LABOR, SOIL QUALITY, AND YIELD IN CONVENTIONAL AND ECOLOGICAL SMALL-SCALE, TROPICAL AGROECOSYSTEMS

By

ALVARO ALEJANDRO VALLE

A THESIS PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

UNIVERSITY OF FLORIDA

2008

A mi familia

ACKNOWLEDGMENTS

The completion of this work was made possible only through the assistance, guidance, and patience of my committee. Special thanks go to the head of my committee, Dr. Hugh Popenoe, for willingly extending his practical and philosophical guidance, time (revision after revision), enormous store of tropical experience, frankness, and hospitality at the HLP ranch. Dr. Marilyn Swisher is an expert on conducting science. Her didactic ability, insistence on conducting fundamentally correct work, and openness to ideas have all been incredibly appreciated. Dr. Robert McSorley has been a model agroecologist for me, and I thank him for this. The earnest enthusiasm, rational and clear opinion, and indispensable scientific understanding will not be forgotten.

Further, I would like to thank personnel of UNAN-Leon. I am often inspired by their intellectual tenacity in the face of limited recognition. Marlon Molina, Adrian Catin, and Don Anibal are especially thanked for their earnest effort, local knowledge of Leon, and friendship during the summer of 2006. Needless to say, this study was critically dependent on the advice, research, and genuine support of Dra. Xiomara Castillo. I am indebted to these persons. Finally, the staff at Laboratorios Quimicos SA made it explicitly clear why they are the foremost environmental testing laboratory in Nicaragua.

A Tropical Environment and Development Fellowship from the Compton Foundation financed this effort. Their intentions, and their desire to support third world research, are honorable. Thanks to Dr. Susan Jacobson, Anne Fitzgerald, and everyone else involved with the Compton Foundation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Master of Science

LABOR, SOIL QUALITY, AND PRODUCTION IN CONVENTIONAL AND ECOLOGICAL SMALL-SCALE, TROPICAL AGROECOSYTEMS

By

Alvaro Alejandro Valle

May 2008

Chair: Hugh Popenoe
Major: Interdisciplinary Ecology

Small-scale agriculture in the developing tropics is often concomitant with rural poverty. High labor requirements can impose a social burden that negatively affects quality of life. Degrading soil quality (SQ) can reduce future productivity. Economic returns are low, because yield per person (or labor productivity) is not sufficient to provide basic necessities. At the center of this problem is the nature of small-scale farming in the developing tropics. The most sustainable management would simultaneously lower labor inputs, increase SQ, and increase yields.

Ecological approaches depend on ecological cycles and relationships within the agroecosystem for management, while conventional approaches look outside the agroecosystem for management options. In our study, we measured labor and labor productivity, SQ and SQ efficiency, and yield of field-scale agroecosystems using either conventional or ecological management. A cross-sectional design with referral sampling was used to study 18 agroecosystems during the June-August 2006 agricultural season in in Leon, Nicaragua. The studied agroecosystems were small-scale sesame farms with sandy- loam andisols in a tropical dry climate. A management index identified the approach to overall agroecosystem management on a scale from conventional to ecological. A semi-structured interview was employed to gather

data labor and yield data for *Sesamum indicum* production. Soil sampling and indicator analysis measured soil quality. These included % organic matter, acidity, phosphorus availability, biotic activity, and bulk density at two depths. T-tests and Mann-Whitney were used to test for differences between the two groups.

Total labor was not different between managements, nor was labor productivity. Labor amounts (man-days/Mz) differed significantly only for fertilization ($p<.05$) and disease management ($p<.10$), with ecological agroecosystems requiring more labor. Conventional agroecosystem allotted a greater proportion of their total labor to weed ($p<.10$) and insect pest ($p<.10$) management than did ecological agroecosystems. Labor productivity was not different between treatments for any practices or in totality, though very small sample sizes lowers confidence in these results. Labor results indicate that where techniques are different, ecological management practices often require more labor. The exception is insect pest control. Where techniques are similar, there is no difference in labor between managements.

No soil quality indicator or efficiency was affected by management regime. Therefore, in most respects ecological sustainability did not change with management. This contrasts with most studies to date. Yield was similarly not different between management, indicating that ecological management does not necessarily lead to yield reductions. Given all this, it seems that neither agroecosystem is more sustainable. This may be due to similarity in inputs between all small-scale systems, regardless of management type.

CHAPTER 1
INTRODUCTION

Rural Poverty

Approximately 2.5 billion rural people are living on small farms in the developing world (International Food Policy Research Institute (IFPRI) 2007). Asians and Africans comprise the bulk of this figure, but there are also 19 million rural dwellers (two thirds are poor) in Central America who are ostensibly tied to small-scale agriculture (Soto 2003). Nicaragua is one of the Central American nations with a poor agricultural populace. Forty three percent of Nicaragua's total population is rural (Food and Agriculture Organization (FAO) 2006), and 68.5% of this rural population is poor (World Resources Institute (WRI) 2005). Considering the high rate of poverty, economic sustainability may be low. Some focus on sustainable productivity of small-scale agroecosystems is needed to alleviate tropical rural poverty, especially where this poverty is extreme, entrenched, or widespread (IFPRI 2007, World Bank 2003, WRI 2005). To this end, we conducted a study on the sustainability of small-scale field production on a western Nicaraguan andisol typical of tropical, developing nations.

Small-Scale Agriculture

Poor people and small-scale farmers suffer from the same fundamental problem: both lack access to resources required to secure a livelihood (Beets 1992, Adger 1999). In the case of small-scale tropical growers, these are mainly land and agronomic inputs of all types (Beets 1992). Even if land is available, deficient agronomic resources can constrict the ability to cultivate additional land or properly cultivate present crops (Alwang and Siegel 1999). These agronomic limits include meager extension services (especially for non-traditional cash crops), limited or insecure credit options, expensive or unattainable inputs, available and willing labor, lacking irrigation infrastructure, and prohibitive mechanization costs. Moreover, restricted access to agronomic resources forces tropical smallholders to rely on local agroecosystems for management support (Altieri 2002, WRI 2005).

What the development community constitutes as small-scale agriculture is contextually dependent on geographic location, agronomic support, and market environment (IFPRI 2007). 61% of all agricultural holdings in Nicaragua are under 14 ha, and 47% are less than seven hectares (FAO 2001). Only 7% of all land in Nicaragua is irrigated (FAO 2006), and we observed virtually no irrigation except on sugarcane and peanut- the domain of large- scale agriculture. Mechanization is usually limited to tractor rental for pre-planting tillage. Our study site is near the Leon (0.5 million inhabitants), Managua (1.2 million), and international (via Pan American highway) markets. Small-scale growers of Leon simultaneously produce for consumption, for markets, and with traditional and modern technologies. This reflects the modern small-scale agriculturalist in the Mesoamerican tropics (Popenoe and Swisher 1998). Given all this, and after consultation with local experts, the upper limit of small-scale holding is set at 10 manzanas (16.80 acres or 6.41 hectares) of ownership or land under production. After this point, we observed that economic production and agricultural scale resembles a more mid-scale operation.

Sustainability

Tropical rural poverty is evidence of low economic sustainability in small-scale production. Low economic sustainability can be attributed to low labor productivity, which is output per person laboring (in our case, the owner-farmer), because labor productivity, in effect, is the economic return to the grower once the product is sold. With all else held equal, the established relationship describes increasing economic returns as labor productivity increases. Labor productivity can be increased by the mechanisms of intensification or extensification, where land is available. For either mechanism, there must be access to various agronomic resources. One of those resources, labor, must become more available in one of three ways to allow further work: willing labor must become available, labor saving machinery must be introduced, or productivity of field labor must increase. In the absence of labor changes, intensification can proceed through better management of possessed resources. The central problem for the small-scale tropical farmer is that both mechanisms are near impossible because access to agronomic resources (including labor and credit), access to land, and research for improved management is limited at best. Even where land is available, a lack of agronomic resources still negates the possibility of extensification. In the absence of outside investment or institutional support, most tropical growers will suffer from vulnerability to ecological and economic flux, weak terms of trade, and a near impossibility to pull themselves out of poverty. (Kiker 1993, Tomich et al. 2001).

Soil has a pivotal role in increasing economic sustainability through crop production. Soil processes and functions are critically involved in primary production. Thus, a critical objective in achieving economic sustainability in the tropics and improving rural livelihoods is maintaining and improving the ecological basis of small farm sustainability- soil quality (Lal 1991, Stocking 2003). Smallholder African farmers, for example, investing in soil conservation often achieve higher land productivity (Byringiro and Reardon 1996), effectively intensifying and increasing economic returns. For agriculture, soil quality is the capacity of an agroecosystem soil to support sustainable plant production (Soil Science Society of America (SSSA) 1997). It is a holistic concept that recognizes the interacting physical, chemical, and biological properties that make soil so important for sustainable production in the tropics. Making soil the holistic basis for production is particularly salient where extension services, context- appropriate research, consulting services, and other support for agro technical soil management is presently out of reach.

The andisols of this study are derived from high silica, pyroclastic ejecta from periodic volcanic eruptions. With high temperatures and an ustic moisture regime, this parent material has a high Si to Al ratio and unique allophane- type clays. Allophane is amorphous clay with comparatively high cation exchange capacities, due to the high surface area and many positively charged exchanged sites. In combination with prevalence of silica oxides, and to lesser degree iron oxides, allophane soils retain much organic matter and are infamous phosphorous fixers. This frequently makes phosphorus a limiting nutrient in andisol agriculture. Consequently, organic matter percentages in dark, native soils are many times above 5% and long-term phosphorus fixation levels are often around 50% (Joergenson and Castillo 2001). In general, the high percentage of organic matter, strong structure, high native fertility, and deep rooting depth makes andisols productive soils, although easily eroded. The ecological sustainability is stronger than for the indigent smallholder in many other developing nations. Nonetheless, conserving and enhancing soil quality is important for the many rural poor whose land is their only real wealth (WRI 2005). (Parfitt 1989)

Sustainable Management

Relatively immediate improvements to labor productivity and rural poverty, without intensive investment, can be garnered by increasing sustainability through better agroecosystem management (Beets 1992, WRI, 2005). The most sustainable management would lower labor requirements, increase soil quality, and enhance yields to impart economic sustainability and ecological sustainability. Any management development that positively affected any of these three variables would increase some facet of sustainability. Due to the integrated nature of sustainability, however, an effect on one sustainability facet is likely to affect another. For example, more socially sustainable production, such as with lower labor requirements, improves economic sustainability through increased labor productivity. It may also improve ecological sustainability, since labor is determinant of soil conserving strategies (Marenya and Barrett 2007).

The spectrum of management approaches ranges from conventional to ecological. Wholly conventional approaches manage agroecosystems from an external perspective, depending on extra-agroecosystem options to systematically control biological communities and supply crop needs. Fully ecological approaches manage agroecosystem from an internal perspective, utilizing the agroecosystem's own ecosystematic functions, processes, and cycles to regulate biological communities and support plant growth. A large range of combined approaches exist. Some combinations, such as integrated pest management, are widely used. The quality of materials often changes with approach, but it is not the fundamental difference. Hence, substituting organic inputs for inorganic inputs may make management more environmentally friendly, but it does not indicate a completely ecological management. (Gliessman 2007)

This difference in perspective leads to practical distinction between management regimes. Ecological management strives for a diversity of crops; fertilizes mainly with organic additions, recycled nutrients, or through biological fixation; eschews industrially-synthesized pesticides in favor of alternative methods that prevent pest population; conserves and builds because soil is viewed as the basis of production; and often uses locally-adapted, heirloom, and traditional cultivars and crops. Conventional management grows one or very few crops; fertilizes mainly with imported inorganic fertilizers; applies chemically-synthesized pesticides for pest control; uses soil mostly as a media for nutrient additions and physical support; and typically sows with industrially enhanced/modified/treated seed of commercially ubiquitous varieties. We will refer to agroecosystems managed ecologically as ecological agroecosystems and those managed conventionally as conventional agroecosystems. We note that organic agroecosystems fall under the heading of ecological agroecosystems.

Research

The main inquiry of this investigation determines which management is likely to produce the most sustainable agriculture in this context. We test the hypotheses that ecologically based management is the most sustainable management for resource poor, small-scale farmers in the tropics, as Altieri (2002) and other have suggested. There is some evidence from Philippine small-scale farmers that they themselves perceive this to be true (Mendoza 2004). We will answer this question and test the hypothesis by comparing labor, soil quality, and yield in conventional and ecological agroecosystems. This is not a legitimate sustainability analysis, since the requisite temporal element of sustainability was not pursued in any fashion. Rather, this is a management analysis that serves as a measured proxy of sustainability. Utility of the analysis is based upon the assumption that response in a reasonably typical year will be similar in the future if management and ecological conditions do not drastically change.

An agroecosystems framework is employed in this observational study. This perspective attempts to understand ecosystem functioning and processes as flows of matter/energy from input pools, to internal pools, to the output. Each pool is affected by the flow from the previous pool. The premise of this is that agricultural fields can be viewed as ecosystems. As these fields contain the components and structure of a natural ecosystem, it is valid to view them as managed ecosystems.

Field scale agroecosystems of sandy loam, andisols under small-scale production of late rainy season *Sesamum indicum* will serve as experimental populations. Growers managing these systems produce varying products during the early rainy season followed by sesame. Sesame labor inputs will be measured for each approach. Soil quality effects of this management will be measured using chemical (percent organic matter, acidity, and phosphorus availability), biological (biotic activity), and physical (structure as bulk density) indicators. Production is measured as yield.

Sustainable agricultural development has been seriously undermined by an inability to fully consider the complex interrelationships involved in production (Lal 1991). This is addressed by calculating labor productivity (output/labor input) and soil quality efficiency (soil quality effect/labor input) in response to a management range. Soil quality efficiency is a term we derived to examine how much soil quality improvement one gains for a given labor input. In reality, it is the same in concept as any other productivity measurement in that it measures output (internal SQ effect) for a given amount of input effort (management labor).

