complex systems that are changing rapidly (Crawford, 1997; Kachondham, 1992). In addition, RRA emphasizes multiple methods of data collection and analysis as well as flexibility. It is not unusual to modify ones RRA methods during the research process in order to best understand the system being studied in the shortest amount of time (Kachondham, 1992).

The principles underlying RRA include (Crawford, 1997; Kachondham, 1992):

1. Maximizing return for input, including time, expense, quality, relevance, and quantity;
2. Valuing the perspectives of the people whose systems are being studied, including listening to them closely and respectfully;
3. Building on emergent understandings, including modifying methods;

4. Building consensus among researchers (and researchers and informants) both in terms of emergent understandings and in terms of outstanding issues or gaps in knowledge;
5. Limiting bias through multi-disciplinary teams, probing understandings in the field, and reflecting on and challenging current inferences; and
6. Cross-checking information by employing multiple data collection methods and by seeking out multiple sources of information and perspectives.

While RRA studies do not adhere to stringent experimental designs and large sample sizes, they are considered a "fairly-quick and fairly-clean" approach to social science studies (Chambers, 1983). Reliability and validity of data are addressed by comparing findings from multiple data sources and types of data sources, member-checking, and subjecting data to scrutiny by researchers with varying expertise.

RRA was chosen for this study as there was a very limited timeframe for collecting data and a wide variety of information that was sought in order to characterize the farmers' agricultural and livelihood systems. The breadth of the data collected was in line with the analytical framework guiding the study: that agricultural systems do not act in isolation but are components of larger livelihood systems that affect the farming decisions farmers make (Garrity, 2007).

A case study approach

In addition to RRA, I also employed a case study approach. Examining cases allows researchers to look deeply into complex phenomena in order to describe, generate theories, or seek causal explanations about well-bounded entities or systems (Stake, 1995). Stake (1995) describes three main types of case studies:

1. Intrinsic case studies that are appropriate when the entity of interest is unique such that it stands alone and not as part of a population of similar entities;

2. Instrumental case studies that are used for investigating exemplars, for example, providing rich descriptions of "best practice"; and
3. Collective case studies that are a subset of instrumental case studies, which are used as a means to delve deeply into several examples of complex phenomena of which there is a larger population from which to derive generalizations.

Of the three types of case studies, this study is an example of the third type, a collective case study: the individual farms and livelihood systems of farmers studied here represented the larger population of farmers in the area using similar resources and strategies. Specifically, individual cases of farmer practices and livelihoods were examined in depth (Yin, 2003). The farmers' cases were not reported individually, however. Instead, they were considered collectively in order to generate insight, theory, and practical understandings of the larger agricultural and livelihood systems the farmers shared. Thus, this study was designed and executed based on reflective and iterative RRA processes in which the data were continually re-evaluated in light of the multiple cases making up the collective case study.

Selecting the agricultural system and the individual farms

In mid-May, 1996, a team of Politani and Cornell researchers surveyed the countryside within 40 km of Kupang in order to identify agricultural systems previously undescribed in the literature. While several systems were considered, the team chose to characterize the system using *T. stans* as a fallow because: (1) *T. stans* was previously undocumented as a fallow species and (2) the small-scale farmers using it appeared to be living at the interface of subsistence agriculture and the market economy. In other words, the fallow system and its context fit the parameters set for case studies by the organizers of the Southeast Asia workshop. The study took place between the end of May and the beginning of August, 1996.

Individual cases of farmers and their families were selected based on several factors. As was the cultural practice in the region, before beginning the study, we met with and obtained permission from the head of each village to speak with the residents of each village. We received recommendations from the village heads as to who might be willing to speak with us and who might be at home or in their fields. In addition, we approached many of those whom we encountered as we walked along the main roads through each village. Before collecting data at a farm, we explained the intent and goals of the study and obtained verbal consent before proceeding. Verbal consent was most appropriate as many of the villagers did not read--written documents tended to be viewed with suspicion. Occasionally, farmers declined to be interviewed, indicating that they were occupied or they were on their way out. Several of these farmers suggested other times we speak with them. When possible, we returned.

Methods of data collection

The role of the characterization template

The characterization template (Appendix C) was not completed until Fall, 1996, after the data collection period for this study (and most other studies presented at the Southeast Asia workshop) was completed. The mismatch in timing between the studies and design of the characterization template was unfortunate but unavoidable, as the managed fallow seminar was charged with reviewing and selecting studies for inclusion in the Southeast Asian workshop, while simultaneously creating the characterization template. Thus, study data needed to be collected, analyzed, and submitted to the managed fallows group for review during Fall, 1996. The template was therefore used as a tool to organize data. The managed fallow seminar and organizers of the Southeast Asia Workshop analyzed the set of characterization templates to identify themes across sites.

In addition, the managed fallows group specifically omitted designating specific methods for data collection, because the group concluded that, even if the characterization template guided future studies, data collection methods should vary according to the cultural context, research partners, and physical distribution of the sites.

Data collection

We, the collaborating Politani researchers, field assistants, and me, used a variety of methods in line with RRA to characterize the fallow phase of the shifting cultivation system and the context in which it operated. Specifically, we designed data collection tools to characterize all aspects of the livelihood systems of farmers using a *T. stans* managed fallow. This included social, economic, political, and biophysical aspects of their livelihoods. The methods used in this study led to a characterization of the livelihood systems of resource-constrained farmers and included filling in the characterization template after the data collection process was complete. Methods included direct observation, semi-structured interviews, accompanied field visits, and informal discussions with farmers and their families.

Semi-structured interviews

Interviews were the primary method of data collection. Among the researchers, we discussed cultural norms and practices and how various styles of interviewing might affect the validity and type of responses we received. This was particularly salient given the difference in perceived status between the resource-constrained farmers and the university and international researchers. Interviewers always worked in pairs, usually composed of male-female teams with different interviewing styles and strengths. We interviewed 19 farmers and their families in their fields and homes, including at least five farmers from each of village. We interviewed an additional seven farmers who we encountered along major roads or at the village stores.

Interviews occurred casually or by appointment, depending on the preference of the farmer. We found it extremely important to allow the conversations to flow, allowing the villagers to identify the issues most salient to their lives. No notes were taken during the interviews, mostly because many of the farmers did not read or write and we didn't want to reinforce our differences. Immediately following an interview, however, the pair of interviewers recorded their notes individually. The pairs later compared their notes for clarity, consistency, and accuracy. This allowed the researchers to mark issues for follow-up with the same family or to investigate with other farm families.

Maps, calendars, and photographs

We used standard RRA techniques such as land-use and land-type maps, transects, crop and work calendars, and photographs. We explicitly gave preference to the local classification systems to inventory components of the agricultural and livelihood systems (Scherr, 1991).

Soil samples

Consistent with Garrity's (2007) call to complement qualitative understandings with quantitative sampling of fallow soil and vegetation, three replicate soil samples were collected per fallow management condition at three soil depths: 0-20 cm, 20-40 cm, and 40-60 cm. In some fields, shallow soils and coralline rocks at the surface limited soil sampling to 0-10 cm or 0-20 cm. For each fallow, there were two (paired) collection conditions: (1) under the canopy of *T. stans* and (2) no canopy cover. Figure 2 illustrates the collection conditions by showing the typical arrangement of *T. stans* in fallowed fields. In addition, soils sampled were chosen based on fallow ages: ranging from yearly cropping (no fallow for the last two years) to an 11 year fallow. Where possible, soils were sampled from three different fallowed fields of each age.

For the older fallows (>5 years), three replicates were not available as few farmers allowed their land to remain out of corn production for such a long time. In addition, soil samples (three replicates) were taken under a three year old fallow of *C. odorata*. These samples were not paired, as the morphology of *C. odorata* is not such that there is a mosaic of canopy-covered and exposed soil; all soil in *C. odorata* fallows is canopy-covered.

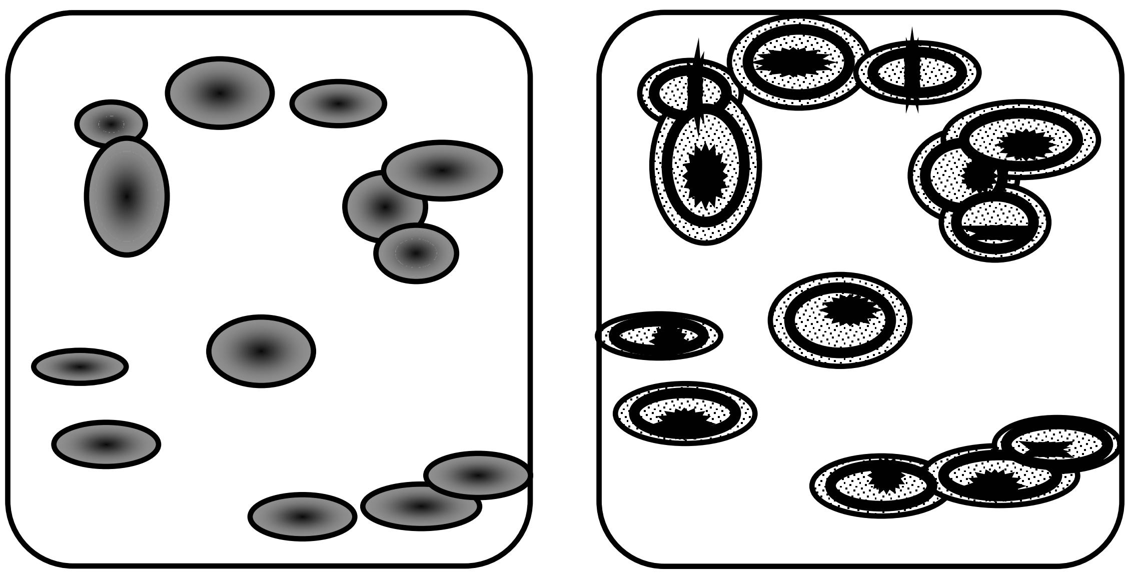

Figure 2. The distribution of *T. stans* in fields in relation to large coral rocks and the area cropped with maize.

Soils were sampled using a soil corer. Replicate samples were placed in small plastic bags and labeled with permanent markers. Soils were air-dried before analysis and/or storage. If a soil sample was sent for analysis, only a subset of the sample was analyzed. All soil samples remained in Indonesia.

Vegetation samples

Fallow vegetation was sampled for nutrient analysis. The vegetation sampling design was less extensive than for soils. The goal of vegetation sampling was to obtain a general idea of plant nutrient content prior to burning. Samples included three replicates by fallow age for *T. stans.* For *C. odorata*, a 3 year old fallow was sampled. In addition, samples were taken of pasture grass and *Mimosa pudica L.* (Leguminosae) in the fallows. All vegetation samples remained in Indonesia.

Reliability and validity within the research process

Checks for reliability and validity reduce errors and bias within the research process. To address both validity and reliability within this study, we used a variety of data collection methods and information sources in order to cross-check (triangulate) understandings. Specifically, the team concluded data collection at the three villages when additional interviews and site visits produced few to no new findings or contradictory evidence.

Data analyses and interpretation

Analysis of soil samples

During collection, soil samples were analyzed for color and texture. For a variety of reasons, only eleven soil samples were analyzed in the laboratory. Each was a composite of the three replicates taken within a single fallow. All samples represented soils taken from under the *T. stans* canopy. The Center for Soil and

Agroclimate Research (Pusat Penelitian Tanah dan Agroklimat), Bogor, Indonesia, conducted standard chemical analyses for the soil samples (Appendix D). The complete set of soil samples may still be stored at Politani, Kupang, Timor.

Analysis of vegetation samples

The vegetation samples were not analyzed and may still be stored at Politani, Kupang, Timor.

Interviews

Data across interviews were compiled by theme: social, economic, political, biophysical, and agronomic factors. Patterns within themes were noted, with discrepancies leading to follow-up interviews. Thus, the data collection and analyses phases were iterative. Finally, the researchers wrote an overall description of each theme, taking into account the variation within the farmers' reports. Interview data were also compiled into tables and diagrams and used to complement data from other sources, such as crop and work calendars. Once the characterization template was created by the managed fallow seminar group, the study data were used to fill out the template.

Calendars, maps, and photographs

The calendars created in conjunction with individual farmers were compared and contrasted, resulting in follow-up interviews when patterns were unclear. Overall calendars were then created. These findings were also used to fill out the characterization template.

Village maps presented a problem. The village centers, the local equivalent of city halls, did not have maps of the villages. The local people did not seem accustomed to representing space in 2-D as if one were looking down on the land from above as is typical for most maps. Thus, map fragments were constructed, but separate maps were not reconciled. In line with the RRA approach, we chose to spend time learning more about the livelihood systems as opposed to surveying landscapes and formally mapping the villages.

In addition, the livelihood systems were documented through photographs when appropriate.

Secondary data collection

Secondary sources for this study were obtained primarily from CRIFC (Central Research Institute for Field Crops) in Bogor, Indonesia, and Mann, Olin, and Kroch Libraries at Cornell University, Ithaca, NY.

Context

While other areas of Indonesia have benefited greatly from economic modernization during the last several decades, the population in the region of Nusa Tenggara Timur (NTT) still relied on subsistence agriculture on marginal or degraded land for their livelihoods. In terms of small-scale and subsistence agriculture, however, the region was known for its diversity of agroforestry and fallow systems, both locally developed and introduced. As these systems may hold promise for other subsistence farmers in marginal areas and as the majority of these systems have not been formally characterized or published, the organizing committee of the Bogor conference requested a study of at least one of the area's systems.

Location of the study

This study took place in three contiguous villages (Belo, Fatokoa, and Tunfeu) in the Kecamatan Maulafa, Kabupaten Kupang, about 5 to 10 km south of Kupang, West Timor, Indonesia, located approximately 10^{o} S latitude and north-northwest of Australia at approximately 124^{o} E longitude. Kupang is the capital of Nusa Tenggara Timur, Indonesia. The eastern side of Timor, called East Timor, is an independent nation, accepted into the United Nations on September 27, 2003 (Human Rights Action Watch, 2003).

The villages of Belo and Fatokoa were comprised of 468 and 7858 ha, respectively. The size of Tunfeu was not available. The topography was hilly with slopes of 20-30%. The altitude in the area ranged from 300-350 m above sea level.

The next chapter describes our findings and analyses.

CHAPTER 4: AN INDIGENOUS STRATEGY FOR INTENSIFYING SHIFTING CULTIVATION

In this thesis chapter, I relate the findings of a collaborative study between the Politani and Cornell University that focused on a subsistence agricultural system, which used *T. stans* as the dominant fallow species. This section serves to (1) provide the political, economic, and social context within which the farmers operated, and (2) characterize the agricultural production systems, including the *T. stans* managed fallow.

Findings: The political, economic, and social context

Political structure

In 1996, the population of the three villages, Belo, Fatokoa, and Tunfeu, were 661, 1248, and 2018, respectively. Approximately 90% of village households were in some way connected to agricultural production, including livestock, while 70% depended directly on shifting cultivation for sustenance. In Belo, for example, of the 661 people, 20 were political officials, 15 had a police or service role, and 10 were laborers. The rest were said to be engaged primarily in agricultural production. Belo had one primary school, two Christian churches, and one village office.

The village government system was a combination of traditional and official systems. The traditional ruling system was based on *adat* (traditional customs). The official government consisted of a hierarchy of political divisions in which the village was subdivided into at least two smaller spatial units. The village head and minor officials were recognized as both *adat* and official leaders. As most villagers were related by either blood or marriage, people indicated that traditional culture was a strong guiding force. The dominant professed religion in the villages was Christianity. (As part of national law in Indonesia, all Indonesians must profess belief in one God and declare one of five nationally recognized religions: Islam, Buddhism, Hinduism, Christianity or Catholicism. Christianity here is Protestant Christianity in contrast with Catholicism.)

There were elementary schools within the villages, but many children moved away at about age twelve to continue their education. Most adults in the villages spoke the local language but not the national language. Literacy rates were not available but appeared low among the adult population.

