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Potentials for Food System Development in Lake Atitlán, Guatemala: Participatory Action Research at the Farm, Community, and Regional Levels

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Abstract

This study explores potentials and constraints for farm and food system development in Lake Atitlán, Guatemala through participative research with smallholder farmers from three Mayan ethnic groups. Semi-structured interviews were conducted with 41 farmers in the Lake Atitlán watershed, and spatial interrelationships were analyzed at the household, community, and regional levels. Research that helps elucidate potentials for agroecological development with consideration for the experiences and knowledge of peasant farmers in the Global South is currently limited.

This study utilized multiple research methodologies including Soft Systems Methodology, Participatory Action Research, and Grounded Theory Methodology, and provides both qualitative and quantitative results.

Results implicate that vast food and resource scarcity coupled with immense changes such as globalization and environmental change have magnified the loss of traditional agricultural systems and exacerbated regional food insecurity. In accordance with these trends, farmer agency and subsequent adaptation strategies are emphasized. Furthermore, factors that may constrain or nurture future development are highlighted through SWOT analyses conducted by smallholders.

The most compelling potentials for sustainable development identified in this study include macro-level influences such as the need for review of contemporary economic policies and land tenure, as well as the need for further research pertaining to climate change adaptation and resiliency. Regional potentials include food system relocalization initiatives, promotion of marginal traditional crops, community-based agrobiodiversity conservation networks, crop diversification, and organic agriculture.

Conclusions highlight the importance of action and participative research frameworks for formulation of appropriate development initiatives in the Global South.

Keywords: Agroecology, Food system, Guatemala, Maya, Participatory Action Research, Smallholders

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List of Abbreviations

BP- Before Present

CA - Central America

CIA – Central Intelligence Agency

CWB – Koppen Classification: Temperature Highland Tropical Climate with Dry Winters

DR-CAFTA – Dominican Republic – Central American Free Trade Agreement

FAO – Food and Agriculture Organization

GDP – Gross Domestic Product

IAASTD – International Assessment of Agricultural Science and Technology for Development

IMAP – Mesoamerican Institute of Permaculture

IMF – International Monetary Fund

MAGA - Guatemalan Ministry of Agriculture, Livestock, and Food

NGO – Non-governmental Organization

NTX – Non-Traditional Export Crops

PAR – Participatory Action Research

PPP – Purchasing Power Parity

SPSS – Statistical Package for the Social Sciences

SSM – Soft Systems Methodology

UN – United Nations

USA – United States of America

USAID – United States Agency for International Development

USD – United States Dollar

WB – World Bank

WHO – World Health Organization

WTO – World Trade Organization

Measurements

1 Cuerda = ~ 21 meters

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1. Introduction and Study Overview

1.1 Introduction

Lake Atitlán is a caldera lake in the Sololá district of the Guatemalan Highlands. The lake is the primary source of potable water in the area and the water also serves as the main conduit of transportation between villages, thereby creating strong socio-economic ties between lakeside communities. Lake Atitlán is marked by a heterogeneous landscape and hosts high levels of cultural, linguistic, and biological diversity. Indeed, the majority of people who live within the food system boundaries are indigenous Mayans from three unique groups: Kaqchikel, Quiche, and Tz'utujil. Atitlán holds profound importance as a cultural and spiritual landscape for Mayan people who regard the lake as a sentient being as well as the "navel of the earth" (Christie, 2009).

A recent UN report (2013) highlights that contemporary agroecological research must be, "holistic in nature, take a landscape or river-basin view and emphasize the sustainable utilization of biodiversity, water, soil, and energy within the agroecosystems." Therefore, this study operates from the perspective of farm, village, and food system levels to illuminate the scales of inquiry necessary in addressing sustainable development issues. Although the boundary demarcation of a food system is a social construction, in this instance the boundaries of the Atitlán food system are topographically limiting – thus the system's boundaries are demarcated around the communities living and sharing life within the Atitlán caldera. In this circumstance, the case study location was chosen because the food system is conveniently defined and organized around the caldera basin, therefore rendering the spatial boundaries of the food system quite evident for all participant actors.

The Lake Atitlán food system is a distinctive case study because it has experienced significant changes in recent years, most markedly from the impacts of globalization and neoliberal capitalism. These changes include wildly altered patterns of land-use, characterized by agricultural shifts from traditional subsistence-based farming to intensive export-based agricultural production models. These dramatic shifts spurred rapid changes both environmentally as well as from within the social fabric of local communities, engendering ecological and economic instability. Environmental shifts include high rates of soil degradation, extinctions of endemic species, high dependency on agricultural inputs, and most precariously: eutrophication in the lake. Eutrophication can be attributed to a multitude of factors such as improper water sanitation facilities, but it is also clearly linked to the increasing use of agricultural inputs (namely phosphorus) that slide from the volcanic slopes of local farms into the endorheic caldera.

The gravity of this situation becomes impressive with the consideration that over 400,000 people depend upon Lake Atitlán for potable water and livelihoods, as well as the subsequent ecosystem services that the lake provides (Rejmankova et al., 2011; Schmitt-Harsh, 2013). Simultaneously, increasing loss of traditional farming practices increases the loss of linguistic, cultural, and biological diversity surrounding the lake through usurping daily practices of place. The erosion of subsistence-based agriculture decreases local food security and increases economic dependency on export-based markets and expensive agrochemical inputs, thereby contributing to systemic poverty.

This situation is critical in one of the poorest countries in Latin America – the World Food Programme (2014) indicates that chronic undernutrition rates among indigenous children in Guatemala remain at 69.5%, and stunting rates among indigenous children occur at a shocking rate of 80%. These statistics are significant within the case study region: upwards of 96% of the local population is composed of indigenous Mayans (Schmitt-Harsh, 2013). Further exacerbating the situation, the area surrounding the Atitlán basin is rife with political instability, violence, and domination of cartels.

Furthermore, a recent UN study (2013) on climate change explicated, "sustainable agricultural development implies the participation in research and knowledge dissemination of the different stakeholders – in particular farmers – who are often women – in developing countries." In order to address this issue, this study strived to incorporate participatory methods that allow research to be tailored to the unique context of social, cultural, economic, political, and environmental realities of the Atitlán food system.

In this thesis, secondary research questions were co-created with key local stakeholders, and semi-structured interviews were conducted with forty smallholder farmers in order to assist in the rapid identification of knowledge and action gaps in the locale, as well as to catalogue their experiences, perceptions, and future development visions. Certainly, "successful scaling up of agroecology depends heavily on human capital enhancement and community empowerment through training and participatory methods that seriously take into account the needs, aspirations, and circumstances of smallholders (Altieri et al., 2012)." Secondary research questions that were identified in this study by key stakeholders included the desire for research regarding in-situ and ex-situ crop agrobiodiversity conservation. Therefore, results of this study also pertain to potentials and constraints of regional seed systems, including on-farm conservation practices, difficulties faced in seed acquisition, drivers of loss of traditional crops and agricultural practices, and interest in regional seed exchange initiatives throughout the Lake Atitlán basin.

Water is a precious and finite resource. Lakes and water bodies around the world are threatened by eutrophication, which is exacerbated and provoked by nutrient-rich agrochemical inputs within conventional agricultural systems. Thus, promotion of agroecological farming practices decreases these impacts and in turn helps to protect the environment and human health. Through the microcosmic focus of the analysis of agroecological development in Lake Atitlán, global trends of watershed management associated with agroecology can be envisioned, creating a depictive illustration for endangered watersheds at the global scale. Lake Atitlán is a unique case for approaching food system studies because of the colossal impacts of conventional agriculture on human health and the local environment. The situation emerges as a strong place of learning, and a compelling argument for organizing around potentials for transition to more sustainable food systems.

1.2 Research Questions

Primary Research Question: What are potentials and constraints for agroecological farm and food system development in Lake Atitlán, Guatemala?

Secondary Research Question: What are potentials and constraints for crop agrobiodiversity conservation in Lake Atitlán, Guatemala?

1.3 Case Study Boundary Demarcation

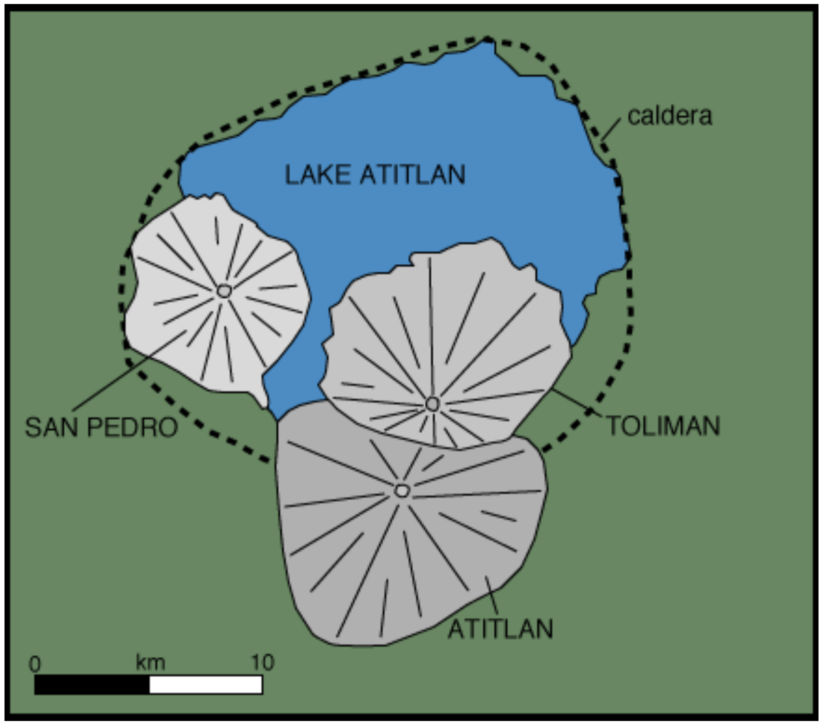

Figure 1: Boundaries of Lake Atitlán Food System **Source:** (Mooser, Meyer-Abich & McBirney, 1958).