CHAPTER 2
LITERATURE REVIEW

Energy Inputs and Efficiency

The scientific community generally contends that there are decreasing energy inputs and concurrently increasing energy efficiency as management becomes more ecological (Powers and McSorley 2001). Pimentel et al. (1983) were of the first to find midwestern organic cornfields to be more energy efficient than conventional growers using high-input techniques. Diverse systems-- including Mediterranean olive groves (Kaltsas et al. 2007), Australian pasture-cereal crop rotations (Nguyen and Hayes 1995), and Danish integrated grain- livestock operations (Dalgaard et al. 2001)— reassert claims of increased energetic efficiency with lower overall energetic inputs. Overwhelmingly, reduced dependence on synthetic fertilizers and pesticides, created and transported with fossil fuels, are the main factors in decreasing energy inputs and increasing energy efficiency in ecologically managed systems (Mader et al. 2002, Sartori et al. 2005). This trend for overall energy inputs holds true after 21 years of production, even including increased fossil fuel usage by tractors for fertilization with organic manures (Pimentel et al. 2005). Clements et al. (1995) affirm that reduced herbicide use in more ecological approaches decreases energy inputs and increases efficiency, despite the usual increases in fossil fuels for mechanical cultivation. They add that this is true as long as cultivation is used in moderation.

Whether these developed world findings can be transferred to small-scale tropical systems, where pesticide are less available and cultivation is often manual, is questionable. Labor is a relatively minor portion of overall energetic inputs in developed world agriculture, since mechanization and accessible agronomic inputs can substitute for manual labor (Giampietro and Pimentel 1990). Understandably, labor is usually excluded, largely discounted, or subsumed in energy assessments of most comparative management studies (Loake 2001). There are, however, a few occasions where labor was tracked in the developed world. The Rodale study of Pimentel et al. (2005) indicates that the diversified, legume- based organic rotations required 35% more labor throughout the growing season to manage more cover crops, cultivate more often, and handle manure applications when needed. This mirrors findings of Karlen et al. (1995) that measured up to 75% more labor in a few cases, due mostly to increased cultivation and handling of manure, in Iowa corn/soy fields. Nguyen and Hayes (1995) find the labor inputs to be higher in the cereal crop portion of their pasture- cereal crop rotations under an alternative management, but labor requirements were lower and productivity higher over the entire cycle under alternative management. The reasons for increased labor were similar to the other studies. The small olive growers in the Kaltsas et al. (2007) study spend more time walking around to inspect insect baiting traps, than their conventional counterpart spraying pesticides on foot.

The utility of these findings is tempered by the fact that labor increases came mostly as more tractor time. In terms of social sustainability, this cannot be considered the same as wielding a machete or even spending more time on one’s feet. Loake (2001) addresses this critical distinction between driving a tractor and the physical exertion of more manual labor by comparing the human energy efficiency of labor on highly mechanized conventional farms to organic farms using no mechanization. Her results indicate that organic farming in the UK is by far more physically stressful, some days expending more energy than is gained, both because more labor is required and because of the physical nature of the work. This is not entirely surprising, but lends empirical evidence for assessing labor inputs as a matter of social sustainability, especially where the returns to that labor are lower than desirable.

A few authors have looked at labor requirements for tropical, small-scale growers. In flooded rice, eight man-days more were required in the organic system for nutrient management (spreading rice straw and applying compost), but two man-days less were required for organic land preparation because soil tilth had improved under this management, making more extensive tillage unnecessary. Despite the initial increases of labor in the organic system, labor decreased throughout the season and summed to 47.5 overall man-days/ha for organic farming and 52.5 for conventional farms. These figures were adjusted to take into account the labor intensity of practices. Additionally, these authors found energy efficiency to increase with organic management, again largely due to reduction in inorganic fertilizers and synthetic pesticides (Mendoza 2004). These findings are not mirrored in small-scale Bangladeshi agriculture, where labor was taken as a measure of social sustainability and found not to be different between ecological and conventional agriculture (Rasul and Thapa 2003). It seems that evidence of management's effect on labor in small-scale tropical farming is scant and inconclusive.

Ecosystem Effects and Efficiency

The decreased use of industrially synthesized fertilizers and pesticides causes changes in agroecosystem structures, processes, and interactions (Drinkwater et al. 1995). Ecological management has shown changes in agroecosystem biological diversity (Menalled et al. 2007, Morandin and Winston 2005), in nutrient cycling (Clark et al. 1998, Tortensson et al. 2006), and in root disease suppression (Bulluck et al. 2001). The effect of management on soil quality is measured via concrete chemical, biological, and physical indicators that address the integrated ability of soil to actively support plant production.

Organic matter is often used as an overriding soil quality indicator because of its critical role in nutrient storage, soil stabilization, ion exchange capacity, biological health, and a myriad other influences (Reeves 1997, Tiessen et al. 2001). It may be especially important in small-scale, tropical systems, where soil organic matter is the major nutrient cache and determinant of soil biological activity. Generally speaking, increases in organic matter increase the ability of the soil to support plant production. A maximum can be reached before soil quality decreases (Sojka et al. 2001), but this usually only happens with excessive manure applications of the type from intensive dairy operations.

A long-term, organic, legume- based rotation in Pennsylvania increased organic matter markedly as residues were incorporated (Drinkwater et al. 1998). Fleissbach et al. (2006), Widmer et al. (2006), and Manna et al. (2005) recently confirmed the common view that organic fertilizers or soil- conserving additions, as in ecological agriculture, increases soil organic matter. This may have positive effects for agroecosystems. Mendoza (2004), for example, explains that decreased labor for small-scale rice was mainly due to improved soil tilth associated with increased soil organic matter. The benefits of increased soil organic matter may not be immediate, however, as measurable increases in organic matter may accrue only after an extended period of accumulation (Fleissbach et al. 2006, Monokrousos et al. 2006). Since ecological management fertilizes mainly with organic matter, and attempts to conserve the soil basis of production with organic additions, it is logical that increases in soil organic matter are often seen (Lotter 2003).

The chemical indicator of acidity also has a large influence on the ability of soil to support primary production. In a very general sense, a pH closer to neutrality allows for the production of a greater number of crops, avoids aluminum/micronutrient toxicity and sodicity, and allows for greater microbial diversity, valuable in root disease suppression. In the case of tropical andisols, an increase in pH is an increase in soil quality. Mader et al. (2003), Fleissbach et al. (2006), Bulluck et al. (2002), and Reagonald (1988) all found pH to increase in differing soils with organic matter additions (for multiple goals) typical in ecological management. The main reasons for an increase in pH with ecological management can be reduced to three. Several of these effects can be in play in any of the studies above. Firstly, significant applications of synthetic fertilizers and certain pesticides in conventional agriculture are known to acidify soil. Avoiding these raises pH. Secondly, as manure is a common organic fertilizer, and as manure often contains salt minerals in differing proportion, an increase in pH may result in acid soils. Finally, even where organic manures are not used, increases of organic inputs, with composts or green manures, can raise pH when low (Ouedraogo 2001). This buffering effect depends on continual additions of organic matter, though, as increased microbial decomposition near neutrality decreases organic matter rapidly (Hugh Popenoe, personal communication, 2007). This may cause pH to drop again, where soils are naturally acidic, after the buffering agent is removed

A more specific indicator of soil quality, given the nature of phosphorus restrictions in andisols, is phosphorus (P) availability. In lowland, tropical soils with high P fixing capacities, Lawrence and Schlesinger (2001) demonstrate that long- term agricultural management of organic matter can affect P distribution, even if total P does not change or is not imported. The relation between distribution, plant availability, and organic fertilizers was seen in flooded rice (inceptisol) cultivation (Salaque et al. 2004). This team reports that greater concentrations of labile and relatively labile P fractions when organic fertilizers (cow dung and ash) were included. Moreover, these 2 fractions were most affected by plant uptake in the control; so that increases in concentrations of these 2 fractions increased plant available P. Reddy et al. (2005) examine the role of organic matter in P availability and find, after 16 weeks of alfisol study, redistributions of P in favor of labile, colloidal P when crop residues are used instead of inorganic fertilizer. On vertisols of higher clay content, with the same methodology, the distribution of P was similar, albeit with a much less drastic effect than in alfisols (Reddy et al. 2001). This lends support to the idea that relatively invariable soil properties become more influential, and organic matter less, as the P fixing capacities become greater. In at least one study, the authors find no ecologically significant effect on P dynamics with differing fertilizers, indicating that soil properties were more at play in controlling soil P dynamics than input matter (He et al. 2006). Castillo and Joergenson (2001) in andisols of the same study area as ours, also find soil properties to be more determinate in the availability of P to biomass then the management regime, even though more P was clearly seen to increase with conventional management. There is the possibility that organo- P complexes may increases unavailability in andisols due to the nature of P occlusion in high organic matter andisols (Borie and Zunino 1983). We should note that rhizosphere association of arbuscular mychorrhizae play a significant role in plant uptake of P (Plenchette et al. 2005), but that this does not necessarily translate into greater yields (Ryan and Graham 2002).

Soil microbes essentially govern nutrient cycling and community stability in the soil ecosystem and to a major extent control nutrient supply and disease. Microbial activity has been measured as a sensitive indicator of soil quality under differing management (Marinari et al. 2006) and during different stages of the same management (Monokrousos et al. 2006). Long-term experiments have concluded that more ecological management results in sustained increases in microbiological activity and nutrient cycling (including P) (Mader et al. 2002). Increased microbiological activity with ecological management also suggests that fundamental differences in agroecosystem ecology are responsible for functional discrepancies between managements (Drinkwater et al. 1995, Clark et al. 1999). Clark et al (1999), for example, reported increases in nitrogen mineralization (indicative of higher microbiological activity) that allowed for increased nutrient cycling to all plants, including weeds. Increased microbiological activity and diversity, prompted by ecological management, has led to suppression of soil borne disease and positive effects on crops (Bulluck et al. 2002).

Research has more recently documented the influences of manure quantity and type in soil microbial community size and composition (Fleissbach et al. 2006). They find the type of organic inputs, and consequently soil organic carbon, influences the microbiotic activity and soil quality. The organo-mineral complexes of andisols, for example, may limit C availability to microbes (Oades 1995), explaining the substantial build up of organic matter in andisols. Interestingly, Marinari et al. (2006) was not able to relate differences in microbial biomass to organic matter. Other distinctions between managements, such as in pesticide use, can therefore also influence soil biology (Hansen et al. 2001). Plenchette et al. (2005) reviewed studies of the management effect on beneficial mychorrhizae. They conclude that conventional agriculture's reliance on chemically synthesized pesticides is more deleterious to mychorrhizae than ecological management not using such inputs. Following suit, Castillo and Joergenson (2001) attribute increased basal respiration in ecological agroecosystems to decreased pesticide use and increased diversity of organic residues from more diverse cropping systems.

A priority for soil quality in the 21st century must be the physical management of soils (Lal 1991, Stocking 2003). Soil erosion in andsiols can be a problem in and of itself, not to mention the disease and aeration problems that puddling from poor structure can cause. Within the same soil type and texture, organic matter will be the primary impactor of physical structure. Since increases in organic matter are more often seen with ecological management, decreases in measured bulk density are expected with more ecological management. A less compacted soil improves physical structure for plant growth.

Output

Most comparative management research examines output ability of conventional and alternative systems. Stanhill (1990), who reviewed 205 comparative studies, estimated an average 10% yield loss by organic systems. He included agroecosystems recently converted to ecological management. These agroecosystems may not be as optimized for production as they might be in the future. Lotter (2003), nonetheless, agreed with the estimated yield losses. Often weeds are blamed for decreased yields under ecological management. One study saw declines of 20% to 35% in wheat yields, despite increases in most soil quality measures, due perhaps to increased weeds (Mader et al., 2002). Clark et al. (1999) posit that weeds proliferate in ecological systems exactly because soil quality is higher, for all plants, under ecological management.

Researchers have also measured similar or higher yields in ecological agroecosystems. Fresh pepper yields in Florida were similar in both managements (Chellemi et al. 2004), while Mendoza (2004) saw rice yields increase with organic management. Mendoza (2004) relates this to disease suppression, more organic matter, and better physical soil structure. Lotter (2003) noticed a trend of increasing ecological yields in drought years, while better climatological years produced higher conventional yields. He attributes this either to increased mychorrhizal hyphae or increased organic matter. Both offer drought resistance. Increases in corn and soybean yields during drought was corroborated by a 22 year field trial at the Rodale Institute that also highlighted yield similarities among management regimes, especially after an initial transition period (Pimentel et al. 2005). Yet, an interesting investigation by Martini et al. (2004) negates the that so called “transition effect” is due to soil quality changes, hypothesizing rather that increasing ecological management experience increases yields after transition. This favors the argument that ecological yields do not differ by management type alone.

Either approach may be more desirable under a given set of physical conditions. Similar tomato yields in California prompted researchers to hypothesize that although differing ecological processes and pathways can be working on the cropping system, they can ultimately lead to the same agronomic response (Drinkwater et al. 1995). Clark et al. (1999) also find a difference in agroecosystem ecology under differing management, but in this case, yields were decreased in the ecological management. We may not know enough about ecological management to produce higher output even though it is agronomically possible (Lotter 2003).

Research attempting to establish which management approach is best should be critically assessed in respect to their validity. Many of these studies are conducted by experts under controlled conditions and warrant closer examination of generalizability. These studies also often attempt to eliminate confounding factors by using the same varieties to compare yields, even though the ideal genotype for conventional agricultural systems may be fundamentally different from those of ecological agriculture (Van Bueren et al. 2002). This is an integral piece of the management, and yet is not often explored. The decreases in conventional yields during drought, normally attributed solely to soil quality matter, could very plausibly be explained by variety differences.

Objectives

The objective of this investigation is compare labor, soil quality, and yields of small-scale field agriculture in the developing tropics. We do this to ascertain whether conventional or ecological agroecosystems, as defined in the introduction, are likely to be more sustainable. Furthermore, we attempt to build understanding of tropical agroecosystems.

Hypotheses

1. Labor inputs will be higher, and labor productivity lower, in ecological agroecosystems.

2. Values of soil quality indicators and efficiencies will be higher under ecological management.

3. Yields will be higher under conventional management.

CHAPTER 3
METHODOLOGY

This research was carried out in the department of Leon, Nicaragua. Farms in the municipalities of La Ceiba, Leon, and Chacaraseca were sampled from late June to early August 2006 by myself and two assistants- Marlon Molina and Adrien Catin of the Universidad Nacional de Nicaragua- Leon (UNAN-Leon). Yield data collection, and the return of soil laboratory results for each participant, took place during January 2007.