The vast majority of villagers were native to the Kupang region in western West Timor. In terms of land tenure, village heads had the power to sell communal lands, which were typically some of the red soil areas in the village. How often they exercised this power was unclear. Most farmers were traditional landholders whose parcels were widespread spatially and composed of a variety of soil types and grades. Unless they were new to the area, most families owned over two ha of land, which was typically inherited patrilineally.

With the city of Kupang within 10 km, a growing market for land existed, albeit at a low price per ha. With increasing governmental presence from Kupang, villagers expressed that they felt pressure to put land into production or to sell it. Farmers were quick to say that while the price they could receive for their land was compelling as the total cash received was above what they had had at one time before, they were learning from the experience of those who had sold land--the money soon ran out and then one did not have anywhere to grow subsistence crops. While villagers were reluctant to sell the highly productive and scarce black soil areas, some were considering selling red soil lands that were in relatively remote parts of the village. Farmers were focusing on fewer fields and adding inputs, so owning large numbers of fields was becoming less attractive. Also, children were leaving the villages to go to the cities for school and often chose to stay in the cities once they finished. Thus, owning land in order to divide it among children was not as high a priority as it previously had been. In addition, villagers said it was hard to protect crops and cattle from being stolen by city dwellers; thus, distant fields had less value than they had previously.

Those buying land were either new immigrants from other rural areas who settled on the outskirts of Kupang after unsuccessful job hunting in the city or were city officials and business people who wanted to have a getaway from the pollution of the city and/or had the means by which to establish high-input plantation crops. Several farmers said that these plantations kept small farmers poor, even though the two groups did not produce many of the same crops. Small farmers did not see themselves competing successfully with high-input systems even if their access to capital improved.

A main paved road ran length-wise across the island of Timor. The villages in this study lay within 5 km of this road, thereby accessible to its irregular regional transportation services. Irregular transportation was also available within the villages.

Drinking water was provided by a number of community wells. Water needs were also provided by some traditional aqueducts used to irrigate the black soils. Electricity was not readily available in the villages, but several families had purchased small generators to power lights and television.

Figures 3, 4, & 5 are maps of the three villages that farmers and researchers prepared together. They illustrate various political and agricultural features of the villages.

Economic structure

Economically, the villagers were in transition from being subsistence farmers to being integrated into the market economy. Typically, they wanted to raise their standard of living, particularly in terms of education and purchased goods. They viewed generating cash through agricultural production as a means to this transition, but nothing was happening as quickly as they would have liked. The villagers cited improving infrastructure, particularly roads and public transportation, as crucial to their market integration, but that they still lacked access to credit, mechanization, extension assistance, and most agricultural inputs.

As previously stated, 90% of the population's livelihood was based on agricultural production, including livestock, with about 70% practicing shifting cultivation. The main agricultural sources of cash for the villagers were the sale of: (1) beef cattle, (2) vegetables, (3) firewood, and occasionally (4) rice (Table 2). For other forms of cash income, some men collected rocks from their fields during the dry season to sell as building and paving material in Kupang (Table 2). Women wove during the dry season and sold the resulting material for cash. In terms of contact with the markets outside the village, people from the city came to the villages to buy firewood, crops, and cattle. Rock collectors brought their trucks to the villages. Villagers, typically men, bought cattle at the Camplong market, and women sold produce at the Impress market in Kupang. See Table 2 for prices of goods and services.

Cash income was said to be spent primarily on education fees for children and for house building. Canned foods, and more recently, television and electricity also consumed their cash income. Among the villagers, however, bartering was still a common means of exchange.

Although farmers expressed a great interest in the market system and in obtaining goods, they said that they did not dare to completely abandon subsistence cropping. Food security and reducing famine risk were prime concerns. Subsistence crops, such as maize, were grown for the family. Maize had little market value as (1) people in town ate rice as their staple food and (2) villagers either did not have the resources to purchase maize or were bound by cultural relationships that did not permit monetary exchange.

Traditional practices did not seem to incorporate the use of many of the cash crops into family diets, i.e., cash crops were not grown before fertilizer and seed became accessible. These were seen exclusively as income generators as opposed to supplemental food for the family. It was difficult to understand and relate the importance of crops hierarchically as some crops had market (cash) value, such as vegetables; some had subsistence value, such as corn; and some had both subsistence and cultural value, such as rice.

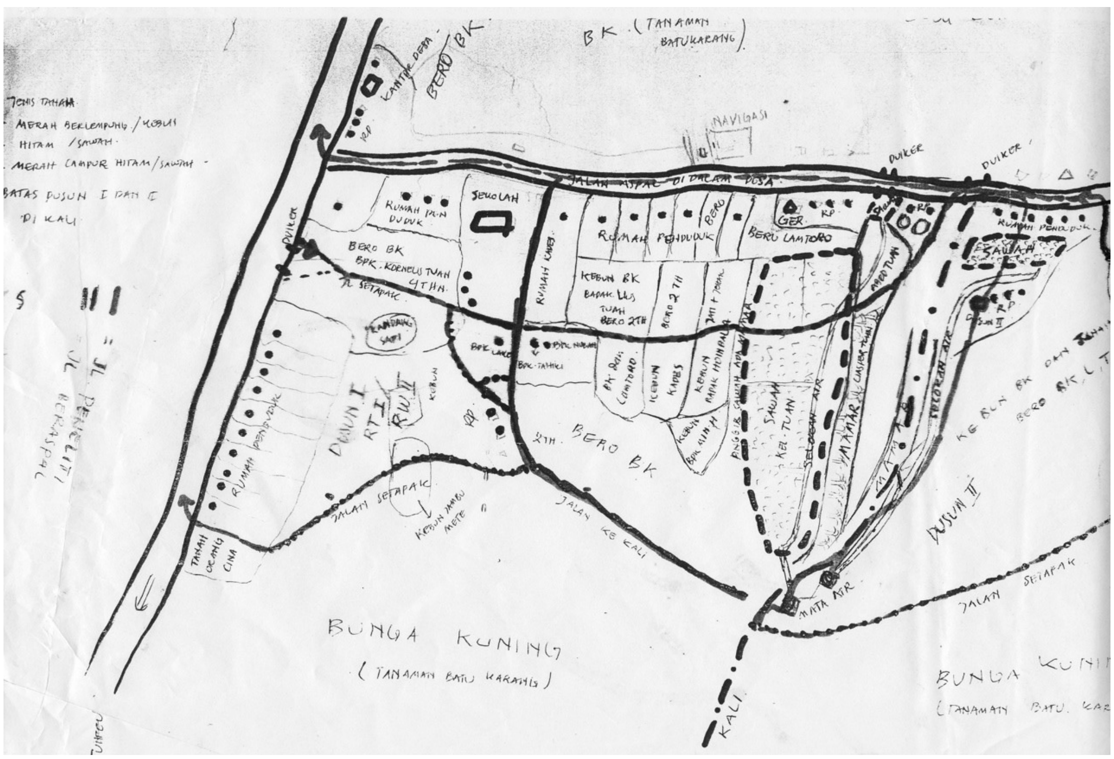

Figure 3. Map of a section of the village of Belo.

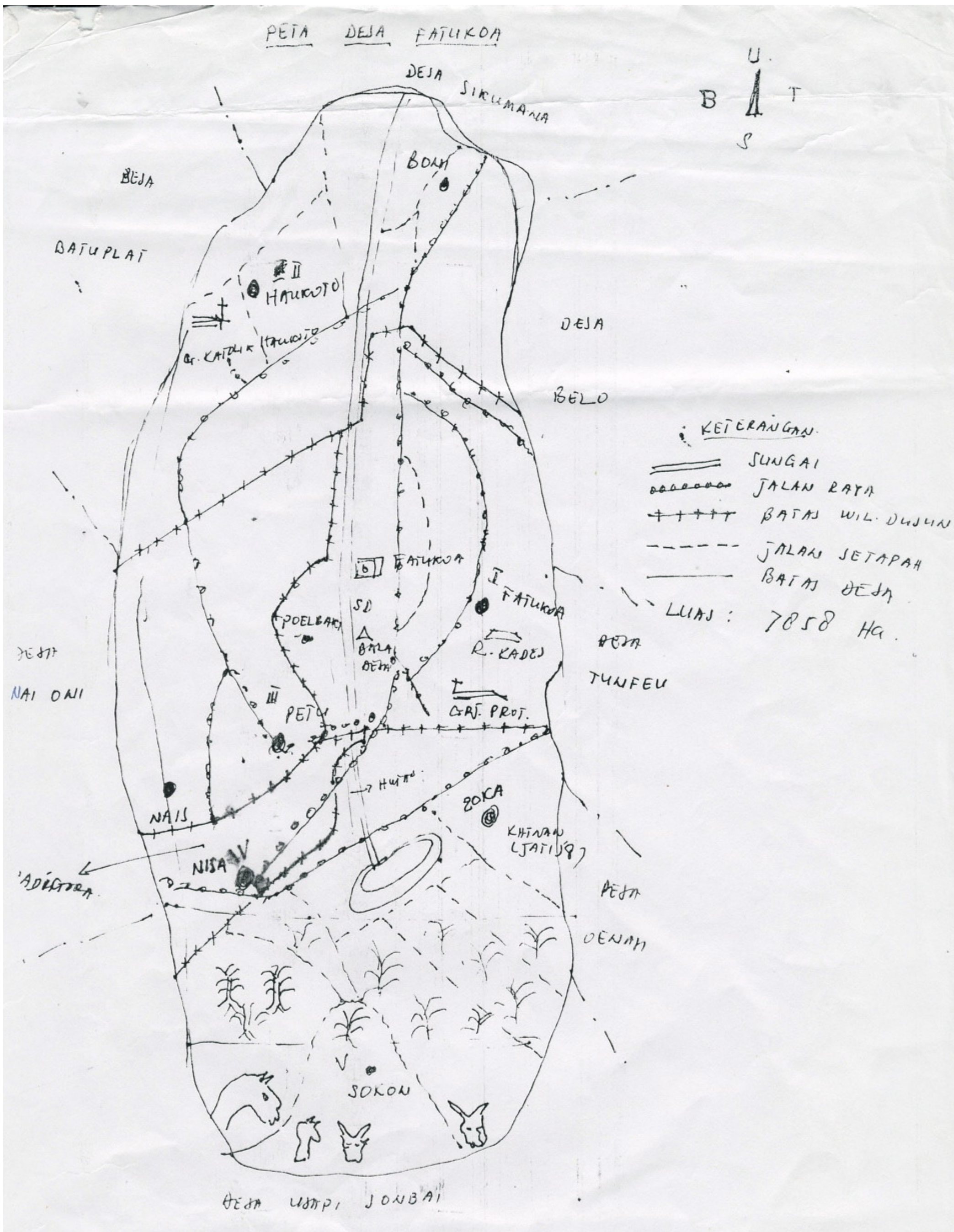

Figure 4. Map of the village of Fatukoa.

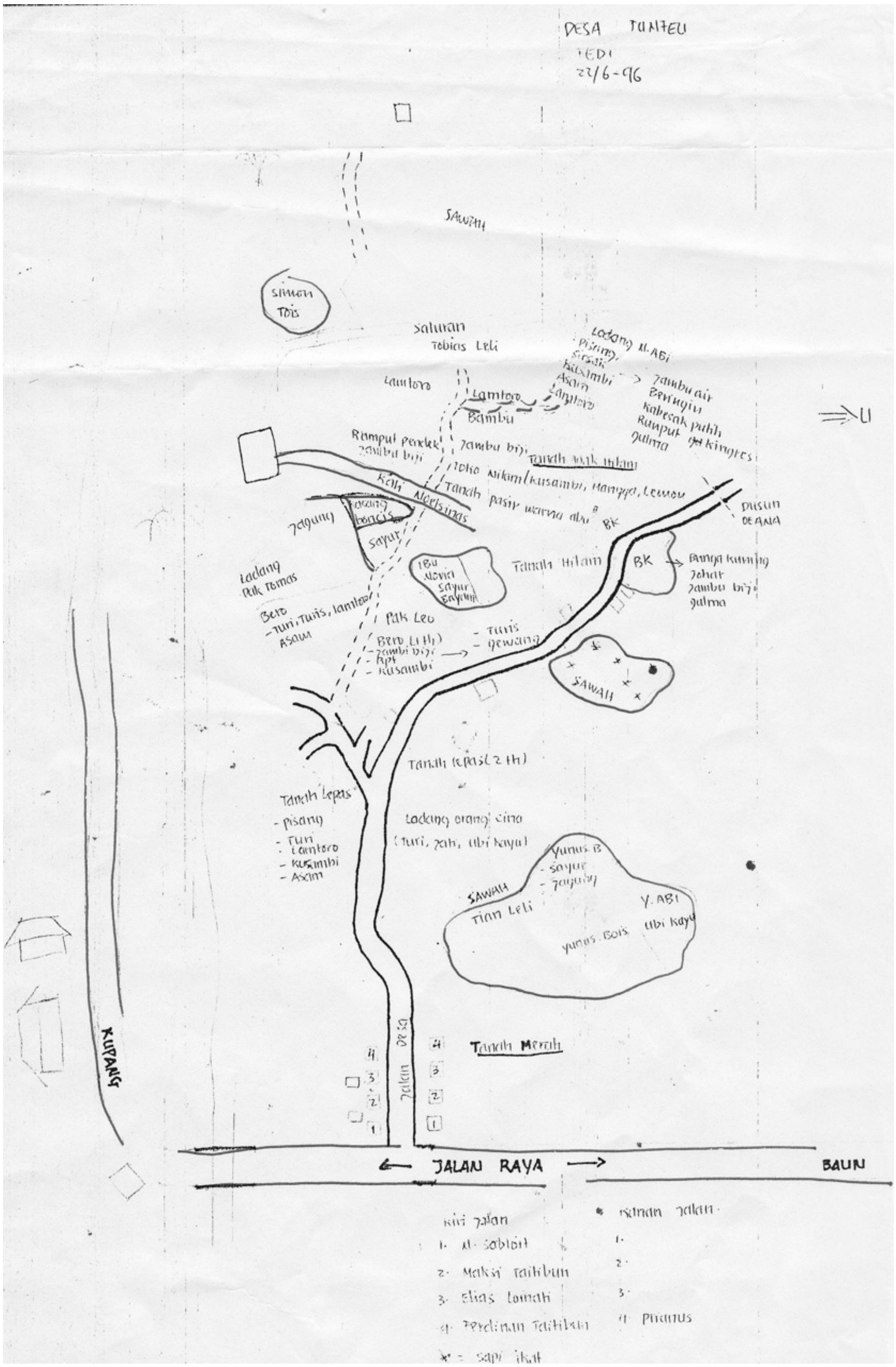

Figure 5. Map of the village of Tunfeu.

Table 2. Categories of income generating products that were part of the livelihood of local farmers in this study.

Category	Product	Description	Transaction	Price
Chicken	*Dewasa* chicken (adult male or female)		Buy	Rp. 4-5.000/head
		Sell at market in Kupang	Sell	Rp. 8-10.000/head
	Jantan chicken (male)		Buy	Rp. 8-10.000/head
		Sell at market in Kupang	Sell	Rp. 10-15.000/head
	Anak (young)		Sell	Rp. 4-6.000/head
	<1 year			Rp. 3.000
	>1 year			Rp. 6.000
Cattle	*Jantan* cattle (male)			Rp. 1,250.000/head
	Betina cattle (female)			Rp. 700.000/head
	Cattle (fattening cattle, usually male)			Rp. 800-1.000.000/head
	2 year old cattle		Buy	Rp. 750-800.000/head
		Fatten	Sell	Rp. 1-1,250.000/head
	Bakalan cattle		Buy	Rp. 400-700.000/head
		Fatten	Sell	Rp. 1-1,250.000/head
			Transport	Rp. 10.000/head
Pigs	*Dewasa* pig (adult)	200 kg	Sell (prices are higher at Christmas)	Rp. 300.000/head
	Pig (young)			Rp. 100-150.000/head

Table 2. (continued).