2. An Agroecological Perspective

2.1 Defining Agroecology

Throughout the world, there are competing visions and conceptualizations of the term "agroecology", however it may be defined as, "the integrative study of the ecology of entire food systems, encompassing ecological, economic, and social dimensions (Francis et al., 2003; Wezel et al., 2009)." Wezel and colleagues (2009) detail, "in many countries there is a combined use of the term "agroecology" as a movement, as a science and as a practice, and in most situations they are strongly intertwined." Thus, conceptualization of the term may include multiple associations and manifestations. As an applied science, "agroecology uses ecological concepts and principles for the design and management of sustainable agroecosystems where external inputs are replaced by natural processes such as natural soil fertility and biological control (Altieri et al., 2012)." Some of the central practices of agroecological thought as used within this study will be briefly explored, including farm and food system research, systems thinking, holons, and case study research.

2.2 Systems Thinking: Farm and Food System Research

Systems thinking may be seen as a central facet of the agroecological perspective, and has been very influential to the evolution of the field, serving as a fundamental tool in the challenge of change towards sustainable agriculture (Bland and Bell, 2007; Gliessman, 2004). Systems thinking is the juxtaposition of a system within its larger environment, in order to analytically deliberate obstacles such as agency, interaction, entanglement, exchange, connections, self-organization, interdependency, and co-evolution (Darnhofer, 2012; Gharajedaghi, 2011). Integration of systems thinking into methodological inquiry may be seen as a major departure from staunch analytical thinking towards more holistic thinking, and may increase the capacity of a researcher to more aptly contend with interdependent sets of variables (Gharajedaghi, 2011).

A farm system may also be known as an agroecosystem, which is inherently an agricultural ecosystem. According to Gliessman (2007),

> "An agroecosystem is a site or integrated region of agricultural production – a farm, for example – understood as an ecosystem. The agroecosystem concept provides a framework with which to analyze food production systems as wholes, including their complex sets of inputs and out pouts and the interconnections of their component parts."

Francis (2003), Gliessman (2007), and Wezel (2009) argue that it is restrictive to delimit research and awareness at the spatial scale of field and farm, and promote use of the greater hierarchical sphere of a food system. According to Wezel and colleagues (2009):

> "This dimension requires multi-scale and trans-disciplinary approaches and methods, to include the study of food productions systems, processing and marketing, economic and political decisions, and consumer habits in society. None of these can be confined nor attributed directly to a certain level of scale, but all are connected intimately with each other across scales and through time in different and complex ways."

Using a systems approach becomes crucial when considering farm and food systems as complex entities in order to more greatly improve understanding of complex functions and interactions in both a systematic and systemic manner. The quest for truly sustainable agriculture dictates comprehension of interactions between all component systems (Gliessman, 2007). A recent study by Darnhofer (2012) emphasized,

> "Farming systems should be considered as open (i.e. it has an environment which affects its state), dynamic (i.e. there are changes in one of more structural properties of the system so that the state of the system changes over time, and purposeful (i.e. the farming system can produce outcomes in different ways, and can change its goals under constant conditions)."

2.3 Holons

The concept of holons can be well summarized by the American naturalist John Muir, who stated, "When we try to pick out anything by itself we find that it is bound fast by a thousand invisible cords that cannot be broken, to everything in the universe" (Hatch, 2012).

Arthur Koestler invented the concept of holons with the aim to promote the conceptual idea that, "parts and wholes in an absolute sense do not exist in the domain of life. The concept of the holon is intended to reconcile atomistic and holistic approaches" (Bland and Bell, 2007). Giampatro (2003) explains, "Holons and holarchies are a new class of hierarchical systems relevant for the study of biological and human systems made up of self-organizing (dissipative) and adaptive (learning) agents that are organized in a nest of elements." This nest of elements can be called a holon. This concept can be extended through a systems thinking approach, which Koestler explains as "as nested adaptive hierarchy of dissipative systems (a system made of holons) can be called a holarchy" (Giampatro, 2003).

The conceptual usage of holons and holarchies can be very beneficial when attempting to understand complex systems, and expressly so when coupled with an approach called triadic reading. Giampietro explains:

> "The concept of triadic reading refers to the choice made by the scientist of three contiguous levels of interest within the cascade of hierarchical levels through which holarchies are organized. In order to do this, it is necessary to define a group of three contiguous levels: a

focal level, a higher level, and a lower level. However, the issue of sustainability requires the consideration of at least five contiguous hierarchical levels at the same time (2003, p. 36)."

A study by Wezel and colleagues (2009) gives insight into another critical aspect of holons:

> "Due to the need to tackle the problems of boundary and change, which are evident for all agroecological research questions, Bland and Bell argue that agroecologists need to take into account how intentionalities seek to create holons (an intentional entity) that persist amid the ever-changing ecology of contexts, and how boundaries can be recognized based on how intentionalities draw and act upon them."

Bland and Bell (2007) believe that an unusual strength of the holon perspective may be magnified by a process called 'flicking', which is achieved through incessantly switching between perspective of holon and holarchy (i.e. whole and part), thereby safeguarding a researcher from remaining explicitly focused on a singular depiction of an entity.

Because holons are a basis of agroecological thought, this study attempted to use the concept of holons through the lens of case study work, using a microcosmic study of a case study farm system (IMAP); a focal level of case studies of four village systems (Panajachel, Santa Cruz la Laguna, Santiago Atitlán, and San Juan la Laguna); and lastly by a higher level study of the Lake Atitlán food system. These levels of inquiry were primarily chosen in order to highlight interrelationships between phenomena as they are experienced by smallholder farmers at a variety of spatial scales. This was used within this study as a working conceptual framework to help illuminate a deeper understanding of the given 'ecology of contexts'.

Triadic Reading of Holons in Atitlán – Filtering the Pace of Changes in the Representation

Higher Level (n+1) (*e.g. Lake Atitlán Food System*) boundary conditions, definition of function for the whole on level n

Focal Level (n) (*e.g. Communities: Four Case Study Villages*) relevant behavior of the whole

Lower level (n-1) (*e.g. IMAP farm system*) initiating conditions, definition of structural stability of elements of the whole

Using 5 contiguous levels to understand the relation between function and structure

N+2 Higher level ----- *Guatemala* ----- system dynamics affecting function definition for the household
N+1 focal level ----- *Lake Atitlán*
N (lower level) ------ *Community-Level Case Studies* ---- higher level (n)
Systems dynamics affecting --- *IMAP farm and regional farm systems* ---- focal level n-1
Individual Smallholders ---- lower level n-2

Figure 2: Conceptual Framework for use of Triadic Reading of Holons and Holarchies in Lake Atitlán Food System Study. Adapted from: (Giampietro, 2003)

2.4 Case Study Research

Case studies are a form of empirical inquiry often employed when boundaries between phenomena and context are not clearly evident, and which serve to describe, predict, understand and/or control an individual entity (Woodside, 2010; Yin, 2014). Overall, "Case studies are especially relevant to agriculture and development studies, where each situation is unique and it is essential to develop applications for new contexts and challenges" (Francis et al., 2009). Inherent aspects of case study design are the iconic data collection approaches and the use of data triangulation (Yin, 2014). Woodside (2010) expounds,

> "Research triangulation within case study research often includes: (1) direct observation by the researcher within the environments of the case, (2) probing by asking case participants for explanations and interpretations of "operational data", and (3) analyses of written documents and natural sites occurring in case environments."

3. Methodological Frameworks

3.1 Soft Systems Methodology

Soft Systems Methodology (SSM) was invented in the 1970's by Peter Checkland, "expressly to cope with the more normal situation in which the people in a problem situation perceive and interpret the world in their own ways and make judgments about it using standards and values which may not be shared by others" (Giampietro 2003).

SSM is a method for structuring thinking about the existent world, and also allows researchers to make models of ways in which the world (or in this instance, food system) might be in the future through comparison of the present situation and possible future situations, thereby generating greater ontological understanding. Through processes involved with Soft Systems Methodology, ideas for improvement of the world (or system) may be ascertained, as well as the realization of subsequent processes necessary for action to achieve a particular forthcoming situational outcome (Checkland and Poulter, 2006).

This study utilized Soft Systems Methodology as an overarching framework, which served as a guide for the formation of a primary research question. Application of SSM was employed in order to generate greater ontological understanding of the systems in question, and thereby also allowed for the amplification of attributes such as worldviews, values, visions, and other socio-cultural and historical dimensions. Use of SSM facilitated a broader grasp of the current situation of Atitlán food and farm systems, and thereby also aided in the formation of feasible future wanted situations. SSM proved to be a practical empirical tool for increasing overall understanding the intricacy of foreign systems and in dealing with the complex situations encountered.

The procedural methodology of SSM relies upon several iterative steps, which traverse theoretical and concrete conceptualizations of the system in question and which may be understood as diverging and converging processes. Giampietro (2003) explains these steps: the first step is to perceive system imbalance, and to recognize the existence of a problematic condition; (2) active creation of viewpoints and angles to define the system; (3) conceptual development and refinement; demarcation of root definitions; (4) construction of models; (5) assessment of theoretical premises in relation to the actual field situation; (6) evaluation of viability and appropriateness of proposed system changes; (8) broad assessment of the overarching research.