Research Context

Agronomy

During the 1970s, the area of Leon was a very profitable monoculture of cotton (*Gossypium hirsutum*). Leon produced the highest global yields of long-staple varieties for a period (Hugh Popenoe, personal communication, 2006). Consequently, this allowed for deep tillage and heavy pesticide use on both large and small land holdings. Heavy machinery and poor soil management promoted soil erosion during winter. Ecological disaster ensued as pest resistance elevated pesticide application to uneconomic, ineffective, and unhealthy rates. Later, land reforms were initiated and many small-scale operations became the norm. Growers were organized into cooperatives with machinery to share. Subsequent economic depression, exacerbated by the collapse of the Soviet Union, hastened the virtually complete withdrawal of production support. Small grower cooperatives are still common, with the machinery retained by individuals who now rent their services. Cooperatives have limited negotiation power, as evidenced by frequent broken contracts. Small-scale growers in cooperatives or otherwise are alone in marketing and selling. This is a new phenomenon because previous small-scale growers sold to committed large landholders or government entities.

Only 7% of all arable land in Nicaragua is irrigated (FAO 2005). Therefore, most production occurs only during the rainy season (May- November). Common crops during the beginning of the rainy season include field corn, Cucurbitaceous species, yucca (*Manihot esculenta*), and fallow hay, with much variation among farmers and between years. All growers plant sesame in the late rainy season, and in this study, they would be asked about labor inputs and production for sesame. The strategic need for a single crop to compare yields and labor amongst management systems was the major impetus for this. Furthermore, similarity in an export commodity allowed for ecological participants to be found via sampling frames of cooperative lists. Coffee has been used for this purpose, but coffee production systems are essentially agroforestry systems and not field production. Additionally, sesame seed is the domain of small- scale, manual labor systems of developing nations and so is an appropriate selection for the tropical population of interest in this study. Sesame production is not new in Nicaragua, but has taken on greater importance for the small-scale grower as higher-value export crops are pursued.

Ecology

The Leon climate is typical of deciduous tropical forest ecosystems. Average annual rainfall is approximately 1500 mm with an average temperature of 26.1 C with more then 85% of this rain coming between May and November (Instituto Nacional de Estudios Territorriales (INETER) 2006). Temperatures vary little throughout the year.

We collected soil samples during a normal dry period within the rainy season. In 2006, the start of the rainy season was dryer than normal. The dry period within the rainy season was drier and longer than historic norms. Labor and yield data would be taken for production during the second half of the rainy season (August-November). August had -26% less rain; September had -55% less; October had 37.6% more rain; and November had 88% more precipitation than historic norms (1972-2000) (INETER 2006). In the last month, seed sets and plants are particularly vulnerable to *Phytopther*a infection. Farmers expressed some concern over excessive rain in November, but ultimately did not seem to be affected by widespread fungal infections.

Leon, the department, is on the Pacific coastal plain of Nicaragua and is in the shadow of an active volcanic corridor running the length of the department from North to South. These soils have been formed by pyroclastic ejecta and are characterized by a high Si/Al proportion and distinguished by the presence of amorphous clay called allophane. Their andisol identity is confirmed in several locations. The latest surveys performed by the present-day soils division of INETER classify them all as ashy, isohypothermic mollic vitrandept of the series Leon, Ceiba, Cerro Negro, or Guadalupe under the 1972 United States Department of Agriculture (USDA) taxonomy (Ministerio de Agricultura y Ganaderia (MAG) 1974). Also, these soils are classified as Vitric Andisols under the 1974 FAO system (Castillo and Joergensen, 2001). These soils would most likely be presently classified as sandy, isohyperthermic, vitric haplustand.

Roughly 75% of the sampled farms were in the Leon and Ceiba series, with the other 25% in either Cerro Negro or Guadalupe series (MAG 1974). In the absence of trustworthy GPS coordinates it was impossible to say with absolute certainty into which series they were classified. This may be of little consequence, since the qualitative description of series from the 1974 survey are all effectively the same: 90cm effective depth, less than 4% slope, sandy loam texture, good drainage, and moderate erosion (MAG 1974). Certain soils may have changed series, due to agriculture and hurricane effects, without changing their volcanic parent material or sandy-loam texture.

Because at least five observed textures of andisols exist within Leon and because basic soil characteristics can change drastically with differing texture, it was necessary to assure that all the farms in the study were of similar texture. We selected sandy-loam to be the soil texture in common because this was the most prevalent texture in the farming communities where we expected to find fields includable in our study. The present-day location of sandy loam texture was also crosschecked with Dr. Xiomara Castillo of UNAN-Leon, with presidents of cooperatives, with the farmers themselves, and with the texture by feel method when in the field. This soil texture was chosen because of its relatively close proximity to Leon. This allowed for many logistical conveniences that would have otherwise made soil sample collection difficult.

Research Design

Our research design is intended to test three hypotheses. We hypothesize that:

1. Labor inputs will be higher, and labor productivity lower, in ecological agroecosystems.

2. Values of soil quality indicators and efficiencies will be higher values under ecological management.

3. Yields will be higher under conventional management.

An on-farm, observational study with a cross-sectional design is used to test these three hypotheses. The majority of comparative management research has used true experiments on research stations with researcher- led design and management. There is evidence, however, that grower management will lead to different recommendations for on-farm production (Sumith and Abetsiriwardena 2005). As Drinkwater (2002) notes, “the most important advantage of on-farm studies is that systems under study are realistic in terms of scale, management practice and constraints faced by the farmer and therefore offer an opportunity to study intact agroecosystems”.

Cross-section is an appropriate design when there are two existing groups and no previously applied experimental intervention can be identified or will be applied. There is, therefore, no control group. This compromises internal validity to a reasonable degree. External validity is robust. The on-farm approach allows us to sample working agroecosystems with all the factors of interest as equal to most small-scale agroecosystems in Nicaragua as possible.

Sample Selection

Our individual sampling units are agroecosystems. An agroecosystem is defines as set of contiguous fields growing late rainy-season sesame on sandy-loam vertisols in Leon. All or only part of fields may be planted in sesame (justification in introduction). A small-scale system is a maximum holding of 10 Mz (6.42 ha) (rented or owned), worked primarily by the same owner-farmer (with hired help for certain tasks), with no irrigation, and using no mechanization post-planting. Our resulting theoretical population is composed of tropical agroecosystems that 1) are small-scale, (2) have been managed in the same manner for at least three years. Growers must have grown sesame at least once within the last 3 years. This ensured that labor as reported would be accurate. Due to our non-probabilistic sampling scheme, we can only extend our finding to members of the theoretical population connected, in some manner, to a cooperative of sesame growers. This is not a major restriction, as most sesame growers will be connected to a cooperative either formally or informally.

Referral sampling is the sampling approach used in this study. Because it was impossible to identify eligible participants *a priori*, referral sampling granted us the only real chance of finding agroecosystems of the accessible population. The initial sampling frame came from lists of cooperatives provided by *Cooperativa Del Campo S.A.* of Leon, Nicaragua, which lead to a list of members of sesame producing cooperatives. We identified members of *Cooperativa La Esperanza* of La Ceiba, Leon (President Sra. Querube Perez) and the *Asosiacion de Productores*

Ecologico de Nicaragua (APRENIC) of Leon, Nicaragua (Director-Manuel Caballero) as the accessible population. We visited each farm and made participation inquiries. After data collection, we asked for referrals. We did this until we could find no further sesame producers in our accessible population. We took a census of the accessible population.

Instrument, Procedure, and Analysis

Refer to Appendix A for schematic protocol of index construction and other information

Management Index

A management index (delivered during semi-structured interview) was created to measure the management approach on a scale. Indices are useful for robustly measuring an underlying variable not easily measured by a single indicator (Bernard 2002). Management indices have been used effectively in translating qualitative management differences into quantitative measure (Mas and Dietsch 2003).

We found no satisfactory indexing method in the literature. Thus, one was constructed. Then, we collected the responses to these questions as part of the semi-structured interview. Finally, we analyzed the management approach of each agroecosystem by using a summative score based on responses to indicators.

Index construction

We asked 10 experts a question by phone and email. What five indicators are most capable of distinguishing between conventional and non-conventional management? I did not mention, unless asked by the expert respondents, that this would be for Central American, small-scale operations. We retained those indicators that had at least 50% consensus. There were seven indicators mentioned by at least 5/10 respondents as capable indicators, and two indicators with 4/10 responses. Given contextual appropriateness and personal opinion, we included the two indicators with only 40% consensus. The original nine indicators, in question form, are listed in Figure 3-1.

After screening with growers outside the theoretical population, consulting with Dra. Castillo of the UNAN-Leon, and testing on our first 3 participants, questions with asterisks (*) were later dropped. They were either contextually nonsensical (items 6 and 7) or participants were unclear and varying in their understanding of environmental harm (item 8).

Ranking the influence of individual indicators on an overall management approach strengthened the index. Ranking was used instead of scoring to force respondents to consider their relative importance. We asked a set of 11 experts to rank the six final indicators from most capable to least capable in distinguishing managements (see Appendix B). The ranking of each indicator came by selecting the mode of the responses. Where there were two or more modes for an indicator, they were averaged to arrive at a final mode and ranking for that indicator. This only happened once with the Diversity indicator. When two separate indicators showed the same ranking, the indicator with more highest- ranks was established as a more influential indicator. The Pest Control and Diversity indicators were both initially ranked as the third most influential indicator, but Pest Control received three *number one* rankings while Diversity received only two *number one* rankings. The six labeled indicators are shown in order of decreasing influence in Figure 3-2.

Indexing procedure

Each indicator was formulated as a question with five possible answers. These questions were presented during the semi-structured interview. Indicators 2,3,and 6 were formulated as questions of type **A**, as seen in the list below. These use relative measures to gauge whether a response indicates ecological or conventional management, with higher score indicating more ecological management. Indicators 1,4, and 5 are formulated, as questions of type **B**, using a scale from least to most ecological. The numbers in parentheses indicate the weight of each response, with responses that indicated more ecological management having higher values.

A. What is the dependence on organic (O) versus inorganic (IO) fertilizers?
(1) Only IO (2) more IO than O (3) equal (4) more IO than O (5) only O fertilizer

B. What is the level of on- farm material recycling (manures, kitchen, and crop residues)?
(1) No recycling (2) low (3) medium (4) high (5) everything possible recycled

During data collection, we noticed that for questions of type **B,** separating between *no recycling* and *low*, and between *high* and *everything possible recycled*, was difficult. Their responses tended to be arbitrary decisions between closely related answers. This presented problems of robustness in the measure of that indicator. To combat this, we collapsed the five possible responses to three —*low, medium,* and *high*- and adjusted points to 1-2- 3 respectively.

Index score

After indicator questions had been presented in the semi- structured interview, we determined the management index score of each agroecosystem. Actual scores for each indicator and tabulations can be found in Appendix B. Figure 3-3 illustrates scoring for a hypothetical agroecosystem exhibiting the maximum level of ecological management. More influential indicators have high indicator weights. In this example, the response points shown are always the maximum possible score, indicating the most ecological approach. Multiplying the indicator points by the response points arrives at each indicator score. The final index score is a sum of the indicator scores and then divided by 6 to standardize the scores.

The smallest possible score is 3.533. This indicates a fully conventional management. The largest possible score is 13.833. This indicates a fully ecological management. The midway point is 8.665. Scores below 8.665 indicate ecological management. Score above 8.665 indicate conventional management.

Semi-Structured Interview

A semi-structured interview was conducted to ascertain the management approach and gather labor and yield data. Semi-structured interviews are useful when one would like the discretion to follow leads, but still needs a pattern to recuperate necessary information (Bernard 2002).

Appendix C contains the interview guide. There were five basic components in the semi-structured interview: 1) eligibility establishment, 2) management indexing questions, 3) basic crop production information, 4) management labor, and 5) yield. Interviews with agroecosystem managers generally lasted from 20 to 25 minutes, and the majority of this was for measuring the labor inputs elicited by differing managements.

Management labor was divided into four practices used for direct field management. Breaking down labor into management practices allowed for precision, as well as a measure of the overall effects of management on individual practices. The four management practices were: fertilization, weed control, insect control, and disease control. We selected management practices that are common components of field management. The practices must require labor input that is affected by management approach. We did not include pre-plant tillage, for example, because all growers hired tractors to prepare equally. Seeding and harvesting also were done equally and management approach played no clear role in these practices.

After documenting eligibility and obtaining consent, a quick orientation and background assessment quelled hesitations of the participants, elucidated doubts, and assisted us in asking more appropriately phrased questions. Presumably, this would allow us to gather the forthcoming labor data in a more efficient and precise manner. One day of labor was set the length of time it takes to complete the task for the day. During most of the season, this is about 4 to 6 hours in the morning. On other days, it can be longer or shorter.

Asking about tasks within individual management practices divided the labor data collection. Farmers, like all managers, break up their practices into daily tasks throughout the season. We exploited this organization conveniently to procedurally ascertain labor inputs. We would first ascertain the order, procedure, and nature of a particular management practice. After this was clear, we could begin to gather data about labor inputs, phrasing our question individually based upon a grower's management style. The typical number of instances a particular task was carried out, the number of workers required, and the number of days with these workers was investigated on a per month basis. Inquiring on a per month basis accounted for labor variability during the season, and thus increased accuracy in labor accounting.

Finally, in January 2007, we resumed the last section of the interview. Land under sesame, seed used, and yields in quintales (1 Qt=46 kg) per Mz were documented. Additionally, we asked for any related commentary.

In order to compare labor inputs for management practices, we calculated them as simple labor amount of man-days/Mz and as a percentage of the total labor. Labor amounts include the labor required by individual management techniques and the agroecosystem ecology it created. Assuming that growers limited labor is distributed according to management needs, percent of total labor might indicate differences in the nature of agroecosystems under differing managements. This is especially true where qualitative differences of techniques within approaches are controlled.

Soil Quality Assessment

To test the hypothesis that soil quality will be positively correlated with increasingly ecological management, we assessed soil quality through the use of five individual indicators. These indicators assess the capacity of these andisols to support the function of sustainable plant production. The utility of multiple empirical indicators to assess the concept of soil quality for sustainability has been established for some time (Bellotti 1998, Doran and Parkin 1996). The natural resources conservation arm of the USDA (2001) is promoting soil quality assessment as a conservation-planning tool. New Zealand's government has found soil quality to be useful as a national planning and assessment tool. (Lilburne et al. 2004). The most current methodological research revolves around prioritizing the utility of different indicators for combination into an index (Shukla and Ebinger 2006, Yemefack et al. 2006, Xu et al. 2006, Erkossa et al. 2007) and for delimitation of differentially managed fields (Monokrousos et al. 2006). There are many different indicators. Nonetheless, there persists a lack of a tested, accepted, and recognized index.

There are several additional reasons why we decided against using or constructing an index. Constructing our own, or using any particular index, precludes close comparison with other data where different indexes or uncombined indicators have been used. Furthermore, analyzing individual indicator's responses to management might more clearly elucidate management- sensitive indicators for andisols.