Corn	Dry corn (not sold)			
	Young corn (sweet corn, irrigated)			Rp. 100/ear (buler)
Non-staple food crops	Bananas			Rp. 750/ hand of 10-15
	Kacang buncis			Rp. 1.250/kg
	Brassica sinaensis			
	Sayur putih			Rp. 100/bundle
	Bawang merah			Rp. 500/bundle
	Daun ubi kayu			Rp. 100/4 bundles
	Kacang turis (pigeon pea) (*Cajanus cajan*)			Rp. 250/milk can or Rp. 1.000/kg
	Kacang nasi (Rice bean)			Rp. 250/milk can or Rp. 1.000/kg
	Labu (pumpkin)			Rp. 50/each if small Rp. 100-125/each if large
	Kacang tanah (peanut)	Nov. and Dec. prices given, prices are lower in April and May.		Rp. 2.000/kg (unshelled) Rp. 6.000/4 kg (shelled)
Woven cloth	*Kain panjang*	2.5m x 1.2m takes about a month to make; farmers have to buy the materials. Sold to stores in Kupang	Sell	Rp. 60.000/ each
Woven scarf/belt	*Selendang*	0.2 m x 1.5 m	Sell	Rp. 4.000/each

Table 2. (continued).

Fertilizer	Urea, TSP, KCl (rarely used)		No data	Rp. 350/kg Rp. 500/kg Rp. 600/kg
Coral rock		Enough to fill a small pick-up truck	Sell	Rp. 10-15.000/truckload
Housing land		For housing by local road (20 x 30 m)	Sell	No data
Field land		Fields for maize crops (600 m^2)	Sell	Rp. 1-200.000
Coconut		Brought to town by truck	Sell	Rp. 100-200/each
Coconut oil		7-10 coconuts fill an oil bottle; value added product	Sell	Rp. 1.500/bottle

Social structure

The majority of inhabitants in the villages were ethnically Helong. Most had immigrated to the area over two to three generations ago. Traditional culture in the three villages was still strong. Most people, related by blood or marriage, were involved in mutual assistance groups (*gotong-royong*). *Gotong-royong* groups were usually family-based and involved no more than 10 people. These groups were extremely important as nuclear families frequently lacked sufficient labor for larger tasks such as constructing houses, preparing fields, planting, and harvesting.

Gender and age roles appeared to be relatively well defined within the villages. Generally, women took care of all water, cooking, childcare, and vegetable cropping needs (Table 3). Men maintained the subsistence crops, collected fuel wood, managed livestock, and constructed and repaired housing and fences (Table 4). Children generally assisted their mothers until they either left the village to attend school or took on adult gender roles (Table 5).

Table 3. Activities calendar: Women.

	End of dry season (July-Sept.)			Beginning of wet season (Oct. to Dec.)			Wet season (Jan. to March)			Dry season (April to June)		
Childcare	------------------------all year round--------------------------											
Prepare food	------------------------all year round--------------------------											
Fetch water	------------------------all year round--------------------------											
Wash clothes	------------------------all year round--------------------------											
Weave	--------------------											----
Work rice paddies								---	---		---	----
Plant, weed, & harvest subsistence fields					--------------------------							
Tend gardens					---	---		---	---		---	----

Table 4. Activities calendar: Men.

	End of dry season (July-September)			Beginning of wet season (Oct. to December)			Wet season (Jan. to March)			Dry season (April to June)		
Clear fallows & plant, weed, and harvest subsistence fields		--										
Tend livestock	----------------------------all year around-------------------------------											
Collect firewood	-------------------------------all year around----------------------------------											
Carpentry and housing construction	Periodically throughout the year											
Work in rice paddies								---	---		---	------------

Table 5. Activities calendar: Children. (b=boy; g=girl)

Activity	End of dry season (July-September)			Beginning of wet season (Oct. to December)			Wet season (Jan. to March)			Dry season (April to June)		
Around the house	------------------both girls and boys all year round------------------------											
Collect water	------------------both girls and boys all year round------------------------											
Paddy rice	b	b						b g	b g		b g	b g
Garden/fields		b	b	b	b g	b g		b	b g	g	g	
Tend animals	------------------------ boys all year round------------------------------											
Kitchen work	------------------------ girls all year round-------------------------------											

Findings: A description of the agricultural system

Soil classification by farmers

The soils were generally classified by local farmers into three types that corresponded to their agricultural use—red, black, and white (Table 6). The most abundant soils were of the red type. Red soils supported upland crops, particularly rain-fed maize. Individual red soil fields were composed of either limestone gravel of dimensions no greater than 10 cm or limestone rocks with dimension in all directions of greater than 30 cm (Figures 6 & 7.)

Figure 6. Young *T. stans* fallow (foreground) on soil with small coralline rocks.

Figure 7. *T. stans* fallow resprouting out of large coralline rocks.

Black soils were relatively rare and located in isolated alluvial areas of bottom lands and on some periodically flooding river banks. These clay soils, often with shrinking and swelling properties reminiscent of 2:1 smectitic clays, ranged in color from black to incompletely mixed red and black clays. If they were proximate to a permanent water source appropriate for traditional aqueduct irrigation, the black soils were used to grow paddy rice. Where water was periodically available or could be carried a short distance by hand, vegetables were grown. Along sloping river banks and on other black soils that were prone to erosion, *mamar* (mixed perennial tree gardens) were maintained. Some black soils along river banks were sandy.

White soils were considered broken and pulverized coral. Farmers did not indicate they used these soils, perhaps due to their upland dry location, their shallowness, and their infrequency in the area.

Soil analysis results

Red soils

Unfortunately, the choice and number of samples analyzed prevented several pertinent questions from being addressed in this study, such as:

1. Did soil chemical and/or physical properties improve with age of fallows under *T. stans*?
2. Did fallow species, specifically *T. stans*, *C. odorata*, and *M. pudica* differentially improve soil?
3. How did the amounts of nutrients in the above ground biomass compare across fallow species before burning?

Due to financial constraints and political factors, only eleven samples were analyzed, but without replicates for each treatment. It was, therefore, only possible to average the results of the soil analysis in order to produce a generalized description of red soil properties in the area. The averaged data are presented in Table 7, while the raw data are given in Appendix D.

The landscape within the three villages was primarily composed of red soils: young or developing soils from coral reef parent material. The soil depth of the areas sampled ranged from <20 to 70 cm. Rock fragments or large rocks made up approximately 50% or more of the soil volume. The soil analyses indicated that soils ranged from being clay to silty clay to silty clay loams. The soils were moderately acidic (pH 5.5) to neutral. The percent organic matter was low (1.72 to 3.78%) as were the N contents and C:N ratios (Appendix D). Base saturation was extremely high, while CEC varied from medium to medium high. Calcium was dominant in solution, with moderate levels of Mg and low levels of K. Soil analyses indicated that there were medium to high levels of available P, but that N contents were low. Thus, in general the soils were shallow. They had adequate fertility, good drainage, and poor workability.

Table 6. Field crops and products by soil type and use category, excluding home garden products.

Soil type	Cash crops and products	Subsistence crops and products
Red (vast majority of land; coralline rocks)	Rocks Cattle Goats Pigs	Maize Beans Cassava Fuel wood
Black (Vertisol-like) (side slopes and bottom lands; 2:1 clay properties)	Vegetables Paddy rice Fruit from *mamar*	Fruit from *mamar*
White soil (rare)	*Jati* (teak) forest	

Table 7A. The results of averaging analyses from 11 soil samples from fields in the maize-*T. stans* shifting cultivation system.

Sample description	Texture			pH		Organic matter			HCl (25%)		Olsen P_2O_5	Bray 1 P_2O_5
	Sand	Silt	Clay	H_2O	KCl	C	N	C/N	P_2O_5	K_2O		
(n=11)	--------- (%) ------			(1:2)	(1:5)	--- (%) ----			(mg 100 g^{-1})		--------- (ppm) -------	
Averaged soil analysis data	7	38	54	6.4	6.1	2.94	0.31	11.82	420	21	207	57.6

Table 7B.

Sample description	Cation exchange capacity (NH_4-Acetate 1*N*, pH7)							KCl 1*N*		Hot water
	Ca	Mg	K	Na	Total	CEC	KB	Al^{3+}	H^+	B
(n=11)	------------------------(me 100 g^{-1}) ------------------						(%)			(ppm)
Averaged soil analysis data	24.5	1.29	0.16	0.16	26.16	20.79	100.00	0.02	0.01	1.59

A history of agriculture in the area as reported by farmers

Overall vegetation description and land use

The landscape of the villages in this study was open savanna dominated by *T. stans*. The rest of the land was covered by secondary forest, *mamar* (perennial tree gardens), forage banks, paddy rice, and vegetable crops. For example, in the village of Belo, there were 20 ha of paddy; 10 ha of vegetables; 31 ha of fruit and *mamar*; 4 ha of forest; and at least several hundred ha of shifting cultivation land dominated by the shrub *T. stans*, weeds, and some unimproved grasses.

Native trees observed in the area include *pole* (*Alstonia villosa*), *kom* (*Zizyphus mauritiana*), *matani* (*Pterocarpus indicus*), and *kosambi* (*Schleichera oleosa*). Exotic and naturalized vegetation in the area included *T. stans*, *L. leucocephala* (glauca), *kapok* (*Ceiba pentandra*), *Sesbania sesban*, and *gamal* (*Gliricidia sepium*). In home gardens, *nangke* (*Artocarpus integra*), *kemirir* (Aleuritis *moluccana*), kelapa (*Cocos nucifera*), orange (*Citrus spp.)* and ornamental species were common.

The agricultural system

Agriculture was by far the most time consuming and important activity in which villagers participated as it provided them with the majority of their direct household needs (food and fuel wood) as well as cash income (Table 2). Agriculture in the villages was divided into crop and livestock systems. Crop production was further divided into shifting and permanent cultivation. Here I briefly describe the major components in the crop and livestock production systems and their impact on the livelihood of villagers. I then focus on particular dynamics of the shifting cultivation system. An overall description of the system, its components and context, was documented in the characterization template (Appendix C).

A brief history of the agricultural systems

According to farmers, in the 1940s, cattle were the primary income generators for most village families, while shifting cultivation provided subsistence needs. Livestock and subsistence food production coexisted but failed to overlap as rocky soils rendered draft animal useless and cattle destroyed the crops if they were not kept out.

Before the War of Independence (1945-1950), the area was relatively well populated with wild animals such as birds, monkeys, and wild pigs. Settled farming practices in the area began in the 1950s, when the primary forest was cleared. During this period, vast areas of forest still existed and were sometimes used as places to hide during World War II.

The first invading vegetation after the opening of the land for agriculture was *L. camara*, an herbaceous weed that was unpalatable to cattle. Although the yields of maize following *L. camara* were not known, older farmers say that the yield of maize was higher with *L. camara* from 1950 to the early 1960s than yields were at the time of this study.

In the 1930s, cattle raising changed from a cut and carry to a free range system due to an increase in the number of cattle. It was too time consuming to cut enough fodder for the number of cattle. Also, there weren't enough trees and vegetation to cut. By the 1960s, coral rock fences were common. This meant that the boundaries of fields used for shifting cultivation became more permanent. The era of free range cattle ended around 1980. The cattle population was high and the vegetation was experiencing over-grazing.

From 1961 to 1964, another shrubby fallow species, *M. pudica*, a viney legume with piercing thorns, out-competed *L. camara* as the dominant fallow species in some areas. As clearing *M. pudica* was dangerous because of the thorns and as the red, coralline soil in which it grew was still considered abundant, land invaded by *M. pudica* was abandoned and taken completely out of agricultural production. Even during the study period, areas infested by *M. pudica* were not cultivated by farmers.

The dominant fallow species at the time of the study, *T. stans*, appeared on the island of Timor in approximately 1961 before the National Tragedy of Gerakan PKI on 30 September 1965, according to farmers over 60 years old from the village of Belo. *Tecoma stans* entered the village of Fatokoa between 1962 and 1965 according to a 50 year old farmer. In the initial years of establishment, *T. stans* shrubs were rare but the species quickly naturalized to the area. *Tecoma stans* entered Tunfeu in about 1965-67.

Tecoma stans, known as *bunga kuning* in Indonesian (literally "yellow flower"), as *hau suf molo* in Timorese by the local farmers of the focal villages, and as Yellow Bells in the Southwestern United States, is a fast-growing, weedy shrub that is reported as a weed in many areas of the dry tropics (Tipton, 1994). It is typically introduced as an ornamental, but it escapes and naturalizes easily. Figure 8 shows the flower and seed pod of *T. stans*, while Figure 9 shows *T. stans* cultivated as an ornamental in one of the focal villages.

Two stories arose as to how *T. stans* was introduced to Timor. One indicated that *T. stans* was brought in as an ornamental to a Protestant church in Kupang. A farmer from the village of Belo then planted it in front of his house. It escaped and soon established itself in the marginal land areas, spreading by wind dispersal of its seeds. Another farmer stated that *T. stans* came into the area from a cattle corral where Chinese traders used to gather livestock to be shipped to other islands. Farmers suggested that in the manure left behind in the corral, seedlings of *T. stans* grew. Due to its beautiful flowers, some people took seedlings from the corral and planted them as ornamental plants.


Figure 8. *T. stans* flower and seed pod.


Figure 9. *T. stans* as an ornamental in West Timor.

T. stans then spread because people were interested in it for their home gardens. In either case, *T. stans* escaped cultivation and became a spontaneous fallow, which had since been intentionally propagated and introduced to other villages. The fallow phase of shifting cultivation was based solely on *T. stans* in the three focal villages. In fact, *L. camara* was rare in the area, though *M. pudica* still appeared in mixed species patches and still dominated small areas.

It was unknown, however, when farmers actively started using *T. stans* as a primary fuel source. In the 1980s, a farmer introduced *T. stans* to the village of Roti to start a font of fuel wood.

Though *T. stans* was the current predominant fallow species in these villages, a new volunteer species had entered the area. The most recent weedy species to invade was *C. odorata*, appearing in farmers' fields since 1994. Farmers did not express much opinion or concern about it. They said *C. odorata* was very much like *L.*

camara in its form. It was also fast-growing like *L. camara* and *T. stans*. Farmers were skeptical that it would take over *T. stans* because *T. stans* survived by growing out of the holes in coralline rock and, thus, withstood fire. Figure 7 shows new regrowth of *T. stans* out of a large coralline rock about a month after the field was burned.

Though some researchers and policy makers encouraged farmers to actively fight *C. odorata*'s establishment, farmers did not think it was worth the effort. In terms of a fallow species, farmers did not indicate a preference for either *T. stans* or *C. odorata*, particularly as *C. odorata* was still new at the time and had a growth form similar to *T. stans* in rocky areas. In addition, farmers said it was not until after *T. stans*' naturalization to the area that they began to use its economical and agricultural functions and perhaps they would find *C. odorata* useful as well.

However, in the Amarasi and Kupang Timur regions where farmers intensively cultivated *L. leucocephala*, the observation that *C. odorata* was out competing *L. leucocephala*, was of serious concern. In these areas, it was not that one weedy shrub was replacing another; it was that a highly valued, nitrogen fixing legume prized for its cut-and-carry attributes was being invaded by a species toxic to cattle.

Livestock production

In this study's three focal villages, most farmers owned two to five head of cattle for fattening and subsequent resale. Cattle were the primary cash income source for most families and were seen as good investments as they could be sold at anytime for quick cash.

Pigs had little market value as many of the non-local immigrants were Muslim and did not consume pork. At Christmas, however, pigs commanded a high market price (Table 2) and were also in demand within the village for family use. Pigs were usually kept in a corral or small animal house. During the day, farmers kept their pigs, chickens, and goats in the *T. stans* fallows.

Goats were recently introduced to the area to increase household income. Farmers in Fatokoa indicated that two goats had been given to each household by a non-governmental organization (NGO) within the last five years to improve nutrition. Goats were fed by a combination of cut-and-carry and tying the goats in the middle of fields to graze. Villagers did not indicate much interest in drinking goat milk or eating goat meat. Instead, goats were a considered a good source of income. They were sold to Muslims in Kupang for Islamic ceremonies.