Within Soft Systems Methodology, "a system may also contain sub-systems, which are called layered structures and are fundamental in systems thinking" (Reynolds and Holwell, 2010). This study considered this aspect as a general facet of systems thinking, in which the concept of 'sub-systems' becomes largely synonymous with the holon approach of holarchies.

Emergence is also largely a product of Soft Systems Methodology, and is principally characterized by recurrent tendencies and patterns that arise as a product of the processes of intricate and dynamic systems (Holland, 1998; Reynolds and Holwell, 2010). Emergent properties and perspectives were heavily utilized in this study, and in fact the inherent reliance on emergence from Soft Systems Methodology encouraged the parallel usage of Participatory Action Research as a subsidiary tool with which to generate additional emergent ontological data.

3.2 Methodology for Research Sub-Questions: Participatory Action Research

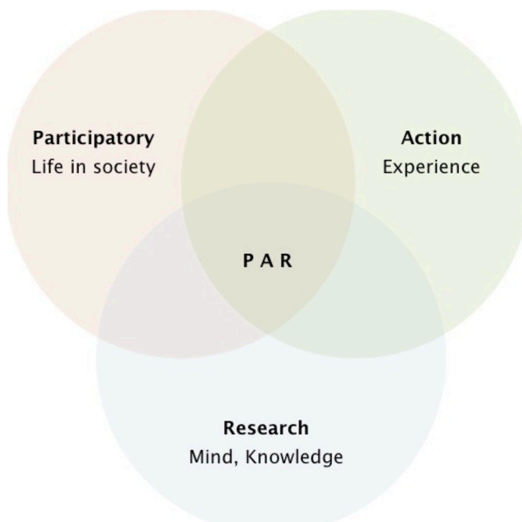

Figure 3: Elements of Participatory Action Research (Source: Wikimedia Commons)

Early action research was developed in the 1940's through the innovative research of Kurt Lewin, which he defined as, "comparative research on the conditions and effects of various forms of social action and research leading to social action" (Chevalier and Buckles 2013). Today, participatory action research (PAR) has continued to evolve with notable influences from the Brazilian tradition of critical pedagogy of Paulo Frerie, and now represents a methodological approach that combines action experience with reflection and data collection (Baum et al., 2006: Chevalier and Buckles, 2013)

The core precept of PAR is the goal of “understanding the world by changing it” (Baum et al., 2006), which includes a scientific yet malleable approach to change, advanced through a cycle of methodological steps (Chevalier and Buckles, 2013). PAR was selected for this study for its documented strength as a methodology to: (1) contribute to social organizing in alignment with the consideration that agroecology is a social movement (2) directly respond to the perspective and experiences of resource-poor farmers (3) invigorate regional food sovereignty and traditional agri-cultures through praxis conscientization (4) promote inspiration and greater empowerment of participant actors (Baum et al., 2006; Gonsalaves, 2005; Putnam et al., 2013; Wezel et al., 2009).
When undertaking research among indigenous communities in the Global South, PAR may also encourage the expansion of environmentally and culturally appropriate, contextually-driven strategies that may inspire greater advancement of goals relating to food sovereignty and security through awareness and community-building (Putnam et al., 2013).

As a social change extension tool, use of PAR can bring elements of social justice to the core of development research by promoting more inclusive research frameworks at the frontlines of communities most profoundly ostracized by contemporary power relations. Pine and Souza (2013), argue that systemic communicative disenfranchisement is integrally connected to material disenfranchisement. In order to remedy this disenfranchisement, Harvey (2005) has also voiced that, “the world must be depicted, analyzed, and understood as the material manifestation of human hopes and fears mediated by powerful and conflicting processes of social reproduction.”

3.3 Adaptive Management

Adaptive management can be defined as, “the purposeful and deliberate design of policies in such as way as to enhance learning as well as to inform subsequent action” (Allan and Stankey, 2009). Overall, it is an iterative environmental management approach that seeks to create policies that are understood, justified, and finally implemented through a process of adaptation - integrally acknowledging that we often lack sufficient awareness and experience to act with complete understanding of associative repercussions and wider implications (Allan and Stankey, 2009; Norton, 2005).

According to Norton (2005), there are three primary characteristics of Adaptive Management:

“1. Experimentalism. Adaptive mangers emphasize experimentalism, taking actions capable of reducing uncertainty in the future.

2. Multi-scalar analysis. Adaptive mangers understand, model, and monitor natural systems on multiple scales of space and time.

3. Place sensitivity. Adaptive managers adopt local places, understood as humanely occupied geographic places, as the perspective from which multi-scalar management orients."

Norton (2005) also contends that adaptive management processes are rooted in localism, and thereby necessitate place-based solutions that reject the "one-sized-fits-all" rhetoric, instead favoring community-based values. This approach is of immense consequence for agroecological fieldwork because it gives the researcher a tool to navigate the unknowns of complex situations while simultaneously ensuring that the research remains grounded in the unique spatial context of a given system.

3.4 Semi-Structured Interviews

Semi-structured interviews entail a series of in-depth and open-ended preformulated questions related to various domains of interest which may be used in order to investigate topics and their cause-effect association, as well as to identify factors, variables, or attributes of variables for analytical purposes (Mukherjee, 2003; Schensul, Schensul, and LeCompte, 1999). Semi-structured interviews should be conducted with a representative sample of respondents, and because of the flexibility of open-ended questions this practice is considered a participatory method (Mukherjee 2003; Schensul, Schensul, and LeCompte, 1999).

3.5 SWOT Analysis

This study used SWOT analysis (as a tool of conceptual modeling within SSM), with both the farm system research, and also with the food system research during semi-structured interviews.

SWOT analysis arose from the Stanford Research Institute in the 1960's, and is simply an acronym for 'strengths, weaknesses, opportunities and threats' - it is an applied process that may be used to investigate both internal and external as well as positive and negative factors (Bohm, 2008; Pahl and Richter, 2007). SWOT analysis is a situational analysis tool, which may aid in the production of tactical knowledge necessary for decision-making from diverse sources; the aim is that the evaluation of strengths and weaknesses with the opportunities and threats can be used to formulate generic strategies (Bohm, 2008; Pahl and Richter, 2007).

3.6 Grounded Theory Methodology

Grounded theory is a research method that serves to explicate the phenomenon(a) being studied and to ultimately generate theories from data. According to Birks and Mills (2011), "strategies used in data collection and synthesis are used to generate a theory that serves to explain a phenomenon from the perspective and context from those who experience it." Theory is therefore directly produced through the records collected by the scholar; consequently this method is especially useful among research focuses in which little understanding has been previously established (Birks and Mills, 2011).

Charmaz (2014) and Birks and Mills (2011), assert that there are a series of crucial methods inherent to Grounded Theory Methodology including: initial and intermediate coding and data categorization; writing memos; theoretical sensitivity; logic; concurrent data collection and analysis; selecting a core category, and theoretical sampling, sensitivity, saturation, and integration.

The method may be also be conceptualized as a form of phenomenological inquest, entrenched with notions of agency, problem solving, emergent processes, social and subjective meanings, and the open-ended study of action (Birks and Mills, 2011; Charmaz, 2014).

4. Research Processes

4.1 Overarching Research Processes

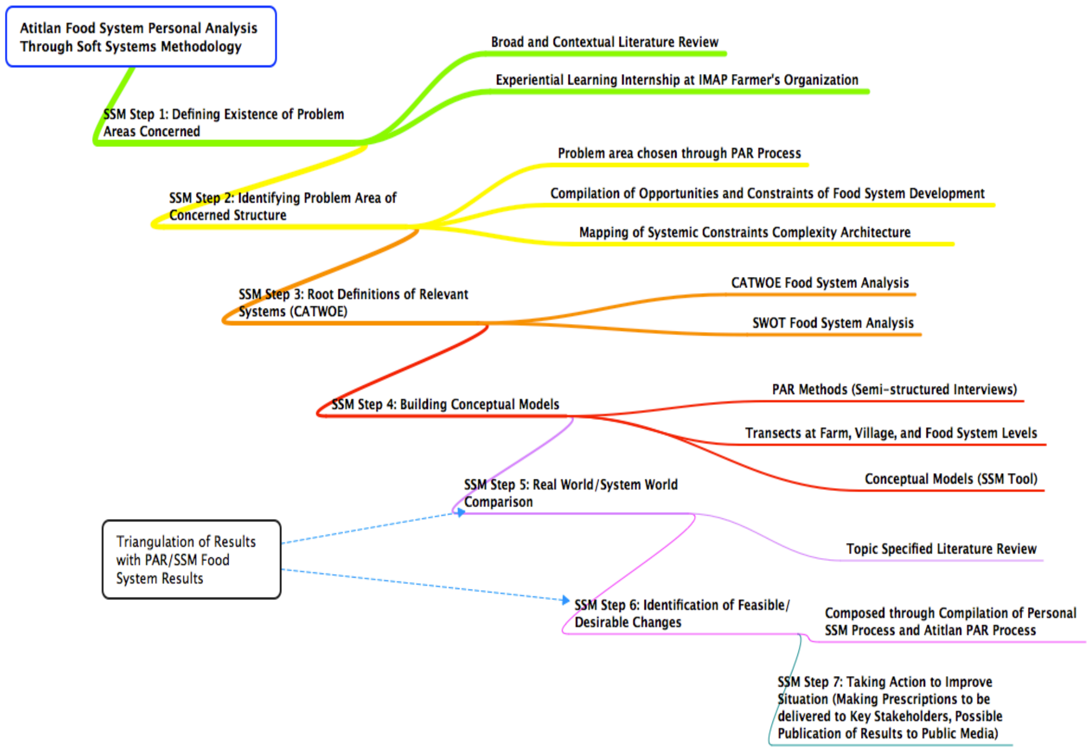

Figure 4: Mind mapping of Overarching Food System Research Process Using Parallel Methods: Soft System Methodology and Participatory Action Research

The formation of the study began with broad literature review of the context of the case study region in addition to the conceptual design strategies necessary for use of multiple research methodologies. The primary research question, "What are potentials and constraints for agroecological farm and food system development in Lake Atitlán?" was devised at this stage.