In building our own minimum data set (MDS) of indicators, our financial and technical capacities were a major determinant. Indicators needed to be affordable, practically collected as soil samples, and reasonably analyzable given the limited expertise, laboratory space, and technology available for soil analysis of the researcher and Laboratories Quimicos SA (LAQUISA, Carreterra Leon, km 33.5). The indicators needed to be plain and common enough to be potentially compared and understood by various grower, academic, and development audiences. Additionally, they must be contextually appropriate (Karlen et al. 2003). Thus, we specifically studied a review and investigation by Andrews and Carroll (2001), a comparative management study on Nicaraguan andisols (Castillo and Joergenson, 2001), a practical manual of the USDA (2001), and an Organization for Tropical Studies (OTS) agroecology field course guide (Swisher 2003). These sources shared similar restrictions, goals, or audiences as this study. Karlen et al. (2003), and Herrick (2000) were consulted for general procedures and considerations in choosing a contextually appropriate and indicative set of biological, physical, and chemical soil quality indicators. The indicators are percent organic matter (%OM), phosphorus availability (PA), acidity (pH), bulk density (BD), and biotic activity (BA).

Soil Sampling

To measure the indicators, we first collected soil samples as described in the protocol in Appendix A. The soil sampling design was a systematic Z transect, with sub sampling, across contiguous fields meeting the operational agroecosystem requirements. We stayed 5 paces from field borders to minimize confounding factors (i.e. tractor marks etc.) With this design, we could move along expeditiously, cover the entire field without bias, and avoid damaging crops. Whenever a field was not rectangular, we divided the field into approximately three equal land areas and adjusted the lengths of the 3 diagonals (of the Z) accordingly.

For %OM, PA, and pH, we collected 7 subsamples with a manual soil auger to a depth of 30 cm across each diagonal. These 7 subsamples (about 2/3 liter each) were homogenized in a bucket to create 1 sample per diagonal. The 3 resulting diagonal samples would serve as the 3 subsamples (about ½ liter) for each replicate. The subsampling increased the precision of our measurements, since there would be 1 sample value per field. Diagonal sub- samples were delivered in sealed, marked plastic bags.

For BD and BA, we collected 7 samples across the field on the same Z transect. After using a shovel to dig a flat-walled hole of 40 cm depth, we used a hammer-in style soil corer ($100mm^3$ 5-cm- deep cylindrical core) to extract a sample from the sidewall. Core ends were sharp and in good condition. BD samples were collected at a 0-15 cm and 15-30 cm horizons.

Biotic activity samples were collected at the 2.5- 7.5 cm depth from the top of the soil. The protocol was realized with 2 subsamples on the 1st diagonal, 2 subsamples on the 2nd diagonal, and 3 subsamples on the last. These 7 sub-samples would be averaged to arrive at one response value for each agroecosystem.

Soil Quality Analysis

All analyses were done at Laboratorios Quimicos S.A. (LAQUISA) chemical laboratory. It is the foremost environmental testing laboratory in Nicaragua. The six indicators follow. Descriptions include the ecological rationale for using the indicator, the method of analysis, and the criteria for interpretation.

Percent organic matter (%OM) measures the amount of organic matter in the soil. The %OM will have an overriding effect on all soil functions and properties. We used the Walkley-Black (1969) method (with no procedural deviations) to measure the % organic carbon of highly stable humic and fulvic acids. We used a conversion factor of 1.74 to translate this into %OM of the soils for ease of communication to a wide range of audiences. An increasing quality of soil is indicated by an increase in the %OM.

Acidity (pH) is also an ecosystem state variable that plays a role in nutrient availability, biological presence and control, and aluminum and iron toxicity to plants. Acidity was determined using 2 parts deionized water solution to 1 part topsoil sample. pH was detected by calomel electrode. Lower pH soils indicate poorer soils.

Phosphorus availability (PA) is of particular interest in allophane soils with high phosphorus P sorption capacities. High sorption capacity is due to a very high surface area of allophane and its affinity to fix P anions from the soil solution (Parfitt 1989). High fixing capacities do not allow P to move freely through the soil solution and be taken up by the plant roots (Parfitt 1989). Determining the potential availability of P is critical to the functional capacity of soils for sustained production. To determine the potential availability of P to the plants, a P fractionation was performed at LAQUISA using the Tiessen and Moir (1993) modification of the Hedley et al. (1982) fractionation procedure. Lawrence and Schlesinger (2001) have used it successfully to trace changes in soil P availability in tropical soils with high P fixing capacities. Finally, I confirmed the appropriateness of the methods for the andisols under study with an expert (Nicholas Comerford, personal communication, 2006).

Four main fractions are analyzed. The first 2 fractions are easily absorbable and colloidal/solution P. These represent relatively available soil P. The last 2 fractions are relatively occluded and fixed, and therefore unavailable. Increasing amounts of resin- P and NaHCO-P in the first 2 fractions and increasing percentages of total P in the first 2 fractions would primarily indicate an increasing soil quality. More P in the first 2 fractions indicates a greater capacity to sustain strong plant growth. Using a P fractionation method to proxy plant-available P does not take into account the symbiotic uptake pathways of P, which are known to be important in providing plants with P.

The amount of biotic activity (BA) serves as a very important indicator of soil quality, especially where nutrient availability is driven mostly by biotic processes (Drinkwater et al. 1995, Monokrousos et al. 2006). Biotic activity is a major component of a higher quality soil, especially where this is the primary nutrient transformer and controller of rhizosphere pathogens. Microbial activity was measured by way of basal respiration, which is the amount of carbon dioxide (CO^2) respired by soil microbes. We used a soil corer in the 2.5 cm-7.5 cm area of the topsoil to gather and transport a soil core for direct use in incubation jars. The core was placed directly into the jar to minimize perturbation and oxidation. Basal respiration was measured after 24 hr incubation in clean 1-gallon glass jars with a soil core, a 20 ml portion of water, and

10ml 1M NaOH. This was done in a non-air-conditioned laboratory with natural lighting at the UNAN-Leon, Campus Agropecuario. Samples remained in the corer for collection in order to minimize perturbation and oxidation. CO^2 captured in the NaOH solution was delivered to LAQUISA in the Paraffin and masking- taped Gerber baby-food bottles as NaOH receptors within the incubation jar. Samples were daily delivered to LAQUISA for titration with concentrated HCL.

The main physical quality indicator is bulk density (BD). Good soil structure is essential to prevent andisol erosion, puddling- facilitated disease, root stunting, and anoxia to soil biological communities. We decided that bulk density is a good general measure of structure. We therefore measured bulk density at the topsoil (0-15 cm) and subsoil (15-30 cm). Bulk densities were determined by weighing after drying in an oven at 110 C for 24 hours. The soil core that collected the sample determined the volume. The first 3 replicates accumulated 24 hrs of drying over two weeks (as opposed to one 24 hr period), since we were not sending these to LAQUISA until regular electricity for ovens failed at the UNAN-Leon. Since compaction is a concern, improving soil quality will be evidenced by decreases in bulk density. Bulk density cores were emptied into brown paper bags. These were delivered to LAQUISA and transferred directly into an oven.

Statistical Analysis

Each agroecosystem was placed in the conventional (n=10) or ecological (n=8) treatment. To compare the means of independent variables, t-tests were performed when the variables were normally distributed. T-test variables were tested for homogeneity of variance using a Levene test. Independent variables that did not initially meet assumptions of normality were log transformed. A Shapiro-Wilke test ($p<.05$) was used to test for non- normality. If independent variables still did not meet assumptions of normality, or sample sizes were too small, a Mann-

Whitney test was used to test for differences in the medians of the samples. Considering the normal amount of variability in an observational study and the small-sample size, statistical significance is set at $p < .10$. All statistical analyses were done using SPSS (Chicago, Illinois).

1. Dependence on synthetic, chemical vs. any alternative pest control (8)
2. Dependence on inorganic vs. organic fertilizer (6)
3. Level of on farm recycling (5)
4. Level of conservation of soil and its' properties (6)
5. Level of crop diversity in time and space (5)

*6. Level of water conservation (5)
*7. Level of fossil fuel usage (5)
*8. Level of environmental protection (4)

9. Dependence on commercial, modified vs. local, traditional seed (4)

Figure 3-1. Original management indicators. Number of responses out of 10 is in parentheses.

1. Soil Conservation (Level of conservation of soil and its' properties) (**6**)
2. Fertilization (Dependence on inorganic vs. organic fertilizer) (**5**)
3. Pest Control (Dependence on synthetic, chemical vs. any alternative pest control)(**4**)
4. Diversity (Level of crop diversity in time and space) (**3**)
5. Recycling (Level of on farm recycling) (**2**)
6. Seed (Dependence on commercial, modified vs. local, traditional seed) (**1**)

Figure 3-2. Final management indicators. The number in parentheses indicates the point value. Higher values indicate more influential indicators.

Indicator points * Response points = Indicator Score

Soil Conserv.	6	*	3	=	18+
Fertilization	5	*	5	=	25+
Pest Control	4	*	5	=	20+
Diversity	3	*	3	=	9+
Recycling	2	*	3	=	6+
Seed	1	*	5	=	5+

	<u>Sum Indicator Score</u>			=	<u>82.99</u> ==Standardized **Index Score=13.833**
	6 indicators				6

Figure 3-3. Index scoring example. A hypothetical response with the highest ecological score is shown.

CHAPTER 4
RESULTS

Census Population

The census population consists of 18 total replicate fields in a binomial distribution. There is a notable absence of management scores between eight and ten (Figure 4-1). The lowest index score was 4.333, and the highest was 13.833.

Energy Inputs and Productivity

Table 4-1 presents medians and p- values for labor (both as absolute inputs and as a percentage of total) and labor productivity using the Mann-Whitney-U test. The sample sizes of the productivity variables (Table 4-2) differed from those of labor inputs (n=10 for conventional and n=8 for ecological). This is because only seven of 18 interviewed growers actually planted late-season sesame. Additionally, within those seven, some did not manage for insect pests or disease. We could not calculate labor productivity for these growers.

Labor inputs for overall management were not significantly affected by management regime. Of the four practices, only for disease and fertilization did management approach significantly affect the amount of labor required. In both cases, ecological management required more labor. Though not significantly different for disease control and fertilization, the proportion of total labor allocated to insect pest management significantly differed by management type. Conventional producers expended a greater proportion of their time managing pests than ecological producers.

There were no significant differences in labor productivity between conventional and ecological management.

Ecological Indicators and Efficiency

Table 4-3 presents means and p-values of soil quality indicators and their ecological efficiencies. For all independent variables, the means of ten conventional replicates and eight ecological replicates were tested for differences using a t-test for independent samples. Soil quality indicators and their efficiencies did not significantly differ in any case.

Output

The median yield for five conventional agroecosystems was 10.125. The median yield for the ecological agroecosystems was 12.000. These did not significantly differ (p=.195).

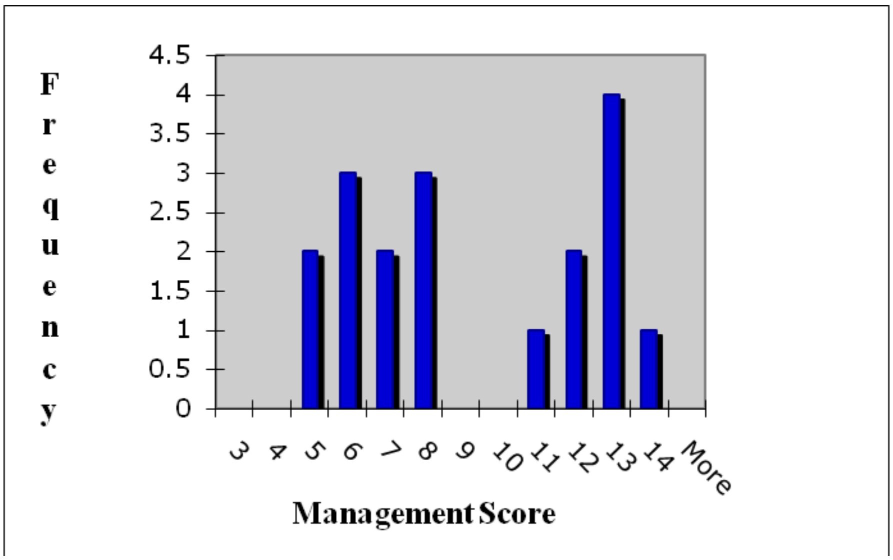

Figure 4-1. Histogram of replicate management index scores. Scores below and above 8.665 indicate conventional (n=10) and ecological (n=8) agroecosystems, respectively.

Table 4-1. Results of Mann-Whitney U test for labor amounts (man-days/Mz), percent of total labor (%), and labor productivity (Qt/(man-day)) between conventional and ecological growers. P-values calculated for overall and per-practice management.

Variable	Median		P-value
	Conventional	Ecological	
Overall			
Labor	19.500	27.700	0.230
Productivity	0.530	0.444	0.439
Fertilization			
Labor	3.250	5.750	0.050*
% of total	13.940	25.690	0.155
Productivity	4.091	16.091	0.699
Weeds			
Labor	15.083	15.600	0.859
% of total	69.620	64.540	0.374
Productivity	0.764	0.437	0.439
Insect Pest			
Labor	2.476	1.440	0.195
% of total	17.690	6.360	0.090@
Productivity	6.863	5.333	0.380
Disease			
Labor	0.375	1.798	0.067@
% of total	0.810	4.580	0.143
Productivity	11.750	48.000	0.157

(@) and (*) indicate significance at p=.100 and p=.050, respectively.

Table 4-2. Sample sizes for labor productivities per practice.

Variable	Treatment	
	Conventional	Ecological
Fertilization	5	2
Weeds	5	2
Insect Pests	5	1
Disease	4	1

Table 4-3. Calculated p-values of soil quality indicator and efficiency means between conventional (n=10) and ecological (n=8) farms using t-test for independent samples.