Chickens ran freely around houses. They were responsible for finding their own food, except when a consistent quantity of eggs was desired, in which case their pecking was supplemented with maize. Eggs and poultry were consumed within the household as well as sold. As most chickens died due to disease during the changing seasons, both from dry to wet (November) and wet to dry (May), chickens were sold off twice annually to avoid uncompensated losses (Table 2).

Permanent cultivation

Permanent cultivation in the villages had several components. Annual crops, such as paddy rice and vegetables, were grown primarily in rain-fed black soils (Tables 6 & 8). Some black soils were irrigated using traditional systems. *Mamar*, perennial tree gardens, were established along river banks, typically in black soils, and at a 200 m radius immediately around springs, in accordance with local law. Some were on wet or swampy land (black soils) while others were on dry land (red or red-black soils). Farmers in the three villages incorporated coconut, beetle nut, jack fruit, banana, and citrus into *mamar*. Modifications made in dry areas allowed for most species to be cultivated, except for beetle nut. *Mamar* required little maintenance, and weeds usually did not have the opportunity to grow due to the combination of a thick canopy cover and understory grazing by livestock such as cattle and goats.

In addition, fodder banks and live-fencing (legumes) were becoming more common, specifically on red soils, with the prohibition of free-grazing. They supplied vegetation for cut-and-carry livestock production. Finally, multi-stratified perennial home gardens surrounded houses and were located on red soil.

Rice paddies, *mamar*, and home gardens had long produced crops for home use. More recently, with improved transportation to Kupang and with some access to germplasm, pesticides, herbicides, and fertilizer, cash crops such as vegetables had become very important income generators for farmers.

Shifting cultivation

Shifting cultivation was the traditional livelihood in the villages. At the time of this study, it consisted of 1-2 years of maize followed by 3-5 years of fallow. Agricultural fields were not fixed, but shifted in space and time, allowing fallow vegetation to recuperate soil properties before cropping again. A mix of crops was planted in each field and local rules required at least some tree planting at the time of fallowing.

*Maize-*T. stans *shifting cultivation system*

Conversion phase

The present slash and burn system produced one subsistence crop of fast-growing maize annually, with zero to low fertilizer input. Following 3-4 years of fallow dominated by *T. stans*, farmers cut the shrubs in late July to early November and allowed the slashed vegetation to dry for several days to a month, depending on its composition (Tables 8 & 9).

Table 8. Crop calendar. (P=plant; H=harvest; S=slash; B=burn; W=weed; and F=fertilize; ---- = growing season; numbers following P and H indicate first and second planting and harvesting)

Activity	End of dry season (July-Sept.)			Start of wet season (Oct. to Dec.)			Wet season (Jan. to March)			Dry season (April to June)		
Sawah (paddy crops)												
Paddy rice								P	P	-----	H	H
Irrigated maize	-----	H2			P1	P1	-----	H1	H1		P2	P2
Vegetables	P H	H	H					P	P	P	P H	P H
Ladang (field crops)												
Kacang turis (pigeon pea)					P	P	-----	-----	-----	H	H	
Kacang nasi (rice bean)					P	P	-----	-----	-----	H	H	
Arbila bean						P	-----	-----	-----	-----	H	
Labu (pumpkin)					P	P	-----	-----	--H-	H	H	
Maize		S	S B	B	P	P	W F	------	H	H		
Cassava (1 yr type)					P	P	------	------	------	H	H	H
Cassava (2 yr type)					P	P	------	------	------	H in yr. 2		
Firewood	All year around; trees cut when cash was needed or when a plot was to be planted											

Table 9. Uses of *T. stans* by season.

Use	End of dry season (July-Sept.)	Start of wet season (Oct. to Dec.)	Wet season (Jan. to March)	Dry season (April to June)
Firewood	------------------	-----------------	------------------	------------------
Slash and burn vegetation	------------------			
Litter fall			------------------	------------------
Stakes for vegetables			------------------	

With *T. stans* as the dominant fallow species, farmers said that a slashed field could be burned as early as two days after slashing, although we saw some slashed vegetation on the ground for over a month. Most trunks were cut between 30 and 100 cm from the ground. Vegetation was burned on site, with the exception of trunks and some branches, which were collected for fuel wood. Leftover material was piled up before re-burning. Burns appeared to be extremely patchy as the slashed vegetation occurred principally around the trunks of slashed *T. stans* (Figure 2). The rest of the vegetation consisted of low-growing grasses. *Tecoma stans* grew throughout the cropping season but did not shade or otherwise compete with the growing maize crop to the extent farmers felt it was necessary to prune or remove it.

The number of plots cultivated by a farmer depended on the availability of labor (immediate family and mutual assistance groups) and the amount of land owned by the farmer. Individual plots were typically one ha or less. The farmers we spoke with said they cultivated from 1 to 3 plots annually.

Cropping phase

Planting occurred from mid-November to late December, as soon as the rains started (Tables 8 & 9). Though government programs promoted a fast-maturing hybrid, Arjuna, McWilliam (1988) reports that farmers found Arjuna to be highly susceptible to pests and that it stored poorly. The farmers we interviewed said they preferred to plant local varieties instead of Arjuna and that they saved seed from year to year. Some farmers held back sufficient seed for a minor second planting if the first planting failed due to inconsistent rains.

The common planting technique was to make a shallow hole with a dibble stick and drop in three maize seeds. If the soil was extremely rocky (gravel to tennis ball-sized pieces) and if the previous *T. stans* fallow was not thick, planting occurred in rows. If the soil had larger but less frequent rocks and, thus, clumps of *T. stans*, maize was planted in circles around the *T. stans* trunks (Figure 2).

These findings are consistent with those of Jones (1983), McWillam (1988), and Gunarto (1985), who all report planting in the region to be in rows or in a less systematic fashion with spacing from 25 x 75 cm to 2 x 2 m.

Finally, though some farmers said continuous annual cropping was possible if fertilizer was used, no one had tried continuous cropping for more than two years.

Pest management

Farmers indicated that no pesticides were used on maize but indicated that one weeding was necessary to prevent weed competition from resulting in low maize yields. A single hand weeding occurred approximately three weeks after the maize germinated, when the seedlings were about 25 cm tall (Table 8). If fertilizer was used, farmers weeded just prior to applying fertilizer. Although weeds were considered a major constraint to maize production systems, they did provide ground cover, protection against soil erosion, as well as initial fallow regeneration.

Applying fertilizer

As fertilizer inputs had become more available since the mid-1980s, some farmers applied fertilizer to each maize plant as a band application (5-10 cm from the plant and 5-10 cm deep) once the maize was about 25 cm tall (Table 8). Farmers said that they did not apply fertilizer at planting.

The government allocated fertilizer to village heads, who distributed it to farmers in their villages. There was no choice in terms of fertilizer type. Some farmers sold part or all of their ration of subsidized fertilizer. However, most farmers claimed that without urea and *komplet* (a NPK mixture that no one had samples of at the time of the study), they would get little to no yield.

Harvesting and yields

Maize was harvested in March (Table 8). No yield data were available. In addition, farmers' estimates were exceedingly difficult to understand or standardize.

Fallow phase

Fields were typically cropped two or three times before fallowing for two to eleven years. Fallow vegetation was allowed to regenerate naturally. *Tecoma stans* re-sprouted from cut trunks at the start of the rainy season. Trunks that arose from holes within coral rocks were reported to survive better than those that did not. This was confirmed by casual observation. According to farmers, the rock protected the trunks and roots from intense heat during burning. Re-sprouting of *T. stans* was preferred to using seed, because canopy cover was quicker and the time needed to produce firewood was faster. The tallest *T. stans* shrubs we encountered were 5 m tall with a diameter at breast height (dbh) of approximately 10 cm. Both farmers and our observations suggested that the species was not prone to pest attack.

Approximately 70% of the farmers in these villages had *T. stans* as the dominant species in their shifting cultivation fallows. In terms of the value of the fallow phase, farmers said the rocky, red soils of the area were relatively infertile in terms of producing crops. Farmers tended to observe the growth of *T. stans* as an indicator of soil fertility. Once an area was covered by *T. stans* for three to five years, the soil was thought to have improved. This was indicated by a change in soil color from red to darker brown and by leaf litter on the soil. Farmers then considered the soil to be restored and ready for another round of crop production. For example, Figure 10 shows a five year old *T. stans* fallow, ready for conversion to cropping.

In addition, farmers used *T. stans* as fuel wood, light construction material, dibble sticks, poles for string beans, weed control, a green manure, and fodder (Tables 9 & 10). For example, Figure 11 shows bundles of *T. stans* being unloaded on the roadside to be sold for fuel wood.

Figure 10. Five year old *T. stans* fallow.

Figure 11. Farmers unloading bundles of fuelwood (*T. stans*) for sale.

Table 10. General comparison of fallow species (adapted from Djogo et al., 2007).

Species characteristics	T. stans	Gliricidia sepium	L. leucocephala	Sesbania grandiflora	C. odorata
Drought resistance	++++	++	++	++	++++
Fire resistance	++++	++	++	+	+++
Fencing material	-	++++	++++	++	-
Fodder	+/-	+++	++++	++++	-
Nitrogen-fixing	-	+++	+++	+++	_
Fuel wood	++++	++	+++	+	+++
Resistance to pests and disease	++++	+	+	+	+++
Biomass production	+++	++++	++++	++	+++
Response to pruning	+++	++++	++++	+	+++
Survival in rocky soils	++++	+++	+++	++	++++

Farmers in the villages said they liked *T. stans* as a fallow species because it was easy to manage, was resistant to drought and fire, and had multiple uses. These attributes made it a strong fallow species in comparison to other local fallow species (Table 10). Once it became established, *T. stans* was difficult to remove as it resisted fire and grew particularly well with its roots growing into large coralline rock.

CHAPTER 5: ANALYSES, INTERPRETATIONS, AND RECOMMENDATIONS WITH RESPECT TO THE CASE STUDY

Soil: Interpreting observations, farmer-derived data, and laboratory analyses

Red soils

Based on general observations of the area, the underlying parent material, agricultural use by farmers, and soil analyses, red soils in the study area most resembled Mediterranean type soils (Adnyana et al., 1994; Lembaga Penelitian Tanah Bogor, 1974/1980; Pusat Penelitian dan Pengembangan Tanaman Pangan, 1991) or Ustropepts (Monk et al., 1997). The long-term management of these soils through slashing and burning vegetation, along with an accumulation of minerals and nutrients resulting from sedimentary rock parent material, may explain the lower than expected pH and the higher than expected CEC and C:N ratio. Another possibility is that these fit somewhere into Rendolls (Monk et al., 1997), Regosols (Pusat Penelitian dan Pengembangan Tanaman Pangan, 1991), and/or Rezina (Yayasan Bhakti Wawasan Nusantara, 1992), particularly as they were generally heavy-textured, shallow, and immediately on coral reef or mixed with coral rock. The discrepancies between Rendolls and the study's soil analyses include an atypically low amount of organic matter as well as the red and reddish-brown color as opposed to darker soil.

One set of soil analyses (Table 11) from Garcia (1963), reported in Metzner (1977), was of the red calcareous soils. This soil appeared similar to that on which Belo, Fatukoa, and Tunfeu farmers cropped in terms of its description and analysis. The soil was red, rocky, and shallow. If this soil was similar, then the maize-*T. stans* system was likely responsible for the decrease in pH and increase in organic matter, which is what is desired from fallowing such land.

Table 11. Soil analyses of the red calcareous soils (Garcia, 1963, cited in Metzner 1977 p. 52).

Sample depth (cm)	Stones (% by volume)	Cation exchange capacity (CEC)		pH (Extract 1:2, 5)	Organic matter			
		Me 100 g^{-1} moisture-free soil						
		Total CEC	H^+	H_2O-KCl	Total	C (%)	N (%)	C/N
0-60	39.5	8.59	2.8	8.4-7.9	11.34	00.78	0.094	8.3
60-160	49.0	8.34	0.2	9.0-8.4	0.22	0.13	0.0086	15.1

Black soils

In terms of soil color, structural properties and use, the black soil appeared similar to those described by Ormeling (1956), Mohr and Van Baren (1954) and Dames (1950) as local pockets of heavy clay or loamy soils that could be used for agriculture depending on water source and texture (see Appendix B).

The black soils also corresponded to two soil types in Monk et al. (1997), based on color and texture: sandy Tropaquents and deep, clayey, sticky Eutropepts. However, Tropaquents are not reported to occur in the study area according to the sources used by Monk et al. (1997). The ISRIC-WISE data set suggests the black soils were Pellic Vertisols, which corresponds well with the shrinking and swelling properties of these soils observed during this study.

Finally, in terms of the two soil maps (Lembaga Penelitian Tanah Bogor, 1974/1980; Pusat Penelitian dan Pengembangan Tanaman Pangan, 1991), the black soils most closely correspond to Grumusols, though they were not mapped to occur in the study area. This lack of correspondence with the map(s) may be explained by the isolated pockets of black soils. In addition, Adnyana et al. (1994) documented Grumusols in the Kupang area, indicating they represent 1.33% of the land surface.

Water holding capacity in the black soils probably varied due to the range of sand to clay ratios, with more clay having greater water-holding capacity. Water stress was still likely for plants, however.

White soils

As farmers in this region did not use white soils, they were not sufficiently well documented in this study, which was consistent with this study's goals in conjunction with RRA principles.

Analysis and recommendations for agricultural systems

Biomass management

Farmers seemed to be making good decisions in terms of managing biomass. For example, green manuring maize fields, even with legume coppices, would not be the best use of resources in the study area for five interconnected reasons. First, cattle were the major income generator, and they needed the vegetative biomass as fodder. This was especially true as cattle fodder in the area was often limited as well as low in N and, therefore, protein. Second, vegetation was sparse in this arid region, so there was little vegetation to incorporate as green manure. Third, low moisture limited decomposition most of the year, so adding green manures to the soil wouldn't result in the rich organic layer that was needed. Fourth, labor was limited, typically to 1 or 2 full-time family members. Given these reasons, it was more sensible to feed cattle than incorporate the vegetation as green manure. The labor was needed for preparing fields, planting, and weeding crops (Tables 6 and 7). Finally, incorporating green manures into soils, which allows for the least loss of nutrients due to volatilization, leaching, or runoff, was nearly impossible given the quantity of large rocks on the soil surface of the fields. It would be advisable, however, to grow tree legumes for cattle fodder. As *L. leucocephala* was grown in nearby villages, it was likely to grow in the focal villages as well. Thus, these findings and analyses suggest that farmers should maintain their current biomass management and, in addition, supplement their current cropping system with nitrogen-rich legume foliage to feed to cattle.

Weed management

Farmers also appeared to be making good decisions with respect to managing weeds. For example, farmers weeded their maize crops only once and timed this weeding to occur when the maize was young and most susceptible to decreased growth due to weed competition. The weedy growth that occurred during the latter part of the cropping season helped form a ground cover, limiting erosion while not greatly affecting crop growth.

Crop residue management

It was not entirely clear how farmers managed crop residues. For this reason, suggestions are made here without evaluating the farmers' practices. It is recommended that crop residues be left in the field to dry naturally and be grazed by cattle. Allowing cattle to graze the stover is recommended because cattle are at constant risk of starvation during the dry season. It is important not to allow cattle to graze areas to bare soil, however, because of the high potential of wind and water erosion. Soil compaction by cattle is unlikely considering the quantity of rocks in the soil.

One benefit of farmers tying or leaving their cattle in *T. stans* fallows was that the cattle tended to stay in the shade of the *T. stans* during the day, hence their manure ended up in the areas that were specifically cropped later. Farmers brought their cattle near their homes for the night to prevent theft, so the manure dropped at home benefited the home garden. Quantitatively, it was difficult to estimate, however, how much N was added from having 2-6 cows on 4-6 ha of land given the manure management strategy and the low N diet of the cattle.