An experiential internship was undertaken starting at the formative stages of this study at the case study farm school, Mesoamerican Institute of Permaculture in Pachitulul, Guatemala. Additionally, a homestay with a Kaqchikel Mayan family was commenced in order to gain a more nuanced understanding of cultural context and daily challenges faced at the household level. At this time, vast participant observation and action learning aided in understanding of the current situation of study systems, and immensely informed the research query. Early Soft Systems Methodological processes were conducted, and Participatory Action Research began during the first week of field research.

The first semi-structured interview with the key stakeholder of the IMAP farm system also served to begin the inquiry of Participatory Action research, in which research sub-questions for the study were identified in tandem with the key stakeholder, Ronaldo Lec Ajcot. In this session, three primary sub-focuses were co-identified:

1) Development of Pedagogical Materials for Sustainable Cropping Systems
2) Crop Agrobiodiversity Conservation (In-situ and Ex-situ)
3) Capacity Building for School Gardens Program (which is hosted by IMAP farm).

Because of time constraints only one option was chosen to explore. Initially, the first option was chosen as focal, and therefore a farming indicators survey and a smallholder perceptions study were developed. The basic premise of the proposed study was to compare adoption use trends and perceptions of various agricultural cropping systems among smallholders who had received an agricultural training from IMAP farm in permaculture and other agroecological practices. This was to be compared with farmers from a nearby village who had not received these trainings. Therefore, a farm system health indicators survey was developed in order to address this, with hopes that trends of farmer's choice in various cropping methods and applications could be later improved for pedagogical materials at IMAP farm. However, this study became impossible to implement due to the rising waters of Lake Atitlán, which submerged the majority of remaining smallholder plots of IMAP farm at the start of the study. Due to the highly skewed land tenure prevalent in the country, these small farm plots along the marginal land lake's shores situated within the flood zone are the only lands smallholders in the village have access to, therefore there were no fields in which to conduct the study. These factors rendered the premise of the initial study invalid: it is simply not a representative example to explore indicators of farm system health on distressed farm systems. This process is important to note, as it gave insight into the truly profound impact of the current land tenure on the health of smallholder farms throughout the study region.

At this point in time, adaptive management was implemented and the study regressed back a few steps into earlier steps in the SSM and PAR processes. This process was easily facilitated by the SSM process, simply leading the study back to another iterative cycle (see diagrams). Strong lessons emerged from this process pertaining to the enormously positive use of fusing of SSM and PAR as parallel methods; it was possible avoid application of a study that was not desirable, but also to easily move to the next sub-topic inquiry that had been pre-defined by key stakeholders at the IMAP farm through PAR processes (see Figure 5). The secondary PAR research focus identified implies a focus on researching potentials for crop agrobiodiversity.

Thus, an interview questionnaire was then formed for the food system interviews in order to address both primary and secondary research questions. During the formation process of the food system interview guide, a secondary semi-structured interview was carried out with the key stakeholder of the farm system. This ensured that the questionnaire was developed in the most participatory manner possible, and also aided in ensuring that the study was developed in respect to socio-cultural, environmental, and economic realities and nuances of the region. The results of the secondary IMAP interview were later complied within the food system analysis.

The food system interview guide was formulated using elements of ethnographic data collection and semi-structured interviews in tandem with PAR approaches in order to highlight culturally specific epistemologies of food system relations. Firstly, questions were developed to gain a deeper understanding of the current situation – including dimensions such as demographics, profile of the farm system, and incidence of household food security. Subsequently, development of the interview guide aimed to gather information regarding potentials and constraints to farm and food system development, which was achieved through broad questions about land tenure, environmental factors, social and economic dimensions, cultivation practices, SWOT analysis, and future visioning.

In order to attain data regarding the secondary question of crop agrobiodiversity conservation, questions were added to the questionnaire pertaining to seed flow, seed banks, and seed conservation dynamics. Maize was chosen as a case study crop in order to illuminate more depth about the interrelationships between various phenomena in relation to crop agrobiodiversity.

After food system data had been collected, it was compared at the hierarchical spatial scale as a whole, and was also analyzed for pertinent trends between villages, ethnic groups, and by gender using Grounded Theory Methodology. Data from farm systems from throughout the greater food system was then compared to data gathered at the farm system level, IMAP.

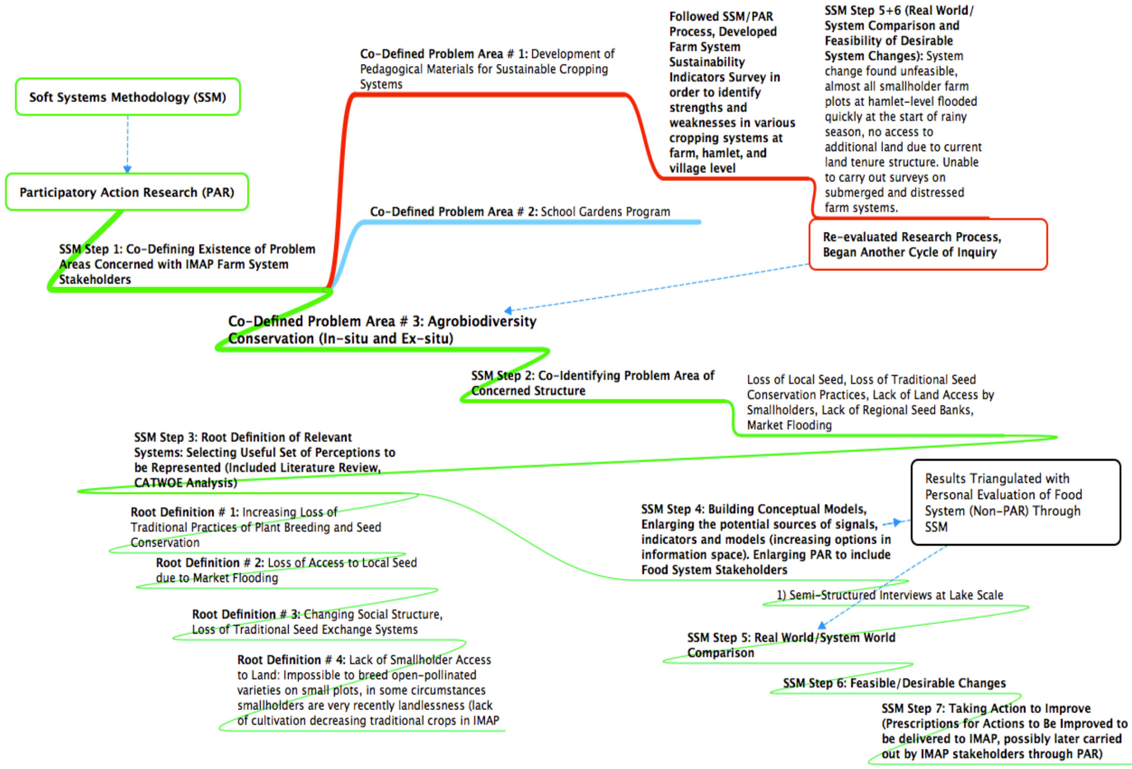

Figure 5: Conceptual use of Methodological Tailor-Making: SSM, PAR, and Adaptive Management Principles applied from Farm to Food System Research during Case Study research

4.2 Food System Interviews and Study Protocol

Interviews were conducted at four villages chosen from geographically disparate locations around the lake. Attention was given to ensure that villages were chosen that represent all three major regional ethnic groups. It was not possible, nor in fact statistically probable to interview non-indigenous farmers, as the department of Sololá is composed of 98.6 % indigenous people (World Bank, 2004; Schmitt-Harsh 2013). Over the course of two months, 40 interviews were collected in the peripheries of four municipalities in the Lake Atitlán basin: San Juan la Laguna, Panajachel, Santa Cruz la Laguna, and Santiago Atitlán. A purposive sample of five female and five male farmers from each municipality was chosen in order to ensure that diverse perspectives were addressed.

Because many farmers speak limited Spanish, a translator with strong abilities in Spanish as well as local languages aided in the interview process. The interview guides were first written in English then translated by the author into Spanish. In the field, Mayan-Kaqchikel translator Esthela

Gomez then translated the questions into Kaqchikel, Quiche, and Tz'utujil in order to converse with the farmers. Participants were therefore given the option to be interviewed in their native language.

Because a study in 2009 (Nagata et al.) based in Santiago Atitlán found a 36.7 % literacy rate among women, and additionally because Mayan languages are not widely written, consent for use of interview data was obtained orally at the start of each interview. Full disclosure of the purpose of the study was explained in detail at the start of the interview session. Participants were given the option to answer anonymously, and to opt out of any questions that they felt uncomfortable answering.

The interview guide was structured to include both structured and semi-structured interview questions with the intention that this would simultaneously allow for more generalized data collection while also allowing for more specified data to be gathered for particular topics. Parallel mixed quantitative and qualitative methods were therefore employed. Mixed methods were also used in this study in order facilitate triangulation of data.