Variable	Mean		P-value
	Conventional	Ecological	
% OM	2.301	2.231	0.802
Efficiency	0.115	0.071	0.161
Acidity (pH)	6.460	6.566	0.271
Efficiency	0.331	0.217	0.196
Basal respiration (mg/cm^3)	11.031	11.081	0.985
Efficiency	0.474	0.342	0.498
P 1st fraction (ug/g soil)	9.941	12.396	0.599
Efficiency	0.494	0.410	0.742
% of total P	1.268	1.920	0.320
Efficiency	0.001	0.001	0.990
P 2^{nd} fraction (ug/g soil)	94.128	76.668	0.362
Efficiency	4.270	2.396	0.195
% of total P	11.456	11.217	0.904
Efficiency	0.601	0.605	0.266
P 3^{rd} fraction (ug/g soil)	342.081	298.425	0.323
Efficiency	16.820	9.501	0.121
% of total P	45.128	44.547	0.922
Efficiency	2.345	1.472	0.187
P 4^{th} fraction (ug/g soil)	248.879	229.283	0.537
Efficiency	12.323	7.212	0.144
% of total P	32.991	33.797	0.741
Efficiency	1.689	1.117	0.203
P total (ug/g soil)	729.440	645.520	0.305
Efficiency	37.351	21.340	0.112
Bulk density (0-15) cm (g/cm^3)	1.175	1.210	0.393
Efficiency	0.764	0.040	0.109
Bulk density (15-30) cm (g/cm^3)	1.166	1.990	0.516
Efficiency	0.059	0.040	0.217

(@) and (*) indicate significance at p=.100 and p=.050, respectively.

CHAPTER 5
DISCUSSION

Census Population

Several unpredicted reasons accounted for a smaller than preferred sample size. Low prices and broken contracts in 2005 kept many farmers from sowing sesame in 2006. During our sampling period, some growers were in Costa Rica as hired labor instead of cultivating their own fields; therefore, we could not interview them. The paradox of smallholders neglecting their fields in favor of casual labor has previously been tied to financing and labor constraints (Alwang 1999). Renting of small parcels is common, so that finding farms managed by the same person, in the same manner, for three years became increasingly difficult. Finally, increased peanut prices had caused land prices to increase, so that some farmers were either renting their lands to large- scale peanut growers or land renting was now prohibitively expensive. Agroecosystems around Leon meeting our operational needs and logistical possibilities consequently became difficult to find. The sustainability of small-scale sesame in Leon is seemingly negatively affected by economic and agricultural trends in the area.

The distribution of the census into two groups, separated by an absence of scores between eight and ten, indicates that small-scale growers here do not often mix approaches equally. They tend to follow a more singular management approach. This may be a result of growers' connections to cooperatives. Ecological growers connected to *Asociacion de Productores Ecologico de Nicaragua*, and conventional growers connected to *Cooperativa La Esperanza*, may have been absorbing similar knowledge through their cooperative. Growers outside these cooperatives may be receiving information from diffuse or different sources with a less unified message, increasing the likelihood of more mid-range management scores if a population of these independent growers is examined.

Labor Inputs and Productivity

All Management

Our stated hypothesis was that total labor inputs would be higher, and labor productivity lower, in ecological management. This hypothesis was not supported by the data of total labor inputs and productivity. Only seven total values were used to compare overall labor productivity, and this weakens the validity of these results. Sample size for labor inputs was adequate, and non-significance can be partially attributed to sizeable variability in labor within treatments. Two conventional growers, for example, used no labor for pest control, while an equal amount used nine man-days. This variability suggests that total labor was driven primarily by individual decisions in pursuing practices. When summed, this variability confounds a possible effect of management. Individually perceived benefits and costs of labor-intensive practices may drive that variability. Individuality is more likely when standardized recommendations for management are unavailable or growers are relatively new to the crop. Both conditions are common with sesame in Leon. Additionally, individual economic ability may affect the labor dedicated to practices. Even though we assumed economic ability to be generally similar among farmers, even a small difference can have a disproportionately large impact when economic capital is small. For example, buying synthetic insecticides this year, and using labor to apply it, can vary depending on the previous year's profits or unforeseen expenses during season. We did not control for these confounding factors.

Measuring no significant difference in total labor is rare. Studies, such as Pimentel et al. (2005) and Karlen et al. (1995), more commonly find overall labor to increase with more ecological management. Those results confirm common perceptions of ecological management in temperate areas (Lotter 2003). For the fewer studies examining manual labor as the main energetic input, at least one study found lower labor requirements with ecological management

(Mendoza 2005). Others have found ecological management practices to be more labor intensive (Kaltsas et al. 2007). Even though data is reported less clearly than Mendoza (2005), Rasul and Thapa (2003) do mirror our finding of no significant differences in labor inputs. However, their study subject was small-scale rice agriculture.

Whether the actual management techniques, or an agroecosystem's ecology (weeds, insects, etc.), determined total labor inputs was not investigated. This is because total labor includes various practices with potentially different techniques, making it particularly difficult to separate the effect of ecology from technique. Because both managements include the same practices, we can safely say that agroecosystem ecology was not different enough to precipitate changes in total labor. When technique differences are eliminated, and the proportional importance of labor per practices is measured, assessing if agroecosystem ecology is different between managements is more feasible. A different proportion of total labor for a practice when techniques are similar, and total labor is not significantly different as it is here, indicates that management is responding to different agroecosystem ecology. Here we examine practices individually to assess whether technique differences or ecological differences affected labor requirements.

Fertilization

Fertilization was significantly different between management. Ecological management required more labor because the technique was more labor intensive. Collecting and spreading manure, composts, fertilizer teas, or other organic fertilizers is often documented as requiring more labor as tractor time (Karlen et al. 1995) or manual input (Mendoza 2005). Two growers were actively and consistently pursuing manure fertilization. These growers registered the highest labor values, and had a strong influence on our measurement of labor in ecological agroecosystems. The results indicate that ecological fertilization techniques- especially where manure is involved- are more labor intensive than those of conventional management.

While cover cropping can reduce labor compared to other organic fertilization techniques (Drinkwater et al. 1998), managing cover crops still requires more labor than inorganic fertilization (Pimentel et al. 2005). Our results do not address this issue because cover crop use was completely lacking. During the rainy season, no participant was willing to cover crop any available land if it could be cash cropped. Additionally cover cropping is most feasible when seed and information are available, neither of which did we observe or seek. This highlights the fact that laborsaving organic fertilization methods are not always applicable to the small-scale, tropical context, for the reasons mentioned.

Most growers seemingly relied on incorporated residues and natural andisol fertility to an extent. It is true that many conventional growers were fertilizing inorganically, and many ecological growers were applying organic fertilizers. Yet given the observed amounts, fertilization seemed mostly supplementary (unconfirmed). Relying on incorporation and soil fertility may be an appropriate strategy for all growers. Fertilizing organically requires higher labor inputs, inorganic fertilizers can be relatively expensive, and there was no advantage of in terms of labor productivity of pursuing one fertilizer management strategy over another.

Disease

Labor for disease management practices differed significantly between managements, with ecological management requiring more labor. We attribute this to technique differences in controlling the primary sesame pathogen- a *Phytopthera* fungus. Conventional management used industrially- synthesized fungicides, since it was relatively accessible and needed only in limited quantities if properly applied. Ecological growers, on the other hand, were either liming the soil around the plant base or removing whole plants to prevent transmission. Liming presumably raised pH enough to kill off the soil borne fungus. Diluting concentrated fungicides in water and applying with a manual sprayer was apparently more labor efficient than hauling bags of lime or pulling plants out by hand. The higher labor requirements of ecological disease control and fertilization techniques could be due to concentration. Inorganic nutrients are more concentrated than organic ones. Similarly, synthetic substances are more concentrated fungicides than lime. In both cases, the more concentrated substance required less labor.

Weeds

Finding no significant difference of weed management labor between managements can be explained by the similarity in practices. All growers used animal-drawn cultivation followed by manual weeding, except for one ecological grower who used goat herbivory and one conventional grower who applied herbicides. Hence, 88% of farmers were managing weeds ecologically by *defacto*. Understandably, labor inputs were not affected by management specific technique. Most studies, Clements et al. (1995) and Loake (2001) for example, have found weeding labor to be higher with ecological management. In those studies, however, cultivation substitutes for herbicides. In our study context, strategies were similar and did not substitute for herbicides. Differences in labor requirements were consequently not seen.

This exposes a weakness in our management index. Grouping all pest management under the same indicator question resulted in a few erroneous readings of fully conventional pest control, when weed control was not conventional. Our management definitions- based on internal versus external perspectives- do not clearly account for tillage as either ecological or conventional. It raises the question whether not using herbicides, without any other deliberate intervention, should be equated with ecological management. We contend that it should not, and further agroecosystem study should more fully consider the degree of purposeful ecological manipulation of weed populations in characterizing management.

Percentage of total labor used for weed control was not significantly different between treatments, despite similar techniques. This suggests that weeds were not more prominent in either system. Organically managed tomato fields have shown more weeds than conventional fields as a result of differing agroecosystem ecology (Clark et al. 1998). These authors suggest increased nutrient cycling to all plants, from greater microbial activity and organic matter, promoted weeds under organic management. Neither of those ecological aspects differed by treatment in our study. The agroecosystem ecology in respect to weeds was, hence, not very different between managements. Weed control labor as a percentage of total was consequently not affected.

Insect Pests

Results for this practice were interesting: labor as man-days/Mz was not significantly affected by management but percentage of total labor was. Both managements apply liquids using a backpack sprayer and removing insects manually from plants. A case for similarity of technique could be made based on this. What they were applying was different, however. Ecological growers applied *Neem/ Capsicum/ Allium* teas to repel pests, while conventional growers applied industrially synthesized insecticides. Because of the very different ecological consequences of insect repellants versus insecticides, our opinion is of differing techniques for combating insect pests. Additionally, diverse cropping and trap crops are strategies for insect pest management in ecological management not pursued in conventional management.

From this point of view, a lower percentage of labor for insect pest management suggests one of two things. Firstly, there could be fewer pests in ecological management. Theory would predict this, since ecological management can lower pest populations by increasing beneficial populations (Mader et al. 2002). Ecological farmers often report fewer pest problems- and consequently less labor for insect pest management- than their conventional counterparts, despite not using synthetic insecticides (Lotter 2003). Our results, because techniques are distinct enough, may alternately be explained by higher labor efficiency of repellants. Practical experience shows that repellants and other non-toxic approaches are less effective and may require more labor for the same effect (Buss and Park-Brown 2006). One might assume botanical repellants to be more labor intensive because they breakdown faster, do not kill, and may require more applications than synthetic insecticides. Based on this assumption, less labor proportionally with repellents would be explained by smaller pest populations in ecological agroecosystems. This indicates different ecology of ecological and conventional agroecosystems. Kaltsas et al. (2007), however, find technique difference to induce higher labor needs in organic olive groves.

The fact that labor as man-days/Mz did not differ significantly between management conflicts the proportional labor findings. Normalizing on a percentage scale may have made the data more amenable to statistical analysis than when presented as man-days. Moreover, the effect of outliers would be diminished when labor is presented as a percentage.

Soil Quality and Ecological Efficiency

Management did not affect soil quality indicators and their efficiencies. This contradicts our hypothesis and most literature predicting ecological management to result in greater soil quality. Three reasons may explain this discrepancy.

A fundamental premise of soil quality studies is that soil- affecting inputs will be distinct as a result of discrete management. Moreover, the magnitude of soil quality change depends on the degree of input dissimilarity (quantitative or qualitative) between managements. This premise is not fully met in the study context, since all management is low-input and systems are rather similar. For example, though fertilizer materials and labor were different between management, most agroecosystems seemingly relied to a large or complete extent on natural soil fertility and incorporated residues. Both managements may have had, for all ecological purposes, a common fertilizer- the soil itself. Failing to measure lower pH in conventional agroecosystems suggest that ecologically significant rate of inorganic fertilizers were not applied. Moreover, percent organic matter itself was unaffected. This is the indicator most consistently associated with distinction in inputs. Other evidence for similarity was in biotic activity. Fewer pesticides in ecological agroecosystems can result in higher soil biotic activity (Plenchette et al. 2005). Since percent organic matter was not different, any difference in soil biotic activity would have been more directly tied to differences in pesticide inputs. We measured no difference in biotic activity, indicating similar pesticide inputs between management.

The ecological context of this study provides a second possible explanation for a lack of an affect. The ecological metabolism in tropical soils is rapid, especially in the wet-season when most organic additions were made. This makes increasing soil organic matter difficult. Measurable increases in organic matter may accrue only after an extended period of accumulation in many soils (Fleissbach et al. 2006, Monokrousos et al. 2006). This period of accumulation may be longer in the tropic because organic matter is decomposed rapidly. Without increased organic matter in ecological agroecosystems, correlated increases in biotic activity, P availability, pH, and bulk density may be too slight to detect. This tropical effect must be tempered by known organic matter occlusion by andisols that allows for accumulation.

Intense sunlight during the soil-sampling period may sterilize topsoil and cause biotic activity to measure equally between managements. We attempted to minimize sterilization by extracting samples 2.5- 7.5 cm below the soil surface and incubating samples. This may have had little effect. No difference in biotic activity does not, however, mean that biotic composition is also unchanged. Widmer et al. (2006) and Marinari et al. (2006) found changes in biotic composition with management. Also, soil quality measurements were taken one to two months prior during a dry period. Biotic activity could very feasibly be altogether distinct during rains.

Andisols soils provide a unique ecological context even within the tropics. The P fractionation shows that management does not induce functionally salient changes in P availability of andisols. Other studies have found management, by way of organic matter, to affect P fractions (Salaque et al. 2004, Reddy et al. 2005). Our results differ from Castillo and Joergenson (2001) who found less total P with ecological management in andisols around Leon. Their sample size was larger than ours, they used a different P extraction method, the soil textures were somewhat distinct, and the effect they found was not terribly immense. This may explain the discrepancies between our results and theirs. Finding no difference in P fractions based on treatment supports He et al. (2006) and Reddy et al. (2001). They argue that as P fixing capacities become greater, P dynamics are more influenced by inherent soil properties than by management. Our results cannot directly support these studies because they experimentally altered percent organic matter to proxy ecological management. We did not measure such a change necessary to validly support their conclusions.

Finally, confounding factors may have played a role. Deep tillage from the cotton years left soils with sizeable differences in organic matter. Given primitive mechanization, already high amounts, and a tropical ecology, three years may be insufficient for ecological management to increase organic matter. Additionally, high pesticide applications floating in from adjacent peanut fields may have affected biotic activity. Finally, we did not sample fields at the same point in their tillage schedule. Some had been disked once, others twice, and some none. In combination with random cattle and human trampling, this likely confounded the effect of management on bulk density. Since organic matter did not differ between treatments, it is unlikely we would have measured a significant difference in bulk density anyhow.

Yield

Sesame yield was not affected by management regime. The sample sizes for each treatment were extremely small, so this finding should be taken with some caution. Having said that, the salient point here is that ecological yields were not reduced as compared to conventional yields. This contradicts extensive reviews by Stanhill (1990) and Lotter (2003) predicting slight yield losses with ecological management, as well as what seems to be a commonly held belief among agricultural scientists. At the same time, it lends some support to Rasul and Thapa (2003) and Mendoza (2004) that ecological management does not necessarily lead to yield reductions in the developing context.