Maintaining soil fertility during conversion

In a dry climate with shallow soils, fast-growing, drought-resistant fallow species are optimal. Even with fast-growing species, however, total biomass accumulation in the dry season in West Timor is likely to be low, so burning while preparing the land would release only small amounts of nutrients as ash. However, farmers reported that they often burned a month or more before the start of the rains. As gusty winds are common in the area, most of the ash may have been blown away by the time the crops were planted. Ash not lost to wind erosion may have run off when the initial rains hit the unprotected ash and soil. Given this and the fact that fertilizers were available only to a limited extent, it would be useful to split the fields and compare yields on burned fallow versus slashed-fallow treatments for several years. In the long term, slashing without burning is likely better because the soil remains protected. In addition, organic matter may accumulate: the non-woody vegetation should decompose during the cropping season, adding some plant-available nutrients and building organic matter over time.

Present fertilizer applications: Possible rationales

The farmers' present timing of applying fertilizer may be due to the inconsistency in the start of the rains. Families often only have enough fertilizer for one crop, though they may have enough seed to plant a meager second crop if inconsistent rains cause early failure of the first planting. Applying fertilizer to an early crop when rains are sporadic may seem more risky to these subsistence farmers than less than optimal yields, since their fields are completely rain-fed. Local experience may indicate that if the crop makes it to 25 cm tall, more likely than not, there will be grain harvested from that planting. In the temperate zone and in "developed" countries, the loss of a crop is often compensated for by governmental assistance, loans, or other forms of social help or insurance. On the other hand, "risk" for subsistence level farmers in this study was uncompensated and was, thus, very real. Wanting average yields over time is reasonable as long as no year is a total loss, leading to hungry families or unmet basic needs. It was important in this analysis to recognize that storage in the region was poor and that there was little to no government assistance if crops failed.

Another possible rationale for the current fertilizer application practices was that the type of fertilizers applied could cause "seed burn." If urea and/or diammonium phosphate were applied, locally high pH conditions could inhibit seed germination. Farmers may have found, though they didn't report this directly, that fertilizing at planting decreased germination rates. They may or may not have recognized an association between fertilizing at planting and reduced germination rates. In addition, if seed burn did occur, farmers may not have known that altering the type of fertilizer, the quantity of fertilizer, or the distance of the fertilizer from the seed could have reduced, if not eliminated, the problem.

The current study did not reveal any specific explanation for the fertilizing practices used. However, interviews suggested that farmers did conduct risk assessments, as they said they would rather get some yield every year than get a great crop some years and be hungry other years.

Fertilizer recommendations

I have based fertilizer recommendations included herein on research summarized in Table 12. As the soils were not acidic and as Ca and Mg were not limiting due to the rock substrate, liming in order to improve nutrient availability to the crop or to decrease Al or Mn levels below that of toxicity was not appropriate for this soil.

In addition, basic developmental physiology indicates that seedlings have higher mineral nutrient requirements for root development compared to that of mature plants. Phosphorus is particularly crucial to early plant development. Thus, it is important to provide nutrients, in this case in the form of fertilizer, in a seedling-available form at planting or soon after. As maize roots are branched as opposed to having a main tap root, it is reasonable to place starter fertilizer as a band 10 cm away from the plants and 10 cm under the soil. A major problem for farmers in developing countries has been the concept of 'if a little is good, a lot is better." Applying higher than necessary amounts of fertilizer, just like overdosing on medicines, can create toxic (typically high pH) environments for roots. Separately and together, urea and diammonium phosphate are more likely to cause unfavorable soil conditions than the older fertilizers such as ammonium nitrate and triple super phosphate (TSP) (Bouldin et al, 1968).

The findings and analyses resulting from this study suggested that half of the nitrogen-phosphorus-potassium (NPK) fertilizer should be banded at planting. The plants should then be side-dressed with the rest of the NPK when the plants reached 25 cm in height. This side-dressing may not actually be needed if the original reason for not fertilizing at planting time was due to previous experience with seed burn. If drought occurs early, and the first planting fails, the fertilizer intended for side dressing could then be applied to the second crop as a band.

If seed burn was not the reason for not banding fertilizer at planting and, instead, sporadic rains were, then fertilizer should be applied as early as possible while still feeling reasonably confident that a drought would not cause crop failure. In addition, extremely heavy rains often fell in short bursts. The trick of the trade for this area may be to have fertilizer that dissolves slowly and does not completely disappear with the first heavy rains. If fertilizer does not dissolve slowly, nitrate will not accumulate. Instead, the nitrate will likely be in the soil solution and leach during rains.

Banding fertilizer, 10 cm over from the planted seeds and 10 cm into the soil, is the most reasonable application method because: (1) fertilizer quantity is limited, (2) the fields cannot be plowed as they are too rocky, (3) the nutrients supplied by the fertilizer need to perfuse the soil volume in order to be plant-available, (4) the crop has a relatively small volume of soil to exploit, and (5) heavy rains will easily wash away surface-applied fertilizer.

Table 12. Constraints to crop production in shifting cultivation. (NC= nutrient accumulation; SI=soil physical property improvement; OM=organic matter; CEC=cation exchange capacity; MC=micro-climate alteration)

Constraint to crop production	Fallow function	Process involved in overcoming constraint	Limits on processes
Potassium (K)	NC	Transfer of nutrients between soil and vegetation via roots (uptake). Removal of nutrients from vegetation to soil via litter, in rain-wash, by burning, root excretions and death, and mineralization of litter (Nye & Greenland, 1960, pp. 34-35). Atmospheric deposition, rain water inputs (Nye & Greenland, 1960). Removing (burning) vegetation leaves soil (often charred black) exposed to solar radiation. The soil temperature rises and OM decreases rapidly (Sivakumar et al., 1992).	
Nitrogen (N)	NC	N_2 fixation, uptake from subsoil (Nye & Greenland, 1960, p. 50 & 65), capture from subsurface lateral flow	1. Absence of effective mycorrhizal strains; P deficiency; toxic soil elements 2. Soil depth and/or acidity; anion adsorption capacity of subsoil 3. Soil depth, slope, rainfall, hydrology
Phosphorus (P)	NC	Transformation of P into more plant-available forms, reduction in P complexes, increased P cycling via mycorrhizae and other special acquisition mechanisms.	P demand by vegetation; production of OM and acids; soil texture, mineralogy, and P-sorption, production of OM and acids; effective mycorrhizal infections; effect of fire temperatures on organic P.
Other nutrients	NC	Sulfur, P, and N	Increases in cation supply in topsoil help hold and store other nutrients (Greenland and Nye 1960) p 46

Table 12. (continued).

Cation supply and/or soil acidity	NC	Burning fallow vegetation, cation recycling from depth or from weathering minerals, fallow organic residue-Al interactions, increases in soil CEC via soil OM	Sufficient quantities of subsoil cations or weatherable minerals; root extension; climate allowing for rapid weathering, quantity and quality of fallow residues; soil microclimate; soil texture and mineralogy
Soil pests	MC	Stimulate antagonists	Interaction between biological, physical, and chemical properties of soil
Weeds	MC	Depleting weed seed bank through enhanced germination, seed death, shading out of weed species, succession allowing for a different species composition/creating a non-favorable microclimate, reducing weed germination and establishment, reducing weed vigor	Post-fire enhancement of germination, seed mortality due to fire and due to inability to survive, fallow/not appropriate, germination habitat once fallow was established, predation by soil fauna; shade duration and intensity; other microclimatic factors (insulation, R/FR, soil moisture status, shade duration and intensity; crop competitive ability.
Soil structure (Cassel & Lal, 1992) moisture retention, and root penetration	SI	1. Root production and mortality 2. Organic residue input effects on soil OM and soil biota	1. Rooting pattern and fine root turnover 2. Quantity and quality of above- and below ground residue inputs; soil micro-climate.

As a nitrogen application is generally recommended just before maximum, often called exponential, crop growth, a split application is probably needed, half by banding and half by side-dressing. No residual effects of fertilizer N would be expected from year to year. However, building up soil organic matter would be a way to build a residual base of organic N.

Relatively large amounts of P additions are needed because typically less than 5% of the P added gets to the above ground dry matter of the crop. Phosphorus is theoretically most available at pH 6. If a bean (a nitrogen fixing crop) is planted with maize, P must be present for nitrogen-fixation to occur. At near neutral pH, residual effects of P can be expected to be relatively high, except in clay soils. The red soils in this study were clays with near-neutral pH, so P residual effects were probably low. Mono-calcium phosphate fertilizers are more appropriate for acid soils, while crystalline iron- or aluminum-phosphates are appropriate for alkaline soils. Use of TSP is superior overall, but was unlikely to be available to the farmers in this study.

As the fertilizer available to farmers was likely to be at least 80-40-40 in the band, urea and diammonium phosphate should be avoided. Ammonium nitrate and TSP at these levels would be acceptable, however. In either case, potassium in its muriate of potash form is recommended (Bouldin et al., 1968).

Allowing weeds to grow during the cropping season, but after crucial crop establishment and growth periods, would minimize N loss via leaching. Post-harvest handling of maize is another aspect of crop production that is important to realizing actual yield; however, it is beyond the scope of this study, except to say the farmers reported that mice were a problem in storing maize.

Conclusions

The *T. stans* fallow system developed following the unintentional introduction of *T. stans* into area fields. Overall, *T. stans* fallows served to restore soil fertility quickly, control erosion, and provide fodder, fuel wood, vegetable stakes, and light timber. As such, fallows based on *T. stans* were considered combinations of more effective fallows and more productive fallows (Table 10) (Cairns, 2007a).

The primary advantage of *T. stans* over *L. camara* and *M. pudica* was that it produced fuel wood for both home consumption and sale, as well as small-scale building material and vegetable stakes. It regenerated and propagated without intervention, was slashed easily, and dried quickly. Farmers managed *T. stans* because it survived burning, re-sprouted rapidly, grew quickly, improved the soil, and produced fuel wood, vegetable stakes, and animal fodder. Maize production following two to four years of *T. stans* fallow was marginal but possible with fertilizer. Slightly longer fallows, greater than four years, were suggested by farmers if no fertilizer was applied. In some instances, fallows were allowed to grow for upwards of ten years without the farmer intending to put them into production.

Tecoma stans should be considered one of the "new" weedy fallow species that has multiple purposes. Even though it does not fix nitrogen, it provides fuel wood, revitalizes soil, and provides some fodder. As *T. stans* is found throughout the semi-arid tropics and is self-propagating, the *T. stans* fallow may be a transferable system to contexts in which: (1) land tenure is secure enough to allow for fallows of at least four years, (2) land pressure is not extremely high (families have two or more ha of crop land, so they did not need an intensive agricultural system), (3) there are few to no resources for inputs or mechanization, (4) soil is shallow and rocky, (5) labor is in short supply, and (6) fuel wood is needed.

In addition, *T. stans* may play an important role as a biophysical and economic bridge from subsistence to market-oriented farming systems. The *T. stans* fallow and its associated cropping system provided sufficient subsistence security such that farmers could explore more permanent agriculture, begin to incorporate tree cash crops or other species into their farming systems, and explore other income-generating strategies.

CHAPTER 6: REFLECTING ON THE ANALYTICAL FRAMEWORK AND TEMPLATE: REACTIONS AND CONCLUSIONS

Reflecting on the theoretical framework: Using fallow systems as an entry point

It was by focusing on the fallow phase of shifting cultivation that we were able to gain insight into the livelihood of the villagers as described in the study. Farmers were very willing to talk about their fallows, and this led to discussions about the rest of their agricultural as well as non-agricultural systems. Such an approach worked well and generated verifiable data. The data were probably more thorough and reliable than they would have been through the use of a written questionnaire, not just because most farmers didn't read, but because the RRA method, informed by the goals of the Southeast Asia workshop, facilitated natural linkages between the social, political, economic, and biophysical systems affecting the farmer.

For example, farmers did not think about cattle only as cattle and the income they generated. Cattle were part of farmers' larger livelihood systems. More cattle may have meant greater income, potentially leading to more economic flexibility in such things as education fees, fertilizer purchases, and house construction. Yet, more cattle may also have meant more work to set up strong fences to keep cattle out of crop fields. They may also have represented an inordinate amount of labor during the dry season in order to collect sufficient fodder for them. It was likely that if the research team had followed a set interview concerning cattle, it would have found that farmers owned an average of 2 or 3 head per household and the money they generated was used for schooling. This would have provided little insight into how changes in the number of cattle or cattle management may have affected the lives of these farmers. This was a primary benefit of using an informal interview style: farmers talked about their lives. Moving from a single focus on fallows to the larger livelihood of farmers occurred naturally with interest, time, and questioning for clarity on the part of the researchers.

During the analysis phase, the characterization template, with its organization of focusing first on one aspect of the farming system but providing cues to look for interactions among other aspects of the livelihoods of farmers, was very effective. It encouraged developing more complete pictures of livelihood systems. The template included identifying where farmer constraints actually existed, not only where they manifested themselves immediately. For example, a lack of cash to buy fertilizer was not as simple as subsidizing fertilizer prices because the infrastructure for getting crops to market and/or licenses to sell crops were not available.

If the goal of the researcher, NGO, or policy maker is to improve the lives of small-scale farmers, an understanding of likely consequences of particular interventions is desirable. At the same time, the characterization template is not foolproof. In fact, given the inherently dynamic nature of the social, political, and economic forces affecting the milieu in which small-scale farmers operate, it is unlikely that exact predictions can be made. Clarifying part of the uncertainty was built into the template, however. Temporal and historical questions and descriptions were included in the template to prompt reflection by the researcher.

During the design of the characterization template, the question of whether this approach manipulated farmers was discussed among the seminar participants. In the end, we decided that using the analytical framework and characterization template did not manipulate farmers any more than other interaction with outsiders would.

More pertinent questions included:

1. Did the farmer gain immediate benefit from the process?

2. Were the researchers expressing their intentions honestly and in such a way that farmers understood why the researchers were interested in speaking with him or her?

3. Did the farmer have a choice as to whether or not he or she participated in the research?

A final point was that the characterization template encouraged uniform data collection across researchers and research sites. A compilation of templates allowed for comparisons across sites and helped elucidate trends in the livelihoods of resource-constrained upland farmers.

Reflecting on methods: Comments concerning the ease and use of the template

Overall, the characterization template served as a valuable guide and reference for this study. It connected the various aspects of the farmers' livelihoods. The organizational order was helpful. It worked well to have the climate parameters last. This kept the system as the main focus. The blanks were easy to fill in, especially as the examples were very clear. Perhaps most importantly, the template was thorough without being overwhelming. We had ample opportunity to describe the main points of the production system as well as components of the other systems without becoming exhausted. There were difficult aspects, however, such as:

1. The fallow phase section did not specifically ask for a description of fallow management. Instead, the wording of the cropping phase boxes prompted descriptions of how the fallow was managed in relation to the cropping cycle.

2. The conversion stage did not prompt a detailed description, yet it was critical to nutrient management.

3. The management advantages and disadvantages in the economic section seemed to require repeat answers from the fallow section.

4. Productive capital was not defined.
5. The land tenure section in the regional section was not clear.
6. There was no designated place to include dates or months. The template should include easy-to-complete activity and crop calendars.
7. Finally, the characterization template did not strongly guide data analysis or decision-making. This work had to occur independently, although the information needed was there. Thus, the characterization template could be used for multiple purposes.

In addition, several specific suggestions arose through the use of the characterization template. These were:

1. Put "credit type" before other credit topics.
2. Add a section for "types of land," which should be delineated by however the farmers classified it. In the Timor case, it was soil type that determined land use.
3. Under human labor, add a section for non-wage, non-household labor, for example, a mutual assistance group.
4. A section for "other uses of fallow/annual crop fields" would be useful. In the Timor study, the men collected rocks from the fallowed fields to sell as building materials (Figure 12).
5. Include a section on weedy fallows, nutrient and other fallow aspects, or how farmers turn a previous constraint into something "useful."

Figure 12. Farmer collecting large coral rocks from fallowed fields.

Conclusions

This case study supported the workshop outcomes (ICRAF, 1997a, 1997b) that agriculture is an integrated as well as integral part of the livelihoods of small-scale farmers. Improvements in agricultural management may assist small-scale farmers toward reaching their goals. However, one must understand the social, economic, political, and biophysical contexts in which agricultural systems operate in order to provide effective agricultural intervention to upland farmers.