Grounded Theory Methodology was used for analysis of the interviews with coding was determined inductively. After the interviews were conducted, data was transposed into an Excel file with some answers coded for quantitative analysis. Some questions were both coded and left with full descriptive answers as given by farmers to allow for qualitative analysis, and qualitative coding was ongoing throughout the data collection process. Notably, some data was pre-coded because of time constraints in the field, and these codes were amended to become more reflective of participant responses as the interview process progressed. For quantitative analysis, after the data was gathered it was first entered into an Excel sheet using Microsoft Office. From this sheet, coding was re-hashed, and finally the codes were transposed into the program Statistical Analysis for the Social Sciences (SPSS), using IBM version 21. Use of quantitative analysis was important in order to gain statistical insight into emergent trends developed through Grounded Theory Methodology. Some of the codes were eventually reduced to binary codes (e.g. Gender, Yes/No responses, etc.). The quantitative analysis used descriptive frequencies in order to understand the vast trends and characteristics of the food system, and Pearson's chi-square test was also used in order to look for emergent trends across multiple categories - most of the data was ultimately crosschecked for significance.

PAR Stage 1: Inquiry ***(SSM – Steps 1-3)***	Identified Overarching Research Question, **SSM- Steps 1-3**	- Contextual Literature Review - Began Experiential Learning Internship - Participant Observation (Homestay with a Mayan- Kaqchikel family)
PAR Stage 2: Action ***(SSM Step 4)***	Started PAR process, Defined Research sub-questions, Created preliminary research proposal, employed adaptive management	- First Semi-structured interview with key stakeholders, - Literature Review, - Created first research proposal (sub-topics) and formulated preliminary study

PAR Stage 3: Reflection ***(SSM- Steps 4-5)***	Created secondary sub-question research proposal, Iterative refinement	- Composed secondary interview questionnaire guides - Translated, organized interviews collection (Food System Level) - Second semi-structured interview (Farm-Level)
PAR Stage 4: Inquiry ***(SSM Steps 6-7)***	Data Analysis and Writing Synthesis	- Used Grounded Theory and SPSS to Analyze Food System Level Results - Analyzed Farm System Results - Triangulated with Farm system study; Literature Review - Writing and Synthesis

Figure 6: Depiction of Research Process with Primary Emphasis on PAR process (Adapted from: Mackenzie et al., 2012).

5. Contextual Overview of the Study

5.1 Country Context

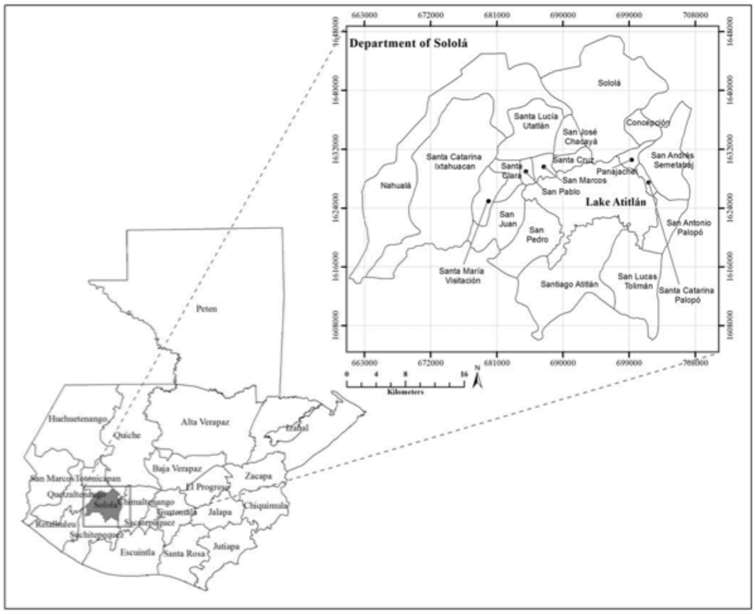

Figure 7: Case Study Region of Sololá Department (Source: Wikimedia Commons)

The Republic of Guatemala consists of a total land area of 108,889 sq. km, and shares national borders with Belize, El Salvador, Honduras, and Mexico.

The population is comprised of 14.7 million citizens, which represent the largest population in Central America, with the highest fertility rate and the youngest population in all of Latin America (almost half of the population is under 19 years of age) (CIA, 2014; World Bank, 2004). The population is composed of 59.4 % Mestizo (mixed Amerindian-Spanish, colloquially called Ladino), while the rest of the population is composed of indigenous Mayans (CIA, 2014). The diversity of Mayan groups in Guatemala may be demonstrated through the notable linguistic diversity of the country: while Spanish is spoken by 60 % of the population, there are 23 officially recognized ethno-linguistic groups (World Bank, 2004). Unfortunately, literacy rates are also very low, averaging 31.1 percent among women 15 years of age and older, and reaching 59 percent among indigenous women (World Food Programme, 2014).

Guatemala ranks very poorly for indicators in public health; the country is among the worst in Latin America for life expectancy, infant mortality, and maternal mortality (World Bank, 2004).

Guatemala is a constitutional democratic republic and won independence from Spain in 1821 (CIA, 2014). Guatemala consistently ranks among the most unequal and corrupt countries in the world, indicating weak governance in terms of rule of law and justice, political instability, and corruption indicators (CIA, 2014; World Bank, 2004).

The GDP (PPP) is 5,300 USD, which is approximately one-half the average standard for Latin America and the Caribbean (CIA, 2014). Poverty is predominately concentrated in rural areas, and occurs at much higher frequencies among indigenous people. Concurrently, over 81% of the poor and 93% of the extreme poor live in the countryside, with poverty rates occurring at 76% among the indigenous, and 41% among the non-indigenous population (World Bank, 2004). Among the most vulnerable groups in the country are indigenous women and children in the highlands, the region of this case study (World Food Programme, 2014).

Guatemala is susceptible to numerous natural hazards including volcanic activity, occasional violent earthquakes, hurricanes and tropical storms (CIA, 2014).

The agricultural sector of Guatemala today represents 23 % of the country's GNP, and most commonly produced commodities for export production are: coffee, sugar, petroleum, cardamom, bananas, fruits and vegetables, and apparel (CIA 2014; Lastarria-Cornhiel, 2003). The crisis of poverty is largely agrarian: some 87 % of the rural poor depend on agriculture (World Bank, 2004).

Land ownership is highly concentrated and skewed in Guatemala, and a World Bank report (2004) found that, "land holdings of the poor tend to be: quite small (too small to provide subsistence); untitled; poorly located; and of poor quality."

5.2 Lake Atitlán Food System: Socio-Economic and Environmental Dimensions

Figure 8: Map of Lake Atitlán Case Studies. *Red:* Farm System Case Study; *Blue:* Food System Case Studies. **Source:** Google Maps

Lake Atitlán is situated in the Sololá department of the Western Highlands of Guatemala. The Atitlán basin is a steep-sided collapse caldera formed at some time around 84,000 BP (Rejmankova et al., 2011). The basin is located within the Sierra Madre volcanic chain, and includes three volcanoes: San Pedro, Atitlán, and Tolimán. The region constitutes 130,000 ha., and the land cover of the lake's surface area is 137 square kilometers, with a distinctive heterogeneous topography (Schmitt-Harsh, 2007; Rejmankova et al., 2011). Land within the Atitlán watershed is comprised of approximately 46% forest, and 32% agriculture (Rejmankova et al., 2011).

Atitlán falls under the Koppen Climate Classification zone CWB: a temperate highland tropical climate with dry winters. Soil composition is chiefly comprised of andisols, entisols, and utisols (Schmitt-Harsh, 2013). Annual rainfall and temperature averages 2,504 mm and 18-24 C, however the precipitous altitudinal gradients have induced an abundance of microclimates and ecological niches (Schmitt-Harsh, 2013). Three notable ecoregions are located within the Atitlán watershed: Sierra Madre Moist Forests, Central American Pink-Oak Forests, and Central American Montane Forests (Jones, 2007). Island biogeography occurs at the volcanic peaks, including an abundance of endangered mammals, birds, reptiles, and amphibians, well as rare xeric and leafy flora wholly unique to these lands (Calderon Barrios, 2007; Jones, 2007).

5.2.2 Socio-Economic and Historical Dimensions

Atitlán basin is currently home to approximately 400,000 people, and the Sololá department contains 19 municipalities (Rejmankova et al., 2011; Schmitt-Harsh, 2013). The first Maya settled in the area in 35,000 BP, and the vast majority of the population are indigenous Maya (96.2%) from three unique ethnic groups: Tz'utujil, Kaqchikel, and Quiche (Schmitt-Harsh, 2013). In some Atitlán municipalities, such as Santiago Atitlán (located on the southwest shore of the basin), indigenous people comprise 98.16% of the population, and 94% of the population speak Tz'utujil language (Nagata et al., 2009; Nagata et al., 2011). It is notably to contrast this dense concentration of Mayans with the fact that sixty percent of the Guatemalan population are not in fact indigenous.

Indices of development in the region are truly abysmal: Atitlán is situated within the fourth poorest region in the country, located within the country's "poverty belt" (Calderon Barrios 2007; Schmitt-Harsh 2013). A study in 2007 (Jones) found that eighty-three percent of the region's population is impoverished, with the bulk of the population surviving through employment as low wage agricultural laborers and subsistence farmers. This trend rings true in the municipality Santiago Atitlán: today the majority of the population earns less than the minimum wage of 1,274 Guatemalan Quetzals (165.81 USD) per month (Nagata et al., 2009).

Nagata and colleagues (2011) give historical overview of the tribulations endured by resident Mayan groups, "for nearly five centuries, the local Maya have experienced repeated cycles of conquest: first by imperial Spain in 1524, and later by international and local capitalism, as well as state terror during the Guatemalan Civil War from the 1960's to the 1990's…the Tz'utujil Maya have experienced both conquest and colonization while maintaining and adapting unique local culture through language, ritual, dress, and food." The impacts of globalization are ubiquitous throughout the Atitlán landscape, and vast capitalist expansion and high influx of tourists are visibly evident in most lakeside villages today. Although the area has been subjected to massive change in recent decades, juxtaposition of past traditions remains a sharp contrast as the customs and lifestyles of local people have largely remained intact.