Many determinants of yield did not seem to differ in an ecologically significant manner between management. There was no difference in soil quality indicators between managements. Although there is some evidence for greater insect pest populations in conventional agroecosystems, no growers reported them to be uncontrollable or economically damaging. Labor used to manage weeds- which can depress yields when herbicides are not used (Clark et al. 1999, Lotter 2003)- was not more prevalent in either management. Both agroecosystems were likely limited by P and seemingly used soil reserves as their main nutrient source, though this is unconfirmed. Finally, both agroecosystems used the ICTA-R and Linea 2000 sesame cultivar. The Drinkwater et al. (1995) hypothesis that different managements may ultimately lead to similar agronomic response was not testable in our study because managements were too similar. Finding no significant difference in yield was not, therefore, entirely surprising.

Conclusions

The objective of this study was to ascertain which type of management is likely to produce a more sustainable agroecosystem. Our results indicate that sustainability of sesame agroecosystems in Leon did not differ between conventional and ecological management. The major sustainability parameters- overall labor inputs, soil quality, and yield- were mostly unaffected by management. Neither management is more likely to augment labor productivity of small-scale farming through intensification or extensification. Similarly, soil quality for long-term productive capacity did not differ by management regime. The economic and ecological sustainability consequently did not differ in any ecologically significant manner, nor were their major labor reductions to improve quality of life.

Sustainability was likely similar because in-common restraints of small-scale sesame production on tropical andisols were more determinant of sustainability than management regime. For example, because neither management adequately addressed energy limitation of weed control in small-scale systems, high labor requirements were not lessened by either management. P availability, in another example, was also not improved by a particular management. Beyond strategies of each management, it is unclear whether any extension service had informed farmers of P fixation of andisol or of saturation techniques to overcome such fixation. In the end, all agroecosystems were of relatively low energy and information input. From experience we know one of these should increase to promote sustainability.

Our conclusions do not support the hypothesis of Altieri (2002) and others that ecological management will increase small-scale, tropical sustainability over conventional management. We note that ecological management research has not been as institutionally supported as conventional management; comparing the sustainability may be of limited utility until ecological strategies are improved (Lotter 2003). Still, results suggest that development organizations should not fully veer from traditional efforts to improve access to energy, land, and financing in favor of implementing ecological management. Ecological management, at least in Nicaraguan sesame, does not seem to be a panacea for the low sustainability of small-scale, tropical agriculture. Additionally, from the comments of growers, it seems that market access and negotiating power may be a more powerful determinant of sesame sustainability in Nicaragua than management regime.

APPENDIX A
PROTOCOLS

Assemble List of Indicators

I. Ask 7 UF and 4 Nicaraguan agriculture experts to freelist the 6 criteria most useful in discerning between managements

II. Keep those mentioned by 50% and nearly 50% but with self-judjed potential

Finalize List of Useful Indicators

I. Compose indicators as 8 directed questions with reponse range

II. Pre-test on similar farmers and first 3 of study

III. Discard contextually invalid or agronimaclly nonsensical indicators

Determine Relative Importance of Indicators

I. Ask 9 origional and 2 new experts to rank indicators from 1 to 6 in oder of increasing discernment capability

II. Determine mode

A. If 2 simultaneous modes for ranking responses of 1 indicator average values and use quotient as mode

B. If 2 indicaotors with same rank(as established by mode) choose indicator with more top-rankings as higher rank

Determine Management Score for Replicate

I. Assign point value(1-6) to indicators based on rank(highest rank=highest value) and to indicator question responses by farmers(most ecological=highest value)

II. Determine management score for each replicate

I. Score each indicator= (indicator value X response value)

II. Sum scores of indicators fro overall management score

III. Divide by number of indicaors(6) to standardize final score

IV. Determine range of possible values

Figure A-1. Protocol for management index construction.

Participant Consent
I. Deliver IRB consent form, read aloud if necessary
II. Obtain written consent

Eligibility Establishment
I. Ask requierimientos generales to document fulfillment of operationalized agroecosystem concept

Formal Participant Orientation
I. Explain objectives and significance of study
II. Emphasize private nature of this study without prejudg. of "better" mgmt..
III. Clarify that index covers all crops and labor, yield specific to sesame

Background Information
I. Ask question in informaction general de cultivos
II. Ask questions in mano de obra
III. Clarify 3 technical points before labor data collection

A. 1 "day" of work is not a set # of hrs but a relative measure to each tarea
B. Labor inputs should be for plot size of sesame this year
C. Responses should be for a "typical" year with ackowledgement of variability

Labor Inputs Documentation
I. Ask farmer about the progresion of tasks within each practice
II. Use this and background information to formulate labor questions individually
III. Collelct labor data about each task within a particular practice

A. Inquire on how many distinct occassions within the season a task is performed
B. if more than once, establish wherein the season each occassion occurs
C. For each task occassion, askhow many days,with how many men does the task last

Interview Closing and Yield
A. Close with asking participants have any further questions
B. Restate commitment to bring back soil analysis results and gather yield data later
C. Gather sesame plot size, seed type, yield, and commentary on next visit

Figure A-2. Interview protocol

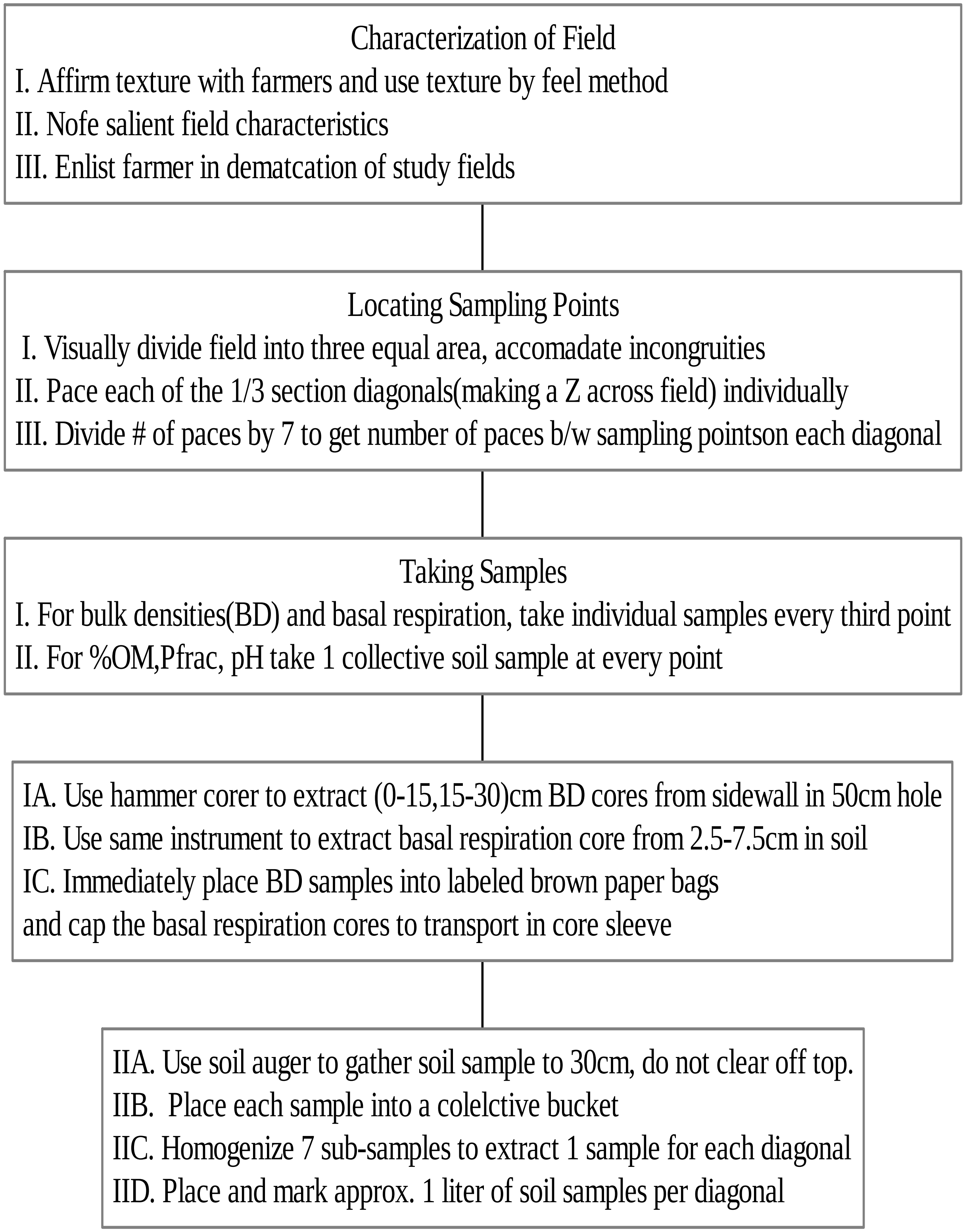

Figure A-3. Soil sampling protocol.

APPENDIX B
INDEX

Table B-1. Indicator rankings by experts.

Expert	A (fertilizer source)	B(recycling)	C (pest control)	D (soil conserv.)	E (crop diversity)	F(seeds)
Jimmy Jones	2	4	1	3	6	5
Peter Hildebrand	3	4	5	2	1	6
Hugh Popenoe	4	2	5	1	3	6
Danielle Treadwell	4	3	5	1	2	6
Robert McSorley	3	4	2	1	5	6
Mickie Swisher	2	6	1	5	3	4
Lori Unruh Snyder	2	6	1	4	5	3
Raymand Gallagher	4	3	6	1	2	5
Freddy Aleman	3	2	5	1	4	6
Alvaro Valle	3	2	4	5	1	6
Roberto Swisher	2	6	1	5	4	3
	Mode	Mode	Mode	Mode	Mode	Mode
	2	4	3	1	3	6
					Adj. Mode	
					3	
Rank	2	5	3	1	4	6
Points	5	2	4	6	3	1

Table B-2. Individual indicator scores by replicate.

Replicate	A(fertilizer source)	B(recycling)	C(pest control)	D(soil conservation)	E(crop diversity)	F(seeds)
I	1	1	1	1	2	3
II	1	1	3	1	1	3
III	1	3	1	2	1	1
IV	2	1	2	2	2	3
V	3	2	3	1	2	4
VIII	1	2	2	1	2	5
IX	5	2	4	2	2	5
X	1	2	2	1	2	1
XI	5	2	5	2	2	5
XII	5	3	4	3	3	4
XIII	5	3	4	3	3	5
XIV	5	2	5	1	1	3
XV	1	2	1	2	3	4
XVI	5	3	5	2	2	4
XVII	5	3	5	3	2	2
XVIII	3	3	2	2	2	1
XIX	5	3	5	2	2	5
XX	4	3	1	1	2	3

APPENDIX C
SEMI-STRUCTURED INTERVIEW

REQUIERIMIENTOS GENERALES
1. Cuantas Mz siembra usted en total?
2. Usa riego en estos cultivos
3. Has sembrado ajonjoli/ptros cultivos en los ultimos tres anos en ese campo.
4. Has usado manejo bien distinto en los ultimos tres anos en estos cultivos.
5. Si si , cuales practicas han sido bien distintos.

INFORMACION GENERAL DE LOS CULTIVOS
1. Cuantas Mz de ajonjoli sembrado este ano y el pasado
2. Que tipo de semilla usan usted?
3. Que cultivos de la primera estan sembrado en el mismo campo del ajonjoli.
4. Como estan arreglado en el campo y como esten sembrado en relacion de uno al otro.
5. Cuanto toma desde que se siembra estos cultivos hast que se cosechan.
6. Hay un rubro entre la primera y la postrera?
7. Cuanto producio usted el ano pasado por Mz.

ENTREVISTA
ORAL INTERVIEW- Indexing questions
1. A que nivel depiende usted en los abonos organicos vs. quimicos (urea, compeleto) para fertilizacion? a. solo organico b. mas organico que quimico c. igual d. mas quimico que organico e. solo quimico, sintetico

2. Cual es su nivel de reciclaje de materiales de la finca (excrementos animales, residues, vegetacion de la finca, residuos de las casa)?
a) ningun reciclaje b) niveles bajos c) niveles medianos d) niveles altos e) todos posible reciclado

3. En el control de plagas y maelezas, cuanto depiende usted en el control quimico vs. control cultural, natural (manipulacion de interaccion y ciclos), o alternativo?
a) solo quimico b) mas quimico que natural c) igual d) mas natural que quimico e) todo natural sin quimico

4. Cual es su nivel de actividad en la conservacion de suelos y sus propiedades, sea en el tipo de labranza, agregacion de material organica, plantas de cobertura, barreras de erosion, o otros?
a) ningunas actividades activas b) niveles bajos c) nivels medianos d) nivels altos e) en todo practica de suelo se considera la conservacion de suelo, y practicas solo para conservacion de suelo

5. Cual es su nivel de diversidad in tipos de cultivos y combinaciones entre una parcela y ano a ano? a) ningun(monocultivo mismo cada ano) b) niveles bajos(1-2 cultivos cada ano-no cambian por ano o reverso) c) niveles medianos(varios cultivos en el ano y cambian regularmente) d) niveles altos(varios cultivos en el ano y cambian cada ano) e) niveles altisimo (maximo variacion en el ano, entre anos, y en el espacio(varias alturas, relay, etc.)

6. Cual es su nivel de dependencia en semillas modificada, mejorado, commerciales vs. semillas tradacionales, tipicas, y de variedad local?
a). solo tradicionels,t, y local b) mas t, t, vl que modificade, mejorada commerciales c) Igual d) mas semillas modificada commercialmentte y mejorada que tradicional, tipicas, e) todas son comerciales, modificadas, y mejoradas.

A=1st mes antes del siembro
B=1st mes, C= 2nd mes D=3rd mes despues de sembrar

MANO DE OBRA
Cuantos trabajadores de aqui de la casa y empleados son..

Tipo:↓	# todo el tiempo				# parte del ia o por dia				# de ninos trabajando			
Mes→	A	B	C	D	A	B	C	D	A	B	C	D

C=de la casa, E=empleado

Para las preguntas siguintes, cuenta una person como .5 persona si solo trabajo medio dia, como los ninos,

FERTILIZACION
Fertiliza o agrega abonos parafertilizar usted?
Por favor cuenatame de sus practicas de fertilzacion?
Si usa abonos organicos, por favor describa sus collecion y transformacion de al materiales organicos.
De sus practicas describido, cuales son.