The practice of using a characterization template is highly beneficial for organizing information and assuring depth and breadth of understanding with respect to the livelihood systems and constraints of resource-constrained, upland farmers. How to apply findings to other locations, as well as synthesizing characterization templates across sites for themes, however, remains in the hands of the researchers, development workers, and policy makers working in conjunction with farmers.

Together, the Southeast Asia workshop, the managed fallow seminar, and the case studies provide an extensive knowledge base as well as promising strategies to improve the lives and livelihood systems of resource-constrained, upland farmers in Southeast Asia.

APPENDIX A: CHARACTERIZATION TEMPLATE (BLANK)

Aspects	Variables	Description, explanation or possible [categories]
SYSTEM SUMMARY	IFM system name	
	IFM system type	Spatial & temporal types per Malcolm's continuum
	IFM system type (use)	[Economic/ecological or more effective/more productive]
	Author/researcher	
FALLOW SYSTEM		Cropping sub-system which incorporates fallow component either spatially or temporally
BASIC CHARACTERISTICS (Crop-fallow components)		Basic description of cropping-fallow system
	Prevalence of fallow system	% of farmers, villages using fallow system
	Plot size, average	Typical size of area managed with fallow species
	Plot size, range	
	Typical topography	Describe topography or landscape location associated with this system, e.g., sloping land, lowland, upland plateau
	Cropping: fallow ratio	Typical, average or range of ratios of cropping phase duration to

		fallow phase duration
	Cropping cycle	Describe niche of fallow spp., cropping diagram
	Prevalence of use	[Locally and/or regionally]
SPECIES LEVEL		
Fallow Species Characteristics		Note: Duplicate this section for each fallow species of significance
	Scientific name	If unknown, fill out key characteristics for identification
	Local name	
	Origin of species	[Exotic/native/naturalized]
	Means of introduction	
	Growth habit	[Tree/shrub/grass/climbing vine/creeping vine]
	Propagation technique	[Natural regeneration/seed/vegetative]
	Life cycle	E.g., time to seeding, other factors relevant to farmer or mgt.
	Key biological characteristics	[Legume/N-fixing, etc]
	Biological limitations to the species	Agroclimatic, nutritional, etc.
Fallow Species Assessment		Advantages and disadvantages of fallow species from the farmers' and outsider/researchers' perceptions

		Note: Outsiders' /researchers' interpretations/observations should be clearly identified by repeating this section or noting them.
	Market sale uses	Cash sale/timber/firewood/ etc.
	Household uses	Food/timber/fuel wood/fodder/etc.
	Ecological uses	Moisture retention/erosion control/fertility enhancing/shade/soil OM/etc.
	Management problems	E.g., thorny, slow to decompose, not palatable to livestock, invasive, pest (disease/insect/pathogen)
FIELD/MANAGEMENT LEVEL		
Fallow Component/Phase Management	Duration of fallow period	What was the length (years/months) of the fallow phase - both typical length and range.
	Cultivation/clearing/weeding practices	Describe those practices used to manage the fallow species or fallow phase (e.g., hand/burning/animal draft/mechanized)
	Burning use	IF YES, describe reason and timing of burning in managing the fallow species or fallow phase (e.g. To prepare the field for fallow phase, management during fallow phase, or to bring field out of fallow phase)
	Animal tillage use	IF YES, what were the purposes and timing of using animal tillage?
	Nutrient management practices	Describe those practices used to manage nutrients associated directly with the fallow species or fallow phase.
	Animal manure use	Includes livestock grazing on fallow or direct application of manure.

	Green manure/compost use	Is green manure/compost applied to improve fallow species growth?
	Inorganic fertilizer use	Was chemical fertilizer applied to improve fallow species growth?
	Pest problems	Describe, e.g., disease/insect/pathogen/none
	Key management constraints	
Cropping Phase/Component		
	Duration of cropping period	Years, months
	Annual crops	Which crops were planted interspersed with or in sequence with fallow species
	Main cash crops	
	Main subsistence crops	
	Cultivation/clearing/weeding practices	Describe those practices used to manage the crop species or phase (e.g., hand/burning/animal draft/mechanized)
	Burning use	IF YES, describe reason and timing of burning in managing the cropping phase (e.g., to prepare the field for cropping or to manage crop residues)
	Animal tillage use	Is animal tillage used for land preparation, weeding, etc. During the cropping phase? IF YES, what were the purposes and timing of using animal tillage?
	Nutrient management practices	Describe those practices used to manage nutrients associated directly with the cropping phase

	Animal manure use	Is animal manure applied directly to improve crop growth? IF YES, describe.
	Green manure/compost use	Is green manure/compost applied to improve crop species growth? IF YES, describe.
	Inorganic fertilizer use	Is chemical fertilizer applied to improve fallow species growth? IF YES, describe.
	Soil/water conservation practices	
	Pest problems	[Disease/insect/pathogen/none]
	Crop losses	Principal reasons for production losses in cropping phase
	Key management constraints	
Livestock Component		Describe how livestock production interacts with the fallow and cropping components of the fallow cropping system
	Type of livestock	
	Main types of interaction	Describe. E.g., grazing on fallow, grazing on crop residues, manure application, cut and carry fodder from fallow, etc.
	Key management constraints	
FARMER ASSESSMENT OF FALLOW-CROP SYSTEM		Assessment of the cost-benefits, advantages/disadvantages of incorporating the fallow component (both species and associated management practices) into the cropping and farming system

		Note: Outsiders' /researchers' interpretations/observations should be clearly identified by repeating this section or noting them.
	Farmer rationale for using fallow system	
Ecological benefits (farmers' view)		
	Primary agro-ecological benefits	
	Secondary agro-ecological benefits	
	Effects on biodiversity	Observed or measured
	Effects on soil	Observed or measured
Economic benefits (farmers' view)		Including cash sales, barter or home use/consumption, labor saving,
	Primary economic benefits	
	Secondary economic benefits	
	Management advantages	E.g., fits in cropping cycle, grows quickly, easy to establish, burns easily, suppresses weeds
	Management constraints	E.g., thorny, slow to decompose, invasive, harbors pests (disease/insect/pathogen)
Evolution of fallow system		

	Prior fallow management systems/practices	
	Change in cropping: fallow ratios	Stable/declining/increasing
	Future pathway of fallow system	
	Constraints to farm system development	
	Experimental data	
FARM HOUSEHOLD SYSTEM		
FARM LEVEL		
	Farm size	
	Household size	
Cropping/Livestock Systems		Describe or diagram other cropping livestock systems on the farm other than those directly involved in the fallow system.
	Cropping pattern cycle	Cropping pattern diagram
	Principal annual crops	
	Principal cash crops	Livestock, perennial, annual crops
	Livestock component	
	Land use distribution	Agroecosystem transect

	Farm labor use	Seasonal labor peaks (diagram?)
	Pest infestations	
	Crop losses	Describe main reasons for crop losses?
External Inputs		
	Regular inorganic fertilizer use	[Yes/categories/no]
	Regular pesticide use	[Insecticide/fungicide/herbicide/none]
	Hired labor use	[Land prep/planting/weeding/harvesting/other/none]
	Irrigation use	
	Agricultural credit access	Does the farm have access to formal or informal sources of credit? IF YES, what were the sources, amounts and terms of credit?
	Credit source	[Bank/coop/trader/landowner/relative]
	Credit type	[Cash/in-kind]
Productive Capital		Describe briefly
	Land tenure	Describe mix of land tenure types (e.g., owned, share tenanted, rented, borrowed, caretaker, etc.)
	Machinery/tools	
	Farm buildings	
	Common property resources	E.g., Forest gathering, communal grazing areas, irrigation

Non-Productive Capital		Dwellings, granaries, savings, etc.
Human Capital	Household labor use	Describe use of family labor (both on-farm and selling of household labor) and the hiring-in of wage labor.
	Use of hired labor	
Non-Farm Income		
	Off-farm activities	[Trading/daily farm work/remittances/seasonal migration/others]
	Non-agricultural activities	List categories
Gender Roles		Describe any distinctions in labor use or decision making based on gender. E.g. Marketing, land use decisions, farm expenditures, livestock care, resource tenure
Household goals		Describe goals of household and trade-offs among options for meeting these goals (in terms of access to resources).
SITE DESCRIPTION		
POLICY LEVEL		Contextual data below apply to scales above the household, such as the community, regional, and/or national levels.
LOCATION		
	Country	
	Region	
	Province	
	District	
	Village	

	Latitude	
	Longitude	
	Altitude	
BIOPHYSICAL ENVIRONMENT		
Climate	Classification	Koppen, others (e.g., sub-humid tropics, etc.)
	Other distinct features	E.g., Typhoons, hurricanes, etc.
	Annual temperature, range	
	Annual temperature, average	
Precipitation	Annual rainfall distribution	E.g., unimodal or bimodal
	Annual rainfall, total amount	
	Seasonal rainfall predictability	
	Annual rainfall predictability	E.g., drought years per 10 yrs
Soils	Soil classification	USDA Soil Taxonomy, local description
	Parent material	
	Organic matter	Depth, %
	Nutrient limitations	Measured (e.g., CEC), described?
	pH	
Topography	Description	

	Significant features of landscape	Describe significant characteristics (e.g. Rivers, lakes, highly sloping, etc.)
Ecosystem	Ecosystem classification	[Forest/grasslands/montane/etc.]
	Climax vegetation	
ECONOMIC CONTEXT		
Labor market		
	Primary daily wage jobs	List categories
	Sources of technical assistance	[Extension/NGO/church/neighbors]
Marketing		
	Prevalent market orientation	[Subsistence/semi-subsistence]
	Travel time to primary market	
	Primary buyer of farm produce	[Trader/direct sale/government/barter]
Land Holdings		
	Farm size, average	
	Farm size, range	
Land market		
	Land access	What was the most likely way a farmer can increase farm size? E.g., leasing/purchase/land reform/share tenanting/inheritance/unlikely
	Most common land tenure	By area? By household? (leasing/purchase/sharecropping/tenants)

Land Tenure	Land tenure patterns	Across class, ethnicity, landscape
	Communal land areas	None/grazing/forest products
	Other land uses	
	Land use patterns	
	By agroecosystem	Transect map
	By land tenure type	
	By _____ (other?)	E.g. Class, ethnicity
SOCIAL CONTEXT		
Demographic		
	Population density	Reasonable measures? Persons/sq. Km? [hi/med/low]
	Dominant migration pattern	[Rural-rural/rural-urban/lowland-upland]
	Migration rate	[Stable/declining/increasing]
	Population growth	[Stable/declining/increasing]
Socio-Cultural		
	Relevant characteristics	Describe briefly if relevant (e.g., ethnicity, religion, kinship, etc.)

	Household structure	[Nuclear family/extended family]
POLICY CONTEXT	Key policies affecting system	
	Local governance system	Categories
	National government system	Categories
HISTORICAL CONTEXT		
	Settlement history	Timeline
	Land use/livelihood history	Timeline
	Key factors in land use change	
RESEARCHER COMMENTS & RECOMMENDATIONS		
RESEARCH APPROACH		Describe briefly the main methods used and sources of data for this characterization
	Comments on socioeconomic data collection	E.g., Sampling, methods, etc.
	Comment on experimental data	E.g., experimental design, duration, methods, etc.
	Role of farmer participation in data collection	

	Related research	Note any related research on this fallow system
LESSONS LEARNED		Researcher assessment of this system in terms of its constraints to development, future trajectory, or lessons for other areas and systems.
	Unique characteristics of fallow system	
	Constraints to fallow system development	
	Likely evolution of fallow system	
	Lessons from evolution of fallow system	
	Key determinants of system applicability elsewhere	[Market/labor requirement/post-harvest processing/ecological requirements/etc]
	Researcher concerns	E.g., key issues of development concern for researcher, or areas for future research
FUTURE RESEARCH		
	Biophysical research needed	
	Socioeconomic research needed	

APPENDIX B: REVIEW OF SOILS OF WEST TIMOR

An extensive search for literature and maps on the soils of West Timor resulted in only a few maps and descriptions. Unfortunately, they varied in scope, detail, and consistency of findings. A commonly expressed sentiment in the literature is that while the geology of Timor is reasonably described, the soils are poorly known (see, for example, Metzner 1977; Ormeling 1956). In addition, of the soil studies that have been conducted, at least three classification schemes have been used, including the USDA Soil Survey, FAO-UNESCO, and an Indonesia-specific system (Monk, Fretes, & Reksodiharjo-Lilley, 1997). Included here are several set of the descriptions applicable to West Timor.

Soils of West Timor reported by Monk et al. (1997)

Monk et al. (1997) present the most detailed maps and description of the soils in Timor based on studies by the Transmigration Unit of the Indonesian government (RePPProT, 1989, 1990a, 1990b) and other industrial and governmental sources (Crippen International, 1980; Direkorat Jenderal Pengairan, 1985; Driessen & Dudal, 1989; Fenco Consultants, 1981; Payton, 1993). These reports and data are not publicly obtainable, so the Monk et al. (1997) interpretation is reported here.

In the area of West Timor, Monk et al. (1997) report 15 soil types in four soil orders and describe 14 of them. The 15th type, while identified on the soil map, was not included in the map legend. The soil types include five Entisols, five Inceptisols, two Mollisols, and two Alfisols. It is important to note that two of the four soil orders represented in West Timor are young or developing soils as opposed to mature soils.

Entisols are a soil order composed of a conglomeration of very young soils and soils developing from relatively inert parent material (Van Wambeke, 1992). The

Entisols that Monk et al. (1997) describe from West Timor include Hydraquents, Troporthents, Ustipsamments, Tropofluvents, and Ustifluvents.

The Hydraquents are described as permanently water-saturated, often saline soils, typical of swamp and marsh land. They are muddy and vary in color from grey, both dark and light, to brown (Monk et al., 1997).

The Troporthents are characterized as rocky, coarse soils developing from karstic coral reefs, among other parent material, on steep, eroding hillsides (Monk et al., 1997).

Ustipsamments, a Psamment, are identified by their coarse texture (sandy) soils and associated properties of "high water permeability, low water-holding capacity, low specific heat, and often minimal nutrient contents" (Van Wambeke, 1992, p. 254) in an ustic moisture regime.

The Tropofluvents and Ustifluvents are described as soils of well-drained, riverine alluvial plains, characterized by layered coarse material. The latter experience seasonal moisture stress (Monk et al., 1997).

Inceptisols are in the transitional stage between Entisols and mature soils and are defined by their stage in development. Typically, their cambic horizons bear identifiable remains of the parent material and have textures finer than fine sand (Van Wambeke, 1992). Van Wambeke (1992) describes three major processes evident in Inceptisols:

4. The removal of carbonates (brown soils overlying white materials coated in lime),
5. The release of iron oxides (high chroma and red soils),
6. The reduction and removal of iron oxides in aquic conditions (grey soils).

In West Timor, Monk et al., (1997) describe a Tropaquent, a type of Aquept. These soils form from alluvial deposition in areas with high water tables, such that the soils drain poorly (Van Wambeke, 1992). In the cases in West Timor, Monk et al. (1997) describe them as medium to fine-textured, grey, and sticky. Sometimes they have grey upper horizons with mottled horizons below (Van Wambeke, 1992).

According to Monk et al. (1997, p.117), West Timor has four types of Tropepts: Dystropepts, Eutropepts, Ustropepts, and Humitropepts. The Tropepts are described as "well-drained, brownish to reddish shallow to deep, medium to fine textured". The first three soil types were considered to be the result of relatively newly eroded surfaces. They were differentiated by their base saturation (high) and by their associated moisture regime (ustic) from Dystropepts, which had low base saturation in at least one horizon, along with the presence of exchangeable aluminum (Al). Dystropepts develop in udic moisture regimes (Monk et al., 1997; Van Wambeke, 1992).