Atitlán basin holds tremendous importance culturally and spiritually for Tz'utujil-Maya, who believe that their people originated from the very same location.

> "The Tz'utujil Maya believe that they occupy *r'muxu kaj*, which means 'the navel of the earth'. Part of the traditionalist Maya perspective is that they live a sacred place. The volcanoes and surrounding mountains are the abode of gods and powerful ancestors. The lake bears the primordial waters of creation, suffused with animative power capable of regenerating and sustaining life, as well as the capacity to destroy it. Among the traditionalist Tz'utujil Maya of Santiago Atitlán, their community is a sacred place, situated at the very center of the world where the first mountains emerged from the waters of the primordial sea (Christie, 2009)."

During the Guatemalan Civil war, in the municipality Santiago Atitlán a massacre of 14 unarmed Mayan civilians occurred at the hands of the Guatemalan army, and under immense international pressure resulted in a government resolution mandating the perpetual departure of the military from the area (Nagata et al., 2009). Today, this trend remains standard around Lake Atitlán, and Guatemalan state police, military, and political figures are not present nor permitted to be in most regional municipalities. As a result, municipalities are primarily governed by traditional community-based Mayan governance structures, and these municipalities may be therefore considered somewhat autonomous.

Notably, land tenure in the highlands has historically been insecure and subject to ancestral disputes, and is presently under a combination of municipal/private and indigenous communal land ownership (Schmitt-Harsh 2013; Jones 2007; Calderón Barrios 2007).

Figure 9: Geographical Distribution of Ethnic Groups in Guatemala (**Source:** Wikimedia Commons)

5.2.3 Agriculture

Agricultural crops of Atitlán include largely subsistence crops such as corn and beans (milpa) and the region also harbors some of the highest concentrations of maize diversity in the world (Schmitt-Harsh, 2013; van Etten, 2006). Local Tz'utujil Maya were historically dedicated to specialized irrigation agriculture, however this practice has hugely declined today (van Etten, 2006).

A wide variety of export crops are also increasingly grown for export markets, including onion, coffee, potato, broccoli, rubber, cardamom, and macadamia (Schmitt-Harsh, 2013). These crops are often cultivated largely on very steep, erodible slopes and marginal lands, characteristic of much of the arable land in the watershed (Calderon Barrios, 2007; Rejmankova et al., 2011). Regional investments and integration into the capitalist export economy have been expanded within the last decade, which may be indicated through magnification of niche commodity specialization that has occurred between villages (Jones, 2007). Some such niche specialization may be demonstrated via the highland regional specialization in household vegetable production, which mediates staple food shortages in lowland plantations and additionally for North American markets (van Etten, 2006). Coffee is one of the most abundantly cultivated regional cash crops, and the majority of growers are smallholders who operate on less than two hectares of land (Schmitt-Harsh, 2013).

5.2.4 Environmental Issues

Lake Atitlán is currently facing profound environmental challenges. These challenges include soil erosion and degradation, loss of biodiversity, pollution and eutrophication of Lake Atitlán, deforestation, and climate change.

A recent study (Schmitt-Harsh, 2013) conducted over a 20-year study period concluded that regional deforestation trends are colossal, "approximately 41,400 ha. of regional forests were converted to other land-use/cover categories, the majority of which occurred in the 1990-2000 time interval."

Toxic and noxious cyanobacteria blooms in Lake Atitlán have been provoked from untreated wastewater and sewage, agricultural run-off and erosion, and nutrient-rich drainage inflow from San Francisco and Quiscab Rivers (Rejmankova et al., 2011). Rejmankova and colleagues (2011) note,

> "uncontrolled nutrient input into the lake has lead to high phosphorous levels, initiating cyanobacteria blooms… increases in phosphorous may be largely attributable to conventional agricultural practices and the applications of agrochemicals and fertilizers. Many studies have concluded that managing phosphorus is critical to maintaining desirable water quality and ecosystem integrity, and with relatively few exceptions, reductions in phosphorous inputs have led to successful recovery from eutrophication."

Without tremendous and swift remediation and mitigation efforts, eutrophication of Atitlán is likely to pose enormous health risks and loss of livelihood to inhabitants, and could potentially lead to ecological collapse of the lake's ecosystems (Rejmankova et al., 2011).

The region's enormous biological diversity is now under major pressure and is highly volatile due to habitat diminishment, which may be attributable to economic shifts, population growth, and slash-and-burn agricultural practices (Jones, 2007; Calderón Barrios, 2007). Atitlán's fish populations have been severely jeopardized due to overfishing and introduction of largemouth bass, which had a large impact on local fish, bird, and amphibian populations (Rejmankova et al., 2011).

Lake Atitlán was declared a "National Park" in 1955, signifying the commencement of watershed conservation efforts, however due to neglect caused by decades of national conflict Atitlán was re-classified as a "Multiple-Uses Protected Area" in 1997, managed by the National Council for Protected Areas (CONAP) (Calderon Barrios, 2007). Today, many initiatives have risen to the challenge of bioregional conservation and sustainability endeavors, and some such organizations include Niños del Lago, Pueblo a Pueblo, Mesoamerican Institute of Permaculture, Todo por el Lago, and Pura Vida Atitlán, among numerous others.

5.3 Farm System Case Study Context: Mesoamerican Institute of Permaculture

The Mesoamerican Institute of Permaculture (IMAP) is a small and innovative farm school in Pachitulul, a small hamlet on the southern shores of Lake Atitlán. IMAP was chosen as the case study farm for this study, and early steps of Participatory Action Research were undertaken at the farm. The key stakeholder chosen for this study is also the founder and primary educator at IMAP farm – Mayan-Kaqchikel anthropologist and permaculturist Ronaldo Lec Ajcot. The farm is notable for large achievements in increasing local food and seed sovereignty initiatives, sustainable agriculture training, and community organizing.

At a food sovereignty conference in 2006 (Cohn et al.), Ronaldo explained how the perspectives of and practices of permaculture fuse with Mayan traditional knowledge at IMAP.

> "Permaculture is not only about food – it's a way of seeing things. It's an applied philosophy…. and I think the principles and ethics of permaculture totally fit with our philosophy, which is a philosophy of care of the earth, care of the people, and equal distribution of surplus. Permaculture is based on traditional knowledge, on what already has been done, on what already has worked and is working. We don't need to reinvent the wheel, so that's where permaculture starts."

Two semi-structured interviews were conducted with the key stakeholder from the farm system case study, Ronaldo Lec Ajcot. The first interviewed was conducted on February 3rd, 2014. The primary aims at that time were to collaboratively define research sub-questions of this study. The second semi-structured interview was conducted in order to ensure feasibility of questions asked for the food system interviews, as well as to highlight perceptions of the key stakeholder on these issues.

During the preliminary interviews, Ronaldo highlighted that at foremost, he would like help to research venues for crop agrobiodiversity conservation including both in-situ and ex-situ methods. He explained, "Seed is very important to us. We are selling seed – but we're running out. There's demand but not enough supply… We need seed for sovereignty, so we don't have to depend on companies."

Indeed, lack and loss of traditional seed has profound impact on the smallholders of Pachitulul: farmers in the hamlet have remarkably meager land ownership, and these tremendous scarcities largely undermine local food security. Because of this, IMAP created a food and seed sovereignty initiative, whereby the bulk of IMAP's lands are rented to smallholders from the hamlet in exchange for production of indigenous crops. The seed from these crops are taken in payment for use of the land, and stored in the IMAP seed bank. Farmers are also allowed to keep their crops, which has had hugely positive impacts on local food and nutrition security. Perhaps the most notable achievement of this land exchange program is the model of agricultural use. All farmers who participate in the land exchange program have been trained in permaculture and agroecological practices, and are stipulated to continue these practices while participating in the program. This model of in-situ and ex-situ conservation coupled with sustainable agriculture practices is simplistic however brilliant, accomplishing many goals.

Nonetheless, the program has become largely endangered at present due to the rising water table of Lake Atitlán. While some fluctuation in the water table is normal, the current level of flooding is unprecedented in recent years. Historic trends reveal that the lake has been documented to fluctuate greatly, and as testament to this many ancient cities are found many meters below the lake's surface. At present, the bulk of IMAP's lands (all land under smallholder cultivation in Pachitulul hamlet) remain either wholly submerged, saturated, and otherwise distressed. The profound land scarcity and highly skewed land distribution in the village has not only has served to undermine local food security, but also serves as a detriment to the continued cultivation of indigenous crops, halting IMAP's seed production. Ronaldo explains the situation simply, "There is no land access – when there is land access there is food."

6. Results

6.1 Results Overview

Themes were extracted from the data collected using Grounded Theory Methodology and were consolidated into two categories: globalization and uneven development as well as environmental change and agricultural adaptation. The PAR-defined research sub-question of crop agrobiodiversity conservation will then be explored, including seed flow, acquisition, and conservation dynamics. Lastly, smallholder views of potentials and constraints will be scrutinized through compilation of data collected from SWOT analyses conducted by Mayan smallholders. Future potentials for farm and food system development are further explored from data collected on smallholder visions for the future.