Tipo:↓(see key below)	# de veces la tareas se hace como describido				# de dias la tareas se hace como describido				# de personas requirida para hacer la tarea				Se hace al mismo tiempo que otra cosa
Month→	A	B	C	D	A	B	C	D	A	B	C	D	

O=solo abono organico, I=solo quimico fetilizantes, OI=organic y quimicos juntos, CRi = comprar o recibir quimicos, CRo= comprar o recibir abonos organicos, R=recoger material organico para abono, T= transformar material organico= quimicos(((Fertilizante, urea, completo)) == abono organo, compost, bocashi(compost especial)

Usa maquinaria para cualquier de estas practicas o transporte?
Si si, mire la tabla

Tipo:↓	Descripcion de maquinaria modelo ano	# de set completos.	# de animals por equipo	# de personas necesario para operar maquinaria

M=manual, C=caballo, B=buey, CO=Maquinaria combustible, T=transporte, P=practicas del campo
rotoveter- monocultivador, arado discos o grados

OTROS ADITIVOS(no para fertilizacion)
Usa usted cualquier otros aditivos al suelo que no sean fertilizantes?
Si si , por favor describelos

Tipo:↓	# de veces la tareas se hace como describido				# de dias la tareas se hace como describido				# de personas requirida para hacer la tarea				Mismo tiempo de fertilizacion o otro aditivos
Mes→	A	B	C	D	A	B	C	D	A	B	C	D	

C=obertura de cualquier tipo, CA=cal, MO=material organica N=Micronutrients
AC=acondicianador de suelo, CRq= compra o recibe aditivos, R=recoger material organico, T=transformar material organico

Espicificar. Cobertura- cascaria de arroz, sacate seco, cobertura, tapa con secate,
Material organico= compost, excremento animals; Abono foliares,

Usa maquinaria para cualquier de estas practicas o transporte?
Si si, mire la tabla

Tipo:↓	Descripcion de maqunaria modelo ano	# de set completos.	# de animals por equipo	# de personas necesario para operar maquinaria

M=manual, C=caballo, B=buey, CO=Maquinaria combustible, T=transporte, P=practicas del campo rotoveter- monocultivador, arado, discos o grados

MANTENIMIENTO
Maniteine usted estos aparatos usados para practicas de manejo.
Si si, describe el mantenimiento y mire la tabla.

Tipo↓	# de veces la tareas se hace como describido				# de dias la tareas se hace como describido				# de personas requirida para hacer la tarea				Otras notas
Mes→	A	B	C	D	A	B	C	D	A	B	C	D	

R=reparara aparatos o maqunaria, M=manual, C=caballo, B=buey, CO=Maquinaria combustible, rotoveter- monocultivador, arado dsicos o grados

PREPARACION de SUELOS
Prepara su suelos, labranza.
Si si, por favor cuentame como hace esas cosas.

Tipo:↓	# de veces la tareas se hace como describido				# de dias la tareas se hace como describido				# de personas requirida para hacer la tarea			
Mes→	A	B	C	D	A	B	C	D	A	B	C	D

M=labranza manual, MC=labranza de maquina

Usa maquinaria para cualquier de estas practicas o transporte?
Si si, mire la tabla

Tipo:↓	Descripcion de maqunaria modelo ano	# de set completos.	# de animals por equipo	# de personas necesario para operar maquinaria

M=manual, C=caballo, B=buey, CO=Maquinaria combustible, T=transporte, P=practicas del camporotoveter- monocultivador, arado discos o grados

MALEZAS
Controlo las malas hierbas o malezas usted?
Si si , describa por favor sus practiceas de manejo de las malezas
De las practicas desccribidas cuales son

Tipo:↓	# de veces la tareas se hace como describido				# de dias la tareas se hace como describido				# de personas requirida para hacer la tarea				Mismo tiempo o uso de fertilizacion, preparacion, o cultivacion, o sembrada
Mes→	A	B	C	D	A	B	C	D	A	B	C	D	

CRhs=comprar o recibir herbicidas sinteticos, industriales, CRHN =Compra o recibir herbicidas naturales, R=recoger material para control natural, T=transformar material organico para control natural, S=sintetico, industrial herbicidas aplicado solo, Nc=herbicidos naturales, commercial aplicado natural, Nf=herbidos naturales de la finca aplicado solas SN=sintetico y natural juntos, C=Compost de cobertura., CR=cobertura de otra, CU=cultivacion

Usa maquinaria para cualquier de estas practicas o transporte?
Si si, mire la tabla

Tipo:↓	Descripcion de maqunaria modelo ano	# de set completos.	# de animals por equipo	# de personas necesario para operar maquinaria

M=manual, C=caballo, B=buey, CO=Maquinaria combustible, T=transporte, P=practicas del camporotoveter- monocultivador, arado discos o grados

INSECTOS
Control los insectos(o las plagas) o no?
Si si, digame como controla insectos usted en el campo
De las practicas describidas, cuales son..

Type:↓	# de veces la tarea se hace como describido				# de dias la tareas se hace como describido				# de personas requirida para hacer la tarea				Mismo tiempo o uso de fert., prep, insect, maleza, o otros control de insectos
Month→	A	B	C	D	A	B	C	D	A	B	C	D	

CRhs=comprar o recibir venenos sinteticos, industriales, CRHN =Compra o recibir venenos naturales, R=recoger material para control natural, T=transformar material organico para control natural, S=sintetico, industrial venenos aplicado solo, Nc=venenos naturales, commercial aplicado natural, Nf=venenos naturales de la finca aplicado solas SN=sintetico y natural juntos, CT=cultivo trampa., BV=barrera viva, F=remover fisicamente

Usa maquinaria para cualquier de estas practicas o transporte?
Si si, mire la tabla

Tipo:↓	Descripcion de maqunaria modelo ano	# de set completos.	# de animals por equipo	# de personas necesario para operar maquinaria

M=manual, C=caballo, B=buey, CO=Maquinaria combustible, T=transporte, P=practicas del manejo

ENFERMEDADES
Controla o no para enfermedaddes (se hielo, o se quema- hongo- pata prieta) usted.
Si si, describe usted su control de
Of the practices you described (see key), what are the…
If cultural methods are used, please describe

Type:↓	# de veces la tareas se hace como describido				# de dias la tareas se hace como describido				# de personas requirida para hacer la tarea				otras notos o contro o aplicacion de herbicidas, veneos, compost, prep, o otro
Month→	A	B	C	D	A	B	C	D	A	B	C	D	

CRhs=comprar o recibir venenos sinteticos, industriales, CRHN =Compra o recibir venenos naturales, R=recoger material para control natural, T=transformar material organico para control natural, S=sintetico, industrial venenos aplicado solo, Nc=venenos naturales, commercial aplicado natural, Nf=venenos naturales de la finca aplicado solas SN=sintetico y natural juntos, CT=cultivo trampa., BV=barrera viva, F=remover fisicamente, CC= contro cultural de otro tipo.

MECANIZACION
Usa maquinaria para cualquier de estas practicas o transporte?
Si si, mire la tabla

Tipo:↓	Descripcion de maqunaria modelo ano	# de set completos.	# de animals por equipo	# de personas necesario para operar maquinaria

M=manual, C=caballo, B=buey, CO=Maquinaria combustible, T=transporte, P=practicas del manejo

SIEMBRA, COSECHA, y RESIDUOS
Describe como siembra.
Describe como cosecha
Describe su manejo de residuos(rastrojo de la cosecha).
De las practicas describidas, cuales osn las..

Type:↓	# de veces la tareas se hace como describido				# de dias la tareas se hace como describido				# de personas requirida para hacer la tarea				mismo tiempo de otras practicas
Month→	A	B	C	D	A	B	C	D	A	B	C	D	

C=harvest, R= residuo se dejan en sima, I=incorporas los residuos, Q=quemar los residuos, R=recoger para otros usos, S= siembra, CR= comprar recinir semillas, P=prepar semillas,

Usa maquinaria para cualquier de estas practicas o transporte?
Si si, mire la tabla

Tipo:↓	Descripcion de maqunaria modelo ano	# de set completos.	# de animals por equipo	# de personas necesario para operar maquinaria

M=manual, C=caballo, B=buey, CO=Maquinaria combustible, T=transporte, P=practicas del manejo

APPENDIX D
DESCRIPTIVE STATISTICS

Table D-1. Mean and standard deviation of response variables.

Response Variables	Mean	SD
% Organic Matter	2.270	0.583
Acidity	6.507	0.216
Basal respiration	11.054	5.128
Bulk Density (0-15)cm	1.190	0.082
Bulk Density (15-30)cm	1.181	0.102
Phosphorous Profile (ug/g soil)		
P1	14.411	13.549
P2	86.368	37.289
P3	322.678	99.623
P4	240.170	69.641
PT	708.687	165.443
Phosphorous Profile (% of total)		
P1	1.979	1.887
P2	12.856	5.326
P3	44.819	9.380
P4	33.399	5.205
Soil Quality Indicator Efficiencies		
% Organic matter	0.12	0.116
Acidity	0.367	0.341
Basal respiration	0.679	0.710
Bulk density (0-15)cm	0.067	0.064
Bulk density (15-30)cm	0.066	0.066
P fractions (ug/g soil)		
P1	0.654	0.596
P2	5.686	9.078
P3	17.383	19.277
P4	13.195	15.614
PT	39.861	48.030

P fractions (% of total)		
P1	0.094	0.081
P2	0.805	1.053
P3	2.462	2.172
P4	1.846	1.739
Labor inputs (man-days/Mz)		
Fertilization	5.518	6.243
Weed control	18.06	13.160
Insect pest control	3.676	5.258
Disease control	0.962	1.300
Total labor	27.242	17.510
Labor productivity (Qt/man-day)		
Fertilization	27.489	40.786
Weed control	0.703	0.363
Insect pest control	5.487	4.769
Disease control	18.967	16.266
Labor Inputs (% of total)		
Fertilization	20.362	16.949
Weed control	67.741	20.466
Insect pest control	15.227	15.101
Disease control	3.777	5.183
Production (Qt/Mz)		
Yield	11.361	1.596

LIST OF REFERENCES

Adger, N. 1999. Social vulnerability to climate change and extremes in coastal Vietnam. *World Development*, *27*(2), 249–269.

Akobundu, I.O. 1987. *Weed Science in the Tropics. Principles and Practices*. Wiley, Chichester, UK.

Altieri, M.A. 2002. Agroecology: the science of natural resource management for poor farmers in marginal environments. *Agriculture, Ecosystems, and Environment*, *93*(12), 1-24.

Alwang, J., Siegel, P.B. 1999. Labor shortages on small landholdings in Malawi: implications for policy reform. *World Development*, *27*(8), 1461-1475.

Andrews, S.S., Carroll, C.R. 2001. Designing a soil quality assessment tool for sustainable agroecosystem management. *Ecological Applications*, *11*(6), 1573-1585.

Beets, W.C. 1990. *Raising and Sustaining the Productivity of Smallholders Farming Systems in the Tropics*. AgBe Publishing, Holland.

Belotti, E. 1998. Assessment of a soil quality criterion by means of a field survey. *Applied Soil Ecology*, *10*, 51-63.

Bernard, H.R. 2002. *Research methods in Anthropology, Qualitative and Quantitative Approaches*. Altamira, Walnut Creek, California.

Borie, F., Zunino, H. 1983. Organic matter-phosphorus associations as a sink in P-fixation processes in allophanic soils of Chile. *Soil Biology and Biochemistry*, *15*, 599-603.

Bulluck III, L.R., Brosius, M., Ebanylo, G.K., Ristaino, J.B. 2006. Organic and synthetic fertility amendments influence soil microbial, physical, and chemical properties on organic and conventional farms. *Applied Soil Ecology*, *19*, 147-160.

Byringiro, F., Reardon, T. 1996. Farm productivity in Rwanda; Effects of farm size, erosion, and soil conservation investments. *Agricultural Eocnomics*, *15*(2), 127-136.

Buss, E.A., Park-Brown, S.G. 2006. Natural Products for Insect Pest Management. Document ENY-350 (IN 197). Florida Cooperative Extension Service, Institutute of Food and Agricultural Sciences, University of Florida. Retrievable at: http://edis.ifas.ufl.edu/IN197.

Castillo, X., Joergenson, R.G. 2001. Impact of ecological and conventional arable management systems on chemical and biological soil quality indices in Nicaragua. *Soil Biology and Biochemistry*, *33*, 1591-1597.

Chellemi, D.O., Rosskopf, E.N. 2004. Yield potential and soil quality under alternative crop production practices for fresh market pepper. *Renewable Agriculture and Food Systems*, *19*(3), 168-175.

Clark, S.M., Horwath, W.R., Shennan, C., Scow, K.M., Lantini, W.T., Ferris, H. 1999. Nitrogen, weeds, and water as yield limiting factors in conventional, low-input, and organic tomato systems. *Agriculture, Ecosystems, and Environment*, *73*, 257-270.

Clements, D.R., Weise, S.F., Brown, R., Stonehouse, D.P., Hume, D.J., Swanton, C.J. 1995. Energy analysis of tillage and herbicide inputs in alternative weed management systems. *Agriculture, Ecosystems, and Environment*, *52*(2), 119-128.

Dalgaard, T., Halberg, N., Porter, J.R. 2001. A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. *Agriculture, Ecosystems, and Environment*, *87*(1), 51-56.

Doss. C.R. 2006. Analyzing technology adoption using microstudies; limitations, challenges, and opportunities for improvment. *Agricultural Economics*, *34*(3), 207-219.

Drinkwater, L., Letorneau, D.K., Workneh, F., van Bruggen, A.H.C., Shennan, C. 1995. Fundamental differences between conventional and organic tomato agroecosystems in California. *Ecological Applications*, *5*(4), 1098-1112.

Drinkwater, L.E., Wagoner, M.W., Sarrantonio, M. 1998. Legume-based systems have reduced losses of nitrogen and carbon. *Nature*, *396*, 262-265.

Drinkwater, L. 2002. Cropping systems research: reconsidering agricultural experimental approaches. *HortTechnology*, 12(3), 1150-1155.

Erkossa. T.K., Fisseha, I., Stahr, K. 2007. Indexing soil quality: a new paradigm in soil science research. *Australian Journal of Soil Research*, *45*, 129-137.