Eutropepts generally form from limestone (mafic and sedimentary rocks), have high base saturation (Ca and Mg), weatherable materials, and good drainage. They are more silty than heavy clays. These properties generally result in "satisfactory water supply and adequate nutrient content" (Van Wambeke, 1992, p. 242). These can be shallow or deep soils. When deep, these are the closest soil type to Vertisols that was included in the descriptions of Monk et al. (1997). Eutropepts differ from Vertisols by their physical properties--less heavy clay and better drained.

Ustropepts are similar in nutrient availability to Eutropepts, except that moisture regimes severely limit agricultural production on these soils (Van Wambeke, 1992). Monk et al. (1997, p. 119) describe Ustropepts as having "soft powdery lime concentrations following evaporation of lime-rich ground water."

The last Tropepts from West Timor, Humitropepts, are generally acidic with high organic matter content. Interestingly, these soils often form in the cool tropics and in udic moisture regimes, neither of which characterize West Timor (Van Wambeke, 1992). The udic moisture regime may occur in areas with a high water table, however.

Two Mollisols are described from West Timor: (1) Calciustolls from the suborder Ustolls and (2) a soil attributed to the suborder Rendolls (Monk et al., 1997). Mollisols are characterized by a surface soil layer that is dark and thick, with high base saturation (>50% at pH 7), low phosphorus (< 10 mg P kg^{-1} soil soluble in 0.05 M citric acid), and saturated in "bivalent cations" (Van Wambeke, 1992, p. 279). These soils have relatively high organic C (> 5.8 g kg^{-1} soil) and are not hard when dry (Van Wambeke, 1992).

Monk et al. (1997) describe the Calciustolls as shallow, well-drained, stony soils situated directly on coral reef, hard limestone or marls. They occur in small areas of Timor and are dark in color, well-drained and weakly acid or neutral. In terms of vegetation, Monk et al. (1997) state that they typically support grassland or savanna vegetation. These soils tend to be K deficient, have moderately high cation exchange capacity (CEC), and are saturated with Ca, which "causes gross imbalances in magnesium in particular" (Monk et al., 1997, p. 120).

The Rendolls are described less specifically than Calciustolls. They are shallow, stony, fine-textured, well-drained soils on limestone and coral reefs (Monk et al., 1997).

Alfisols are generally high base saturated soils forming from limestone or mafic rock in ustic moisture regimes (Van Wambeke, 1992). They have low CEC and demonstrate clay accumulation in their horizons (Van Wambeke, 1992). If they are light-textured (<40% clay) on the surface layer, Alfisols tend to harden under dry conditions. Alfisols may contain rocks in up to half of their volume (Van Wambeke, 1992). Two Alfisols, both part of the suborder Ustalfs, are described in West Timor: Rhodustalfs and Haplustalfs.

Rhodustalfs are well-drained, weathered soils on coral reefs and older alluvial fans. The surface is composed of friable clayey soils with finer textures below. They tend to be acidic to neutral and have high CEC and high (Ca) base saturation (Monk et al., 1997).

Of the soils Monk et al. (1997) report as occurring in West Timor, only a subset of these soils are reported to occur near the location of this study, specifically 5-10 km south of Kupang, West Timor. These are Inceptisols: Eurtopepts and Ustropepts; Mollisols: Calciustolls and Rendolls; Alfisol: Rhousdtalfs; and the unidentified soil.

Soils of West Timor reported by ISRIC-WISE

Another set of soil data for West Timor came from the ISRIC-WISE data bank (Batjes, 2006). The soil map includes six soils for West Timor based on derived data. Based on the number of pixels assigned to each soil type, the distribution of soils on West Timor are Lithosols (49.5%), Chromic Luvisols (the first type listed) (26.7%), Pellic Vertisols (14.4%), Chromic Luvisols (5.9%) (the second type listed), Eutric Fluvisols (3%), and Orthic Acrisols (0.5%).

The Lithosols are characterized as neutral to alkaline (pH 7.3-8.5), high base saturated soils, with low Al saturation. The depth listed for these soils indicates they are rocky out-croppings or non-soils, but this may be an artifact of the combination of recording technique and a lack of sampling (Batjes, 2006).

Both sets of Chromic Luvisols are mildly acidic (pH 5.5-6.5) with high base saturation, medium levels of organic matter and a heavy texture (Batjes, 2006).

Luvisols generally have good drainage. The Chromic attribute indicates high color saturation. Based on the resolution of this GIS map, Chromic Luvisols are the only soil present in the study area discussed in this thesis (Batjes, 2006).

The Pellic Vertisols are mildly acidic to neutral (pH 6.5-7.3), medium-heavy to heavy texture, with high base saturation, and medium-low organic matter contents (Batjes, 2006). Vertisols are known for being heavy clays that swell and shrink with fluctuating moisture levels. Their texture can make them difficult to work (Van Wambeke, 1992).

The Eutric Fluvisols are a mildly acidic to neutral (pH 6.5 to 7.3), medium-heavy texture, with high base saturation, and medium to low organic matter contents (Batjes, 2006).

Finally, Orthic Acrisols are acidic (pH 4.5-5.5), medium-low base soils, with medium-low organic matter levels and a heavy texture (Batjes, 2006).

Soils reported in West Timor based on government sources

There were two soil maps at the scale of 1:5,000,000, both produced by sections of the Indonesian government (Lembaga Penelitian Tanah Bogor, 1974/1980; Pusat Penelitian dan Pengembangan Tanaman Pangan, 1991). The first (Pusat Penelitian dan Pengembangan Tanaman Pangan, 1991) indicates that there are six soil types in Timor: Alluvial, Grumusols, Latosols, Regosols, Mediterranean, and soil complexes, the last of which accounts for the majority of the land area in West Timor. The soils in the study region are shown as primarily Mediterranean, with some possibility of Regosols and soil complexes.

The second map (Lembaga Penelitian Tanah Bogor, 1974/1980) indicates that there are four soil types present on West Timor: Alluvial, Grumusols, Mediterranean, and Litosols. Of these, Mediterranean and Litosols are indicated for the study area.

Additional government sources (Yayasan Bhakti Wawasan Nusantara, 1992) state that Grumusols account for 1.33% of the Kabupaten Kupang region and that Alluvial soils and Mediterranean/Renzina/Litosol complexes are in the general area. According to Adnyana et al. (1994), the soil types in West Timor are Mediterranean, Merah Kuning (Red-Yellow), Grumusols and Alluvial.

Soils in West Timor from other sources

Ormeling (1956) reports several major soil types. He describes local pockets of grey and black, loamy, heavy clay soils on limestone and fine-textured marl, which have poor structural properties. These are referred to as margalitic soils in Indonesia. According to Mohr and Van Baren (1954, cited in Ormeling, 1956), these soils are similar to India's black cotton soils: extremely impermeable, difficult to work even with livestock such as buffalo, susceptible to gully and sheet erosion, extremely sticky when wet, and cracked and hard when dry. The topsoil layers are neutral to mildly alkaline due to their base saturation. Some of these are too saline to cultivate, although others are used for cropping (Ormeling 1956).

Dames (1950, p. 180) describes margalite soils as "black earths of Indonesia," occurring up to 200 m above sea level on "limestone, marls, calcareous shales and tuffs, volcanic [material]…and on recent alluvial deposits...[They are] extremely plastic and sticky when wet, shrinking and cracking when dry". They are high base-saturated, primarily with Ca and Mg, and have a high adsorption capacity (50-100 me 100 g^{-1} clay). Finally, they are neutral to mildly alkaline, with alkalinity increasing with depth (Dames, 1950).

Ormeling (1956) also describes alluvial soils on one of the plains (South Belu Plain) as being of high fertility and having good physical structure. These soils are annually flooded and have supported annual cultivation for more than thirty years. Ormeling (1956, p. 53) describes the soil types under grasslands as composed of “rock-hard clods”. Ormeling (1956) also states that most Timorese prefer to cultivate the hills because of their loose, fertile soils, and compatibility with a digging stick and dibble.

Metzner (1977), however, reports that, in areas used for shifting cultivation, rock fragments compose over 40% of the soil volume in the top 30 cm and the C horizon occurs at less than 50 cm from the soil surface. Conceptually, this suggests a craggy coral surface with soil filling the cavities in and among the rocks.

Metzner (1977) also includes soil analysis data from a study conducted in eastern East Timor (Garcia et al., 1963). This study includes 11 soil types, without attributing them to an established classification system. Note that these soils occur on the extreme other end of the island of Timor compared to the study location.

APPENDIX C: CHARACTERIZATION TEMPLATE FOR *T. STANS* FALLOW SYSTEM

Aspects	Variables	Description, explanation or possible (categories)	Comments
SYSTEM SUMMARY			
	IFM system name		Maize-*Tecoma stans* Fallow System
	IFM system type	Spatial & temporal types per Malcolm's continuum	Shrub-based accelerated fallow (Cairns, 2007a)
	IFM system type (use)	[Economic/ecological or more effective/more productive]	More productive: fuel wood and more efficient than scrub
	Author/researcher		Ir. A.P.Y. Djogo, Ir. M. Juhan M.P., Aholiab Aoetpah S.Pt., Yohan Nenomnanu, Martha Benu, Mince Wea, Fedi Koy, Catoojie, Jack, Ellen mccallie
FALLOW SYSTEM		Cropping sub-system which incorporates fallow component either spatially or temporally	Local and Arjuna maize production
BASIC CHARACTERISTICS (Crop and fallow components)		Basic description of cropping-fallow system	Fixed fields of approximately 1 ha were slashed and burned (1-11 yr. fallows) just before the rainy season. One or two years of short season maize was planted at low densities. Some initial fertilizer and weeding occurs.

	Prevalence of fallow system	% of farmers, villages using fallow system	100% of the farmers planting maize in the study area
	Plot size, average	Typical size of area managed with fallow species	0.5-1 ha., corresponding to fixed fields.
	Plot size, range		
	Typical topography	Describe topography or landscape location associated with this system, e.g., sloping land, lowland, upland plateau	Parent material was uplifted coralline rock, shallow 2:1 clay soils, well drained, sloping with erosion hazard
	Cropping: fallow ratio	Typical, average or range of ratios of cropping phase duration to fallow phase duration	1:4-5 with a range from 1:1 (with synthetic inputs) to 1:11.
	Cropping cycle	Describe niche of fallow spp., cropping diagram	Grow well directly out of exposed coralline rock; slashed trunks survive burns; provide fuel wood for home and market; provide soil property amelioration under the shrub canopy
	Prevalence of use	[Locally and/or regionally]	Predominant in this area, occurs in other pockets of at least Western Timor as an escaped ornamental and fallow sp.
SPECIES LEVEL			
Fallow Species Characteristics		Note: Duplicate this section for each fallow species of significance	*T. stans* (Bignoniaceae); yellow bells

	Scientific name	If unknown, fill out key characteristics for identification	*T. stans* (Bignoniaceae)
	Local name		*Bunga kuning* (Indonesian); *hau suf molo* (Timorese)
	Origin of species	[Exotic/native/naturalized]	Escaped ornamental; native to Andes (S. America); common as an ornamental worldwide
	Means of introduction		Escaped ornamental, brought from city to village as an ornamental in front of homes or introduced by free-ranging cattle
	Growth habit	[Tree/shrub/grass/climbing vine/creeping vine]	Shrub to 4 m
	Propagation technique	[Natural regeneration/seed/vegetative]	Wind dispersed; regenerates from coppicing resprouts concurrent with annual crop
	Life cycle	E.g., time to seeding, other factors relevant to farmer or mgt.	Based on seed morphology, no indication of seed dormancy or being long-lived
	Key biological characteristics	[Legume/N-fixing, etc]	Survives coppicing, fire (at least when rooted in rock); extended drought (7-9 months)
	Biological limitations to the species	Agroclimatic, nutritional, etc.	Cattle were not fond of it
Fallow Species		Advantages and disadvantages of	Disadvantage: may be difficult to

Assessment		fallow species from the farmers' and outsider/researchers' perceptions	eradicate; adv.: out-competes *putri malu* and *Lantana camara*, perennial and does not need to be re-planted, self-seeds; goats will eat limited amounts; dries sufficiently to burn in 2 days
		Note: Outsiders' /researchers' interpretations/observations should be clearly identified by repeating this section or noting them.	
	Market sale uses	Cash sale/timber/firewood/ etc.	Fuel wood
	Household uses	Food/timber/fuel wood/fodder/etc.	Fuel wood
	Ecological uses	Moisture retention/erosion control/fertility enhancing/shade/soil OM/etc.	Shade for cattle; said to improve soil fertility, structure, and moisture retention
	Management problems	E.g., thorny, slow to decompose, not palatable to livestock, invasive, pest (disease/insect/pathogen)	Not palatable to cattle, deciduous in dry season
FIELD/MANAGEMENT LEVEL			
Fallow Component/Phase Management			
	Duration of fallow period	What was the length (years/months) of the fallow phase - both typical length	Typically 3 to 5 years

		and range.	
	Cultivation/clearing/weeding practices	Describe those practices used to manage the fallow species or fallow phase (e.g., hand/burning/animal draft/mechanized)	Coppicing and burning before planting annual crops around the base of the shrub; weeding of the fallow, nor intentional planting; coppicing occurs as early as 3-4 months before planting, but may occur immediately before burning. Coppicing of *T. stans* by machete to approximately 30 cm above the ground or out of the rock from which it emerges. Branches and trunk were used or sold for fuel wood.
	Burning use	IF YES, describe reason and timing of burning in managing the fallow species or fallow phase (e.g. To prepare the field for fallow phase, management during fallow phase, or to bring field out of fallow phase)	Coppiced to clear canopy for light penetration. Burned to release nutrients into the soil, clear the site for planting and to remove plant-plant competition with crops; Burning may occur as early as 2 days following coppicing, though waiting longer was more common. Burning occurs before the onset of the rains. Often farmers burn several months before the rains were expected.
	Animal tillage use	IF YES, what were the purposes and timing of using animal tillage?	None, hand weeding, sometime the soil was turned with a hoe if it has not fallowed for at least 2-3 years.