6.2 Study Composition

In this study smallholders of Kaqchikel ethnicity were interviewed at a slightly higher rate than the other two ethnic groups, at a rate of 42.5 %. Although measures were taken to identify the most representative sample possible, the slightly skewed ethnic distribution can be partially attributed to slightly larger Kaqchikel population densities in two of the case study villages, Panajachel and Santa Cruz la Laguna. Tz'utujil smallholders were interviewed at the lowest rate, of 27.5%, and Quiche were interviewed at a rate of 30%.

Kaqchikel women were the most represented group with nine interviewees, and Tz'utujil men and Quiche women were the least represented groups, with five interviewees each (Figure 10).

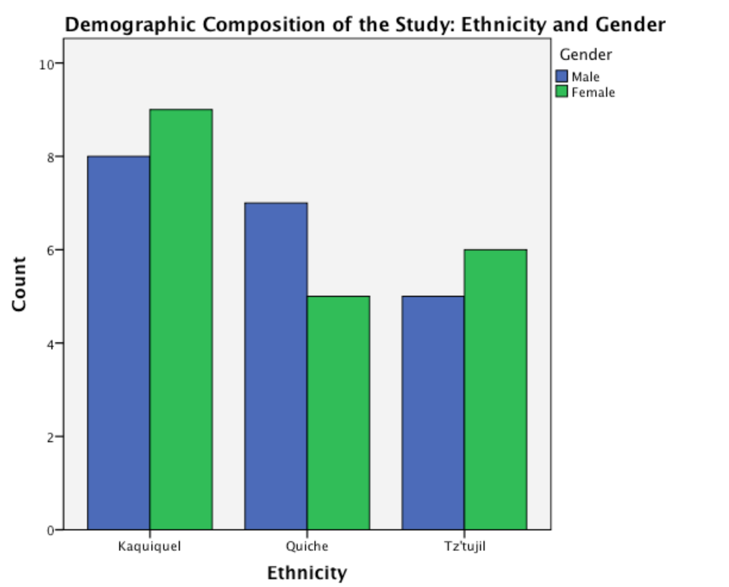

Figure 10: Demographic Composition of the Study

Guatemala has a notably high relative birth rate, and this was reflected in the household composition of this study. Twenty-five percent of farmers reported families composed of five members, and 25% of the farmers had nine family members or more.

6.3 Globalization and Uneven Development

6.3.1 Food and Maize Sovereignty

Household food security was measured from self-reported estimates of annual household nutrition or food deficit. Food insecurity proved to be rife within the study, with the majority experiencing food insecurity (55%). The worst instances of household food insecurity were reported at widely different dates throughout the food system. In Panajachel, lack of food was reported to begin in May and generally last until December. Some farmers mentioned that food insecurity was palpable at all periods of time throughout the year (n= 3). In San Juan la Laguna, all farmers mentioned that the worst periods of food shortage are generally experienced between July and August until October (n= 10). No notable differences were found between villages or Mayan ethnicities in relation to the degree of household food security. Men and women reported food security trends at the same rates.

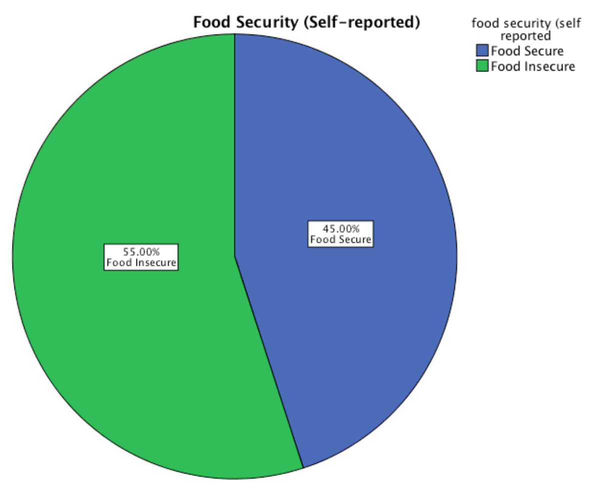

Figure 11: Prevalence of Food Security

In terms of agricultural practices, food secure households were found to be slightly less likely not to use slash and burn agriculture (46.7%), and were likewise less likely to use fallow (58.1%). Food secure households were more likely to use agroforestry systems (53.6 %). Agricultural benefits were shown to improve household food security: households receiving agricultural benefits were less likely to be food insecure (55.6%).

A notable trend that decreased household food security was engagement with off-farm work (62.5%). In most villages, off-farm laborers reported to labor in off-farm work most frequently from October-December, primarily for coffee harvest. In terms of crop consumption patterns, maize and chiplin gave insight into possible indicators of household food insecurity. Food insecure households are more likely to eat chiplin (55.3%), a crop abundant in regional forests and therefore easily foraged.

Food insecure households were much more likely to also be maize insecure (59.1%), illuminating the importance of this staple crop. Overall, households primarily reported that they are not maize sufficient. Based upon self-reported data pertaining to household need to purchase maize, 57.89 % of households reported that they must purchase maize. Households with maize deficit are more likely to consume izote (60%), and are also more likely to cultivate chiplin (60%).

6.3.2 Economic and Social Dimensions

Membership in cooperatives, social movements, and other social or political networks was not reported by any smallholders. This insinuates overall low social networking amongst rural farmers in the region.

Farmers were interviewed in regards to their primary motivations for production in order to determine the degree of market alignment of smallholders in the food system as well as to illuminate trends related to economic factors. Precisely half of farmers interviewed reported that they were producing for home consumption as well as to sell their products on market. Thirty-two percent of farmers were producing only to sell on the market. A minority of farmers (17.50%) indicated that they produced only for personal consumption.

Off-farm work was reported by 20% of farmers, and this work was largely seasonal and often affiliated with coffee harvest. A slight majority of smallholders were found to be receiving some form of agricultural benefits, (53.85%), and all of these benefits were reportedly from MAGA. In terms of agricultural education, nearly eighty-three percent of farmers reported that they have received some form of agricultural training.

A myriad of attributes were associated between degree of market alignment and other factors, therefore degree of market alignment may be understood as a strong indicator of other farm and food system indicators. Traditional agricultural practices were more positively correlated with farmers whose motivation for production is either for wholly subsistence-based or partially subsistence-based purposes. For instance, among smallholders who cultivate solely for subsistence, slash and burn agriculture was used at a more frequent rate (18.8%) than farmers with increased market alignment. On the whole, subsistence farmers are less likely to own their land. Smallholders who rent their land most often produce for both subsistence purposes as well as to sell their crops at the market. Subsistence farmers are slightly more maize sufficient, and farmers who produce solely for market production are slightly more maize insecure. Farmers who produce solely for subsistence purposes are also much more likely not to receive agricultural benefits. Respondents who produce for subsistence purposes were most likely to acquire their seed from neighbors and family members, and there were no reported subsistence farmers who purchase seed from the market.

Farmers who produce for reasons aligned with market production are most likely to primarily acquire their seeds from the local market and from within their village. Farmers who produce for market purposes were more notably more likely not to use slash and burn agriculture. Farmers who receive benefits are most likely to produce both for personal consumption and for market (61.%).

6.3.3 Land Tenure

Land ownership and access emerged as a major theme of this study. The immensely skewed land distribution of the region was found to have enormous impact on food security and sovereignty. In Figure 12, average land ownership trends (in cuerdas) was gathered as mentioned by smallholders throughout the food system.

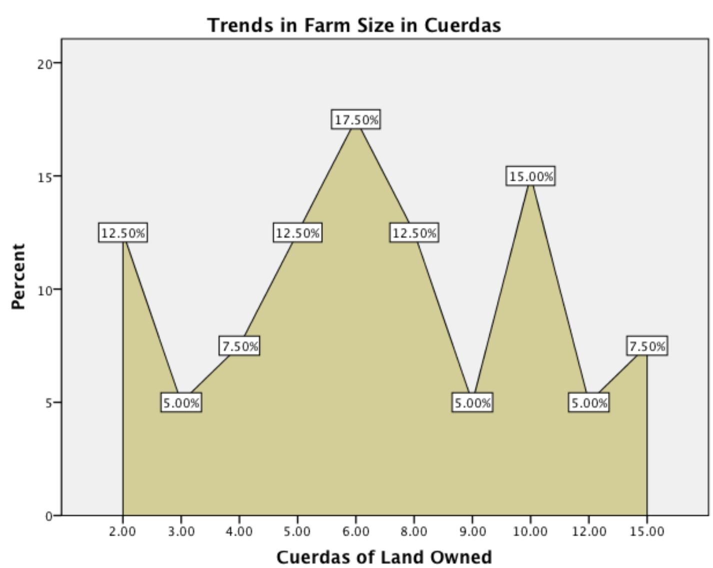

Figure 12: Trends in Farm Size

Figure 13 depicts responses to the question, "How much land do you need to support your family?" Nearly 31% of farmers felt that they required around ten cuerdas at a minimum, with slightly higher rates also recorded, which may also reflect some of the larger family sizes of the study area. Comparing the two tables of land ownership and land needed, obvious and widespread land scarcity becomes evident. Seventy percent of farmers owned their land, while 30% of smallholders had insecure tenure and rent their agricultural land.

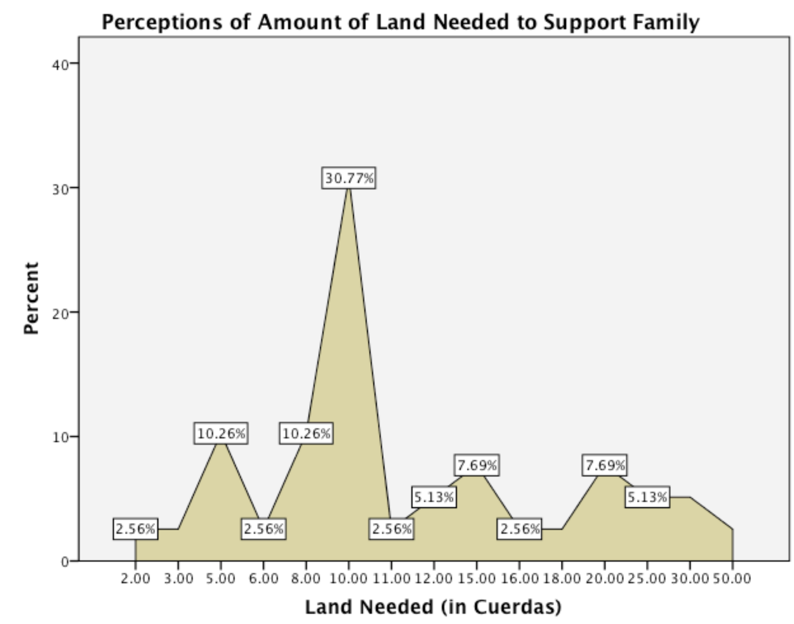

Figure 13: Perceptions of Amount of Land Needed to Support Family

6.3.4 Gender, Village, and Ethnicity

The vast majority of variables proved to be fairly uniform by gender across the food system. A few notable exceptions emerged, highlighting divisions of labor between sexes. Men are more likely to have received agricultural training (51.5%), however other gendered inequalities were not hugely evident in terms of receiving benefits, land tenure, food security, prevalence of off-farm work or other factors.

In terms of difficulties in seed acquisition, men were most likely to cite that they did not know where to find local seed varieties. Women were most likely to cite the cost of seed as their biggest impediment to seed acquisition. Men are slightly more likely to be interested in regional seed exchange (53%). Cultivation trends between genders are fairly uniform, however women are more likely to cultivate homegardens than men, more likely to apply organic compost, and were also likely to cultivate chipilin (52.4%). Although climatic change perceptions were reported at a similar rate between genders, women were less likely to adopt any form of agricultural adaptation in response to climate change, while men employed adaptations at a higher rate.

By village, trends also remain fairly uniform with some subtle exceptions. Slash and burn agriculture is used at a much higher rate in Santiago Atitlán and Santa Cruz la Laguna. In San Juan la Laguna, farmers were much less likely to delay their harvest due to climate change than other villages. San Juan la Laguna was much less likely to use fallow, while in Santa Cruz the practice was much more widely reported. San Juan la Laguna farmers reported the highest incidence of off-farm work, and in Santiago Atitlán off-farm work is the least common.

Ethnicity did not generally prove to significantly impact perceptions, resource distribution, or agricultural practices.

6.4 Environmental Impact and Agricultural Adaptation

6.4.1. Overview of Agricultural Cropping Systems

Fallow field practices were reportedly used by nearly eighty percent of farmers. A Tz'utujil farmer explained, "Here we used to always practice fallow, but now we have less land. Because of this we sometimes make our fallow time shorter, and sometimes for poor families with little land we cannot make any fallow or we will starve. But also without fallow there is always less food."

Seventy percent of farmers reported use of agroforestry systems, and homegardens were used by 78% of respondents. Slash and burn agriculture was used at a rate of nearly 52%. Organic compost application was reported by 61% of smallholders. A farmer in Santiago Atitlán said of this, "We used to have more space and land, back then we would make a compost of dung, but now people don't have enough land for animals so the compost is not as good." 38 out of 40 farmers interviewed reported application of industrial agrichemicals or fertilizers.

6.4.2 Consumption and Cultivation Case Studies of Marginal Key Crops

Chia (*Salvia hispanica L.*), chipilin (*Crotalaria longirostrata*), izote (*Yucca guatemalensis)* amaranth (*Amaranthus hypochondriacus)* and chaya (*Cnidoscolus chayamansa*) were chosen as crops to identify use and cultivation practices and trends in the food system as some of the most nutritious regional native crops. Among three notable crops (chia, amaranth, and chaya), both consumption and cultivation practices were virtually non-existent, with almost no documented use by smallholders in any village.

Two marginal and nutritious indigenous crops studied are still commonly used throughout Lake Atitlán. Chipilin is consumed at a widespread rate of 95%, and izote flowers were reportedly consumed by 77.50% of smallholders interviewed. Cultivation patterns are much less frequent: chipilin was purportedly cultivated by 52.5% of smallholders, and izote was cultivated by approximately 37.5% of smallholders.

Out of interest of land use trends, cuerdas of milpa sown were reported and compiled into Figure 14. Upon analysis, there did not prove to be correlation between milpa size by village, ethnicity, gender, nor family composition. Additionally, there was no notable correspondence between milpa size and degree of market alignment, nor incidences of household food security and maize sufficiency.

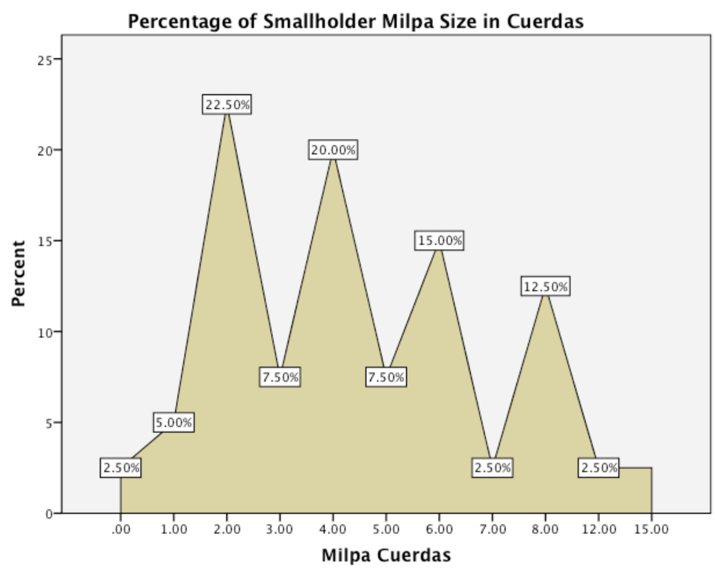

Figure 14: Trends in Smallholder Milpa Size

6.4.3 Gauging Interest in Organic Agriculture

Interest in organic agricultural methods was met with widespread enthusiasm. Of the forty farmers interviewed, only three farmers did not have interest in learning more about organic agriculture.

Many farmers were interested in organic farming training because they hoped that use of organic methods might improve their soil quality. In Panajachel, a Kaqchikel farmer expressed his hope for organic agriculture, "I think I might have more strength in my earth and already with so many chemicals my land [now] doesn't produce." Indigenous farmers also uphold widespread perception that organic methods may improve soil fertility (n= 9). Many farmers perceived organic agricultural practices to be better for human health (n= 8), produce better food quality (n= 1), and produce better quality maize (n= 1). Some farmers cited interest in learning more about organic agriculture due to the eutrophication of the lake (n= 3). Other reasons for interest included the high costs of agrichemicals and fertilizers (n= 6).

Among farmers who were not interested in organic methods, one smallholder cited that organic and traditional methods are very time consuming (n= 1). A farmer in Panajachel said, "I am not interested because the land always needs chemicals for good production." In Santa Cruz la Laguna, a farmer described his disinterest, "It is very difficult [organic agriculture] and the milpa already doesn't grow well anymore."

6.4.4 Climate Change: Perceptions and Adaptations

Shifts in climatic patterns were reported at very high rates in this study, and these perceptions did not significantly differ by village, ethnicity, or gender. A mere 7.5% of farmers interviewed perceived no change in the climate.

The vast majority of farmers (85%) perceived that the temperature has increased, and no farmers mentioned a temperature decrease. Additionally, 55% of farmers experienced less rain, and 15% reported more rain. Delayed onset of winter season was reported by twenty percent of farmers interviewed.

In response to these perceived changes, farmer agency may be understood through individual adaptation responses to these perceived disturbances. Seventy percent of farmers stated that they have delayed planting their crops due to changing weather patterns, and 27.5% of farmers have additionally delayed harvest. One cultivator noted that he has changed the crops that he cultivates in an attempt to mitigate harvest losses. Only seventeen percent of farmers interviewed had not changed their agricultural practices due to climate change.

Environmental perceptions and agricultural cropping practices had widespread association. Environmental perceptions and farmer agency in their choice of cultivation practices also had impact on other topics, therefore these disparities and similarities will be highlighted.

Farmers who also reported use of agroecological practices reported perception of less rainfall at higher rates. Farmers with homegardens were much more likely to indicate that they perceived less rainfall at a rate of 55.6%. Farmers who use organic compost are also much more likely to indicate less rainfall, at a 59.6% rate. Likewise, perception of less rainfall was indicated at a higher rate among farmers who use fallow (54.8%).

Farmers who were maize sufficient were much more likely to report that they experienced less rainfall (62.5%); among maize insecure households this perception rate dropped to 45.5%. Maize sufficient households had a much larger propensity not to adopt any changes to their farm system due to climate change, at a rate of 57.1%. Maize insecure households were much more likely to have delayed planting to due climate change (61.5%). These trends may indicate some causes of food insecurity among smallholders, and highlight the importance of further research into climate change adaptations.

6.4.5 Agrichemicals: Perceptions

Over sixty percent of farmers indicated that they perceived negative impacts either in regards to human health or environmental impacts due to agrichemicals or fertilizers. Only 37% indicated that they had not noticed any impacts from agrichemicals and fertilizers.

In Panajachel, a Kaqchikel man said, "when the children are small they are more often ill from the agrichemicals and fertilizers." Another Kaqchikel farmer also indicated that the impacts are more difficult for children, "The children have poor health and live less now." Four farmers from three villages mentioned the magnification of negative impacts on children. Smallholders also cited an overall increase in