Fleissbach, A., Oberholzer, H.R., Gunst, L., Mader, P. 2006. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. *Agriculture, Ecosystems, and Environment*, (118), 273-284

Food and Agriculture Organization of the United Nations (FAO). 2001. *World Census of Agriculture: 2000 Round*. Food and Agriculture Organization of the United Nations. Statistics Division. Retrieved August 28, 2007 at http://www.fao.org/ES/ess/census/wcares/default.asp

Food and Agriculture Organization of the United Nations (FAO). 2006. *Compendium of Food and Agriculture Indicators*. Food and Agriculture Organization of the Unites Nations. Statistics Division. Retrieved August 28, 2007 at http://www.fao.org/es/ess/compendium_2006/list.asp

Food and Agriculture Organization of the United Nations (FAO). 2007. *Nicaragua Country website.* Food and Agriculture Organization of the United Nations. Retrieved August 28, 2007 at http://www.fao.org/world/nicaragua/prof_es.htm

Food and Agriculture Organization of the United Nations (FAO). 2005. *Nicaragua Country Profile.* Food and Agriculture Organization of the United Nations. Retrieved August 28, 2007 at http://www.fao.org/countryprofiles/index.asp?lang=es&iso3=NIC

Giampietro, M., Pimentel, D. 1990. Assessment of the energetics of human labor. *Agriculture, Ecosystems, and Environment*, *32*, 257-272.

Gliessman, S.R. 2007. *Agroecology: The Ecology of Sustainable Food Systems*. Spring- Verlag, New York

Hansen, B., Alrøe, H.F., Kristensen, E.S. 2001. Approaches to asses the environmental impact of organic farming with particular regard to Denmark. *Agriculture, Ecosystems, and Environment*, *83*, 11–26.

He, Z.Q., Grain, T.S., Honeycutt, C.W. 2006. Soil phosphorus dynamics in response to dairy manure and inorganic fertilizer applications. *Soil Science*, *171*(8), 598-609.

Hedley, M.J., Stewart, J.W.B., Chauhan, B.S. 1982. Changes in inorganic soil phosphorus fractions induced by cultivation practices and by laboratory incubations. *Soil Science Society of America Journal*, *46*, 970–976

Herrick, J.E. 2000. Soil quality: an indicator of sustainable land management? *Applied Soil Ecology*, *15*, 75-83.

Instituto Nacional de Estudios Territoriales (INETER). 2006. *Boletines Meteorologicos 2006*. Dirreccion General De Meteorologia. Retrieved August 10, 2007 at http://www.ineter.gob.ni/Direcciones/meteorologia/Boletines/Boletines%20del%20periodo%20lluvioso/boletines2.html

International Food Policy Research Institute (IFPRI). 2007. *The Future of Small Farms for Poverty Reduction and Growth*. IFPRI, Washington, DC.

Kaltsas, A.M., Mamolos, A.P., Tsatsarelis, C.A., Nanos, G.D., Kalbutji, K.L. 2007. Energy budget in organic and conventional olive groves. *Agriculture, Ecosystems, and Environment*, *122*(2), 243-251.

Karlen, D.L., Duffy, M.D., Colvin, T.S. 1995. Nutrient, labor, energy, and economic evaluations of two farming systems in Iowa. *Journal of Production Agriculture*, *8*(4), 540- 546.

Karlen, D.L., Ditzler, C.A., Andrews, S.S. 2003. Soil quality: why and how? *Geoderma*, *114*, 145-156.

Kiker, C.F. 1993. Macroscale economic and policy influences om the sustainability of tropical agriculture. In Ragaland, J., Lal, R. (Eds). *Technologies for Sustainable Agriculture in the Tropics*. ASA Special Publication 56, American Society of Agronomy, Madison.

Lal, R. 1991. Soil Research for Agricultural Sustainability in the Tropics. In: National Research Council (NRC), 1991. *A Plan for Collaborative Research on Agriculture and Natural Resource Management*, Washington D.C., 66-90

Lindegarth, M., Gamfeldt, L. 2005. Comparing categorical and continuous ecological analyses: Effects of 'wave exposure" on rocky shores. *Ecology*, *86*(5), 1346-1357.

Lawrence, D., Schlesinger, L. 2001. Changes in soil phosphorus during 200 years of shifting cultivation in Indonesia. *Ecology*, *82*(10), 2769-2780.

Lilburne, L., Sparling, G., Schipper, L. 2004. Soil quality monitoring in New Zealand: development of an interpretative framework. *Agriculture, Ecosystems, and Environment*, *104*, 535-544.

Loake, C. 2001. Energy accounting and well- being- examining UK organic and conventional farming systems through a human energy perspective. *Agricultural Systems*, *70*, 275-294.

Lotter, D.W. 2003. Organic agriculture. *Journal of Sustainable Agriculture*, *21*(4), 59-128.

Mader, P., Fliessbach, A., Dubois, D., Gunst, L., Fried, P., Niggli, U. 2002. Soil quality and biodiversity in organic farming. *Science*, *296*, 1694-1697.

Manna, M.C., Swarup, A., Wanjari, R.H., Ravankar, H.N., Mishra, B., Saha, M.N., Singh, Y.V., Sahi, D.K., Sarap, P.A. 2005. Long- term effect of fertilizer and manure application on soil organic carbon storage, soil quality, and yield sustainability under sub-humid and semi-arid tropical India. *Field Crop Research*, *93*, 264-280.

Marenya, P.P., Barrett, C.B. 2007. Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in Western Kenya. *Food Policy*, *32*, 515-536

Marinari, S., Mancinellie, R., Campiglia, E., Grego, S. 2006. Chemical and biological indicators of soil quality in organic and conventional farming systems of Central Italy. *Ecological Indicators*, *6*, 701-711.

Martini, E.A., Buyer, J.S., Bryant, D.C., Hartz, T.K., Denison, R.F. 2004. Yield increases during the organic transition: improving soil quality or increasing experience? *Field Crops Research*, *86*, 255-266.

Mas, A.H., Dietsch, T.V. 2003. An index if management intensity for coffee agroecosystems to evaluate butterfly species richness. *Ecological Applications*, *13*(5), 1491-1501.

Menalled, F.D. Smith, R.G. Dauer, J.T., Fox, T.B. 2007. Impact of agricultural management on carabid communities and weed seed predation. *Agriculture, Ecosystems, and Environment*, *118* (1-4), 49-54.

Mendoza, T.C. (2004). Evaluating the benefits of organic rice agroecosystems in the Philippines. *Journal of Sustainable Agriculture, 24*(2), 93- 105.

Ministerio de Agricultura y Ganaderia (MAG). 1974. *Clasificacion de los Suelos de Nicaragua*. La prensa, Managua.

Monokrousos, N., Papatheodorou, E.M., Diamantopoulos, J.D., Stamou, G.P. 2006. Soil quality variables in organically and conventionally cultivated field sites. *Soil Biology and Biochemistry*, *38*, 1282-1289.

Morandin, L.A., Winston, M.L. 2005. Wild bee abundance and seed production in conventional, organic, and genetically modified canola, *Ecological Application, 15,* 871–881.

Moser, C.M., Barrett, C.B. 2003. The disappointing adoption dynamics of a yield-increasing, low external input technology: the case of SRI in Madagascar. *Agricultural Systems, 76*, 1085–1100.

National Research Council (NRC). 1991. *Soil and Water Research Priorities for Developing Countries*. National Academy Press, Washington D.C.

Nguyen, M.L., Haynes, R.J., 1995. Energy and labour efficiency for three pairs of conventional and alternative mixed cropping (pasture-arable) farms in Canterbury, New Zealand. *Agriculture, Ecosystems, and Environment*, *52*, 163-172

Oades, J. 1995. Recent advances in organomineral interactions; implications for carbon cycling and soil structure. In, Huang, P.M., Erthelin, J., Bollag, J.M., McGill, W.B., Page, A.L, (Eds). *Environmental Impact of Soil Component Interactions*. Lewis Publishers, Boca Raton, pp. 119-134.

Ouedrago, E., Mando, A., Zombre, N.P. 2001. Use of compost to improve soil properties and crop productivity under low input agricultural systems in West Africa. *Agriculture, Ecosystems, and Environment*, *84*, 259-266.

Parfitt, R.L. 1989. Phosphate reactions with natural allophane, ferrihydrite and goethite. *Journal of Soil Science*, *40*, 359–369.

Pimentel, D., Berardi, G., Fast, S. 1983. Energy efficiency of farming systems: organic and conventional agriculture. *Journal of Sustainable Agriculture*, *9*, 359-372.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., Siedel, R. 2005. Environmental, energetic, and economic comparison of organic and conventional farming systems. *Bioscience*, *55*(7), 573-582.

Plenchette, C., Clermont-Dauphin, C., Meynard, J.M., Fortin, J.A. 2005. Managing arbuscular mychorrhizal fungi in cropping systems. *Canadian Journal of Plant Sciences, 85*(1), 31-40

Popenoe, H.L., Swisher, M.E. 1998. Traditional farming systems: panacea or problem? In Hatch, L.U, Swisher, M.E. (Eds). *Managed Ecosystems: The Mesoamerican Experience*, Oxford Press, New York.

Rasul, G., Thapa, G. 2003. Sustainability analysis of ecological and conventional agricultural systems in Bangladesh. *World Development*, *31*(10), 1721-1741.

Reddy, D.D., Rao, A.S., Singh, M. 2001. Crop residue addition effects on myriad forms and sorption of phosphorus in a Vertisol. *Biosresource Technology*, *80*(2), 93-99.

Reddy, D.D., Rao, A.S., Singh, M. 2005. Changes in P fractions and sorption in an alfisol following crop residue application. *Journal of Plant Nutrition and Soil Science*, *168*(2), 241-247.

Reeves, D.W. 1997. The role of soil organic matter in continuous cropping systems. *Soil and Tillage Research*, *43*(1-2), 131-167.

Reganold, J.P. 1988. Comparison of soil properties as influenced by organic and conventional farming systems. *American Journal of Alternative Agriculture*, *3*, 144–155.

Ryan, M.H., Graham, J.H. 2002. Is there a role for arbuscular mychorrhizal fungi in production agriculture? *Plant and Soil*, *244*(1-2), 263-271.

Salaque, M.A., Naher, U.A., Islam, A.B., Pathan, M.B.U., Hossain, T.M.S., Meisner, C.A. 2004. Inorganic and organic phosphorus fertilizer effects on the phosphorus fractions in wetland rice soils. *Soil Science Society of America Journal*, *68*, 1635-1644.

Sartori, L., Basso, B., Bertocco, M., Oliviero, G. 2005. Energy use and economic evaluation of a three year crop rotation for conservation and organic farming in NE Italy. *Biosystems Engineering*, 91(2), 245-256.

Soil Science Society of America (SSSA). 1997. *Glossary of Soil Science Terms*. Soil Science Society of America, Madison.

Schjonning, P., Elmholt, S., Munkholm, L.J., Debosz, K. 2002. Soil quality aspects of humid and sandy loams as influenced by organic and conventional long-term management. *Agriculture, Ecosystems, and Environment*, *88*, 195-214.

Shukla, M.K., Lal, R., Ebinger, M. 2006. Determining soil quality indicators by factor analysis. *Soil and Tillage Research*, *87*, 194-204.

Sojka, R.E., Upchurch, D.R., and Borlaug, N.E. 2003. *Quality soil management or soil quality management: performance versus semantics*. In Sparks, D.L (Ed.). Advances in Agronomy. Volume 79. Academic Press, New York, pp. 1-68.

Sumith, D., Abeysiriwardena, Z. 2005. Management of on-farm yield trials for testing adaptability of crop varieties. *Experimental Agriculture, 41*, 245-254.

Stanhill, G. 1990. The comparative productivity of organic agriculture. *Agriculture, Ecosystems, and Environment, 30*, 1-26.

Stocking, M.A. 2003. Tropical soils and food security: the next 50 years. *Science*, *302,* 1356-1358.

Swisher, M. 2003. *Agroecology Field Course Manual.* Organization for Tropical Studies, Costa Rica.

Tiessen, H., Moir, J.O. 1993. Characterization of available P by sequential extraction. In: Carter, M.R. Editor. *Soil Sampling and Methods of Analysis*, 75–86. Lewis Publishers, Ann Arbor.

Tiessen, H., Sampaio, E.V.S.B., Salcedo, I.H. 2001. Organic matter turnover and management in low input agriculture in NE Brazil. *Nutrient Cycling in Agroecosystems*, *61*(1-2), 99-103.

Tomich, T.P., Kilby, P., Johnston, B.F. 1995. *Transforming Agrarian Economies, Opportunities Seized, Opportunities Missed*. Cornell Press, Ithaca.

Torstensson, G., Aronsson, H., Bergstrom L. 2006. Nutrient use efficiencies and leaching of organic and conventional cropping systems in Sweden. *Agronomy Journal*, *98*(3), 603-615.

Tschakert, P. 2007. Environmental services and poverty reduction: options for smallholders in the Sahel. *Agricultural Systems*, *94*, 75-86.

Soil Quality Institute, National Resources Conservation Service, United States Department of Agriculture (USDA). 2001. *Guidelines for Soil Quality Assessment in Conservation Planning.* USDA, Washingtion D.C.

Van Bueren, E.T.L, Struik, P.C., Jacobsen, E. 2002. Ecological concepts in organic farming and their consequences for an organic crop ideotype. *Netherlands Journal of Agricultural Science*, *50*(1), 1-26.

Widmer, F., Rasche, F., Hartmann, M. Fleissbach, A. 2006. Community structures and substrate utilization of bacteria in soils from organic and conventional farming systems of the DOK long-term field experiment. *Applied Soil Ecology*, *33*(3), 294-307.

World Resources Institute (WRI) in collaboration with United Nations Development Programme, United Nations Environment Programme, and World Bank. 2005. *World Resources 2005: The Wealth of the Poor- Managing Ecosystems to Fight Poverty*. Washington, DC: WRI.

Yemefack, M., Jetten, V.G., Rossiter, D.G. 2006. Developing a minimum data set for characterizing soil dynamics in shifting cultivation systems. *Soil and Tillage Research*, *86*, 84-98.

Xu, M., Zhao, Y., Liu, G., Wilson, G.V. 2006. Identification of Soil Quality Factors and Indicators for The Loess Plateau of China. *Soil Science*, 171(5).

BIOGRAPHICAL SKETCH

Alvaro Valle earned a B.A. in biology from Tufts University (Medford, MA) in 2003. Before coming to the University of Florida (UF), he worked in the outdoors in various positions. After completing his M.S. degree in interdisciplinary ecology, he plans to join the Horticulture Department at UF, ultimately hoping to infuse some revolution into the agricultural "sciences."