	Nutrient management practices	Describe those practices used to manage nutrients associated directly with the fallow species or fallow phase.	Piling of coppiced material around shrub trunk and burned. This was where the cropping occurs.
	Animal manure use	Includes livestock grazing on fallow or direct application of manure.	Animal manure may inadvertently contribute nutrients to the system if cattle or goats were tied to the shrub. Animals overnight in pens near the houses. They were walked through some field on the way to grazing areas or may be tethered to *T. stans*, but within reach of grass.
	Green manure/compost use	Is green manure/compost applied to improve fallow species growth?	Litter fall occurs naturally during the early dry season. It was unknown as to whether any of this litter decomposes before burning. No intentional green manuring was practiced.
	Inorganic fertilizer use	Was chemical fertilizer applied to improve fallow species growth?	No, some may be applied (if available) to enhance annual crop
	Pest problems	Describe, e.g., disease/insect/pathogen/none	None indicated, nor any obvious
	Key management constraints		Do not seem to grow in dense clumps
Cropping Phase/Component			
	Duration of cropping period	Years, months	3-4 months

	Annual crops	Which crops were planted interspersed with or in sequence with fallow species	Primary crop was maize
	Main cash crops		None
	Main subsistence crops		Maize
	Cultivation/clearing/weeding practices	Describe those practices used to manage the crop species or phase (e.g., hand/burning/animal draft/mechanized)	Dibble stick used to plant maize seed (seeds from the previous year's crop) in a single hole. Often plant in combination with other annuals. Hand weeding occurs with the second band fertilizing approximately three weeks after planting when the crop was approximately 20 cm high. No further weeding usually takes place.
	Burning use	IF YES, describe reason and timing of burning in managing the cropping phase (e.g., to prepare the field for cropping or to manage crop residues)	What happens to the stover?
	Animal tillage use	Is animal tillage used for land preparation, weeding, etc. During the cropping phase? IF YES, what were the purposes and timing of using animal tillage?	No
	Nutrient management practices	Describe those practices used to manage nutrients associated directly with the cropping phase	

	Animal manure use	Is animal manure applied directly to improve crop growth? IF YES, describe.	No
	Green manure/compost use	Is green manure/compost applied to improve crop species growth? IF YES, describe.	No
	Inorganic fertilizer use	Is chemical fertilizer applied to improve fallow species growth? IF YES, describe.	Yes. First application and second applications
	Soil/water conservation practices		None obvious, system was completely rain-fed
	Pest problems	[Disease/insect/pathogen/none] describe	Yes.
	Crop losses	Principal reasons for production losses in cropping phase	Drought preventing flowering, ear formation, grain filling; insects; storage
	Key management constraints		Do not survive/grow well directly out of the soil, prefers exposed rock.
Livestock Component		Describe how livestock production interacts with the fallow and cropping components of the fallow cropping system	Improve policy environment, no more free grazing; occasionally gets into fields
	Type of livestock		Cattle, goats
	Main types of interaction	Describe. E.g., grazing on fallow, grazing on crop residues, manure application, cut and carry fodder from fallow, etc.	Livestock were to be kept out of fields during cropping. Cattle and goats may be tied to *T. stans* during dry season. Cattle may graze on grass in fields during dry season, but they avoid *T.*

			stans as a food source.
	Key management constraints		Have to monitor them
FARMER ASSESSMENT OF FALLOW-CROP SYSTEM		Assessment of the cost-benefits, advantages/disadvantages of incorporating the fallow component (both species and associated management practices) into the cropping and farming system	Farmers seemed not to have considered not using *T. stans* as they were already used to weedy specie fallows that required little management; also *T. stans* was a multi-purpose shrub in that it provides sufficient fuel wood for home consumption and sale. Its major disadvantage may be that was cannot be used as fodder.
		Note: Outsiders' /researchers' interpretations/observations should be clearly identified by repeating this section or noting them.	
	Farmer rationale for using fallow system		It was there. It re-grows after coppicing. Maize yields were sufficient after a *T. stans* fallow followed by slashing and burning.
Ecological benefits (farmers' view)			
	Primary agro-ecological benefits		Provides for good micro-site for maize growth following several years of fallow and slashing and burning. It was unknown as to which properties were

			most important. *T. stans* probably improves soil structure, water retention, fertility, as well as decreasing subsequent competition with maize.
	Secondary agro-ecological benefits		
	Effects on biodiversity	Observed or measured	
	Effects on soil	Observed or measured	Observed and measured: less compacted soil, richer color
Economic benefits (farmers' view)		Including cash sales, barter or home use/consumption, labor saving,	
	Primary economic benefits		Fuel wood (home and sale)
	Secondary economic benefits		Vegetable stakes, construction material (mediocre)
	Management advantages	E.g., fits in cropping cycle, grows quickly, easy to establish, burns easily, suppresses weeds	Re-grows after coppicing; survives burning, particularly when growing out of rocks. Re-grows during cropping phase, but slower than maize, sparse canopy, self seeding via wind dispersal, out-competes more noxious weedy

			fallow species
	Management constraints	E.g., thorny, slow to decompose, invasive, harbors pests (disease/insect/pathogen)	Does not grow in dense clumps, may not be competitive against *Chromolaena odorata* (newly present)
Evolution of fallow system			
	Prior fallow management systems/practices		*Lantana camara* fallow, then *putri malu*; all invasive weedy fallow at least since 1940.
	Change in cropping: fallow ratios	Stable/declining/increasing	Hard to tell, but previous fallows did not have the economic/household benefit of fuel wood production
	Future pathway of fallow system		Moving more toward income generation;; would like to intensity production of maize (via purchased inputs) or move completely into the market system and produce only cash crops
	Constraints to farm system development		Drought, soil fertility (probably)
	Experimental data		See text for soil analyses.

FARM HOUSEHOLD SYSTEM			
FARM LEVEL			
	Farm size		3-7 fields?
	Household size		Did not appear to be particularly large; typically 2-4 children at home who were under 10
Cropping/Livestock Systems		Describe or diagram other cropping livestock systems on the farm other than those directly involved in the fallow system.	Mamar Vegetables Paddy rice Irrigated maize Upland maize
	Cropping pattern cycle	Cropping pattern diagram	See Figure 2.
	Principal annual crops		See Table 8
	Principal cash crops	Livestock, perennial, annual crops	Cattle, vegetables
	Livestock component		Cattle
	Land use distribution	Agroecosystem transect	Insert from text (Belo)
	Farm labor use	Seasonal labor peaks	See Tables 3, 4, & 5.
	Pest infestations		Some
	Crop losses	Describe main reasons for crop losses?	Within wet-season drought, inconsistent onset of rains

External Inputs			
	Regular inorganic fertilizer use	Yyes/categories/no]	Yes, urea primarily; some TSP and KCl
	Regular pesticide use	[Insecticide/fungicide/herbicide/none]	Yes, primarily on vegetables
	Hired labor use	[Land prep/planting/weeding/harvesting/ other/none]	No
	Irrigation use		Traditional aqueducts for some paddy rice; hand irrigation or use of flood plains for vegetables
	Agricultural credit access	Does the farm have access to formal or informal sources of credit? IF YES, what were the sources, amounts and terms of credit?	Informal, subsidies for fertilizer
	Credit source	[Bank/coop/trader/landowner/relative]	?
	Credit type	[Cash/in-kind]	In kind and subsidies
			Land , cattle
Productive Capital		Describe briefly	?
	Land tenure	Describe mix of land tenure types (e.g., owned, share tenanted, rented, borrowed, caretaker, etc.)	Traditionally owned, newly purchased
	Machinery/tools		Machete, truck
	Farm buildings		Corrals for livestock; stone fences

			around fields
	Common property resources	E.g., forest gathering, communal grazing areas, irrigation	Wells, grazing areas
Non-Productive Capital		Dwellings, granaries, savings, etc.	Homes
Human Capital	Household labor use	Describe use of family labor (both on-farm and selling of household labor) and the hiring-in of wage labor.	See activity calendars
	Use of hired labor		No, but use of mutual assistance groups (*goyong-royong*) for land clearing, harvesting, and house building.
Non-Farm Income			
	Off-farm activities	[Trading/daily farm work/remittances/seasonal migration/others]	
	Non-agricultural activities	List categories	Weaving; collecting rocks from fields
Gender Roles		Describe any distinctions in labor use or decision making based on gender. E.g. Marketing, land use decisions, farm expenditures, livestock care, resource tenure	See Tables 3 & 4.

Household goals		Describe goals of household and trade-offs among options for meeting these goals (in terms of access to resources).	Education for kids, material goods (TV), modern clothes
SITE DESCRIPTION			
POLICY LEVEL		Contextual data below apply to scales above the household, such as the community, regional, and/or national levels.	
LOCATION			
	Country		Indonesia
	Region		Nusa Tenggara Timur
	Province		(Kotamadya) Kupang
	District		(Kecamatan) Maulafa; (Kabupaten) Kupang
	Village		Belo, Fatokoa, and Tunfeu
	Latitude		Approx. 10 degrees S
	Longitude		
	Altitude		Approximately 300m
			5-10 miles of Kupang city
BIOPHYSICAL ENVIRONMENT			
Climate	Classification	Koppen, others (e.g., sub-humid tropics, etc.)	Ustic

	Other distinct features	E.g., Typhoons, hurricanes, etc.	
	Annual temperature, range		To 36 C
	Annual temperature, average		25 C
Precipitation	Annual rainfall distribution	E.g., unimodal or bimodal	Unimodal with drought of several days to several weeks within the rainy season
	Annual rainfall, total amount		1000-1500 mm
	Seasonal rainfall predictability		Unpredictable
	Annual rainfall predictability	E.g., drought years per 10 yrs	At least 1 in 10
Soils	Soil classification	USDA Soil Taxon, local description	Limestone (coral)
	Parent material		<5 cm
	Organic matter	Depth, %	
	Nutrient limitations	Measured (e.g., CEC), described?	
	Ph		
Topography	Description		
	Significant features of landscape	Describe significant characteristics (e.g., rivers, lakes, highly sloping, etc.)	Limestone rock outcroppings, slopes of >15 degrees
Ecosystem	Ecosystem classification	[Forest/grasslands/montane/etc.]	Monsoonal, savanna

	Climax vegetation		Monsoonal forest
ECONOMIC CONTEXT			
Labor market			
	Primary daily wage jobs	List categories	
	Sources of technical assistance	[Extension/NGO/church/neighbors]	NGO, government extension
Marketing			
	Prevalent market orientation	[Subsistence/semi-subsistence]	Semi-subsistence
	Travel time to primary market		45 min -2 hours, up to 5 km by foot, but public transportation to city once on the major village road
	Primary buyer of farm produce	[Trader/direct sale/government/barter]	
Land Holdings			
	Farm size, average		Most Helong villagers have 2 ha or substantially more; typically 2-11 plots of shifting cultivation (.5 to > 1 ha/ each)
	Farm size, range		? (1-11 shifting cultivation plots)

Land market			
	Land access	What was the most likely way a farmer can increase farm size? E.g., leasing/purchase/land reform/share tenanting/inheritance/unlikely	Purchase, but farmers were not looking to buy more land. They would prefer to intensive their production through higher inputs or access to black soil for cash crops, but this land was limited and not for sale.
	Most common land tenure	By area? By household? (leasing/purchase/share cropping/tenants)	By household, traditionally land was inherited, but now it was commonly purchased as well
Land Tenure	Land tenure patterns	Across class, ethnicity, landscape	Helong own the majority of land; new-comers were purchasing parcels.
	Communal land areas	None/grazing/forest products	Grazing and forest land
	Other land uses		
	Land use patterns		
	By agroecosystem	Transect map	
	By land tenure type		
	By _____ (other?)	E.g., class, ethnicity	
SOCIAL CONTEXT			
Demographic			

	Population density	Reasonable measures? Persons/sq. Km? [hi/med/low]	Belo was reported to has 661 people on a total of 468 ha in the village; Fatokoa has 1248 people on 7858 ha. These numbers have not been verified.
	Dominant migration pattern	[Rural-rural/rural-urban/lowland-upland]	Inland rural to less inland rural, rural to urban, plus urban sprawl
	Migration rate	[Stable/declining/increasing]	Increasing, but demographics probably indicate an aging village population and a younger urban population as children leave for schooling
	Population growth	[Stable/declining/increasing]	
Socio-Cultural			
	Relevant characteristics	Describe briefly if relevant (e.g., ethnicity, religion, kinship, etc.)	Helong people, most villagers were related, by blood and/or by marriage
	Household structure	[Nuclear family/extended family]	Non-newcomers were typically all related within a village. Live in nuclear family units within the village. Mutual work group members were typically related.
POLICY CONTEXT			
	Key policies affecting system		No free-grazing

	Local governance system	Categories	Village, sub-village
	National government system	Categories	Republic
HISTORICAL CONTEXT			
	Settlement history	Timeline	
	Land use/livelihood history	Timeline	See text.
	Key factors in land use change		Putri malu, L. camara, T. stans, now C. odorata, cattle
RESEARCHER COMMENTS & RECOMMENDATIONS			
RESEARCH APPROACH		Describe briefly the main methods used and sources of data for this characterization	
	Comments on socioeconomic data collection	E.g., sampling, methods, etc.	Informal interviews, observation
	Comment on experimental data	E.g., experimental design, duration, methods, etc.	Soil sampling

	Role of farmer participation in data collection		Medium, mixed; also used as researcher training
	Related research	Note any related research on this fallow system	None found, but a comparison with the Amarasi system which was in close proximity would be interesting
LESSONS LEARNED		Researcher assessment of this system in terms of its constraints to development, future trajectory, or lessons for other areas and systems.	
	Unique characteristics of fallow system		Easy management, secondary product producing shrub fallow
	Constraints to fallow system development		Low annual crop yield due to unreliable water patterns and lack of inputs; *C. odorata* might out complete it, but farmers seem not to care as long as the specie was easily managed
	Likely evolution of fallow system		*C. odorata* based, still a weedy shrub
	Lessons from evolution of fallow system		Marginal system that makes due; weedy species can be good
	Key determinants of system applicability elsewhere	[Market/labor requirement/post-harvest processing/ecological requirements/etc]	Lots of land
	Researcher concerns	E.g., key issues of development	Selling off of land to new comers and

		concern for researcher, or areas for future research	then learning the "long-term value" of owning land
FUTURE RESEARCH			
	Biophysical research needed		
	Socioeconomic research needed		The poverty problem here isn't so much the agriculture.
COMMENTS			
			How determine when to slash? Based on vegetation? Debt?
			The basic stereotype was that only marginal people used slash and burn: How marginal were these farmers?
			Likely direction of livelihood?
			Likely direction/importance of shifting cultivation?
			What role will fallow play in this?
			Timing of burning vs. Rains and planting

APPENDIX D: RAW DATA FROM SOIL ANALYSES OF *T. STANS* FALLOWS

Field	Sample description	Soil depth	Texture			pH		Organic matter			HCl (25%)		Olsen P_2O_5	Bray 1 P_2O_5
			Sand	Silt	Clay	H_2O	KCl	C	N	C/N	P_2O_5	K_2O		
		(cm)	------- (%) -------			(1:2)	(1:5)	---- (%) ----			(mg 100 g^{-1})		---- (ppm) -----	
1	Field cropped at least 2 yrs	20-40	3	22	75	5.5	5.2	1.77	0.05	35	477	18	409	64.5
		40-60	3	24	73	5.8	5.4	1.72	0.17	10	500	18	320	56.6
2	8 yr fallow	0-20	4	23	73	6.5	6.4	3.01	0.32	9	294	23	161	29.6
		20-40	2	20	78	6.3	5.8	1.96	0.23	9	495	20	157	184.8
3	4 yr fallow	0-20	3	75	22	6.9	6.7	3.75	0.40	9	321	18	108	9.9
4	5 yr fallow	0-20	13	71	16	7.3	7.0	7.57	0.93	8	534	38	337	19.7
		20-40	21	7	55	7.0	6.8	3.78	0.40	9	427	20	85	27.3
5	8 yr fallow	0-20	3	27	70	6.9	6.4	2.61	0.29	9	450	29	210	158.3
6	10 yr fallow	0-20	7	58	35	6.2	5.9	2.38	0.22	11	340	14	80	34.9
		20-40	6	53	41	6.0	5.5	2.12	0.17	12	391	15	313	8.9
		40-60	8	37	55	5.9	5.6	1.71	0.20	9	388	14	97	38.9

Field	Sample description	Soil depth	Cation exchange capacity (NH_4-Acetate 1*N*, pH 7)						KB	KCl 1*N*		Hot water B
			Ca	Mg	K	Na	Total	CEC	KB	Al^{3+}	H^+	
		(cm)	------------------------ (me 100 g^{-1}) --------------						(%)			(ppm)
1	Field cropped at least 2 years	20-40	17.43	1.51	0.12	0.13	19.19	17.21	>100	0.00	0.00	0.99
		40-60	18.09	1.54	0.16	0.19	19.98	16.81	>100	0.00	0.00	1.21
2	2 yr fallow	0-20	29.18	1.60	0.25	0.19	31.22	23.70	>100	0.00	0.00	2.02
		20-40	17.18	1.85	0.12	0.08	19.23	17.70	>100	0.00	0.00	1.08
3	4 yr fallow	0-20	29.48	0.54	0.12	0.11	30.25	20.83	>100	0.07	0.02	1.74
4	5 yr fallow	0-20	67.89	1.48	0.28	0.26	69.91	46.23	>100	0.00	0.00	2.00
		20-40	30.42	1.10	0.16	0.27	31.95	23.83	>100	0.00	0.00	1.91
5	8 yr fallow	0-20	23.61	1.59	0.24	0.14	25.58	20.33	>100	0.04	0.02	2.17
6	10 yr fallow	0-20	10.44	0.92	0.12	0.13	11.61	14.24	82	0.04	0.02	1.42
		20-40	12.66	1.03	0.12	0.13	13.94	15.03	93	0.06	0.02	2.52
		40-60	13.57	1.06	0.12	0.14	14.89	12.83	>100	0.00	0.00	0.39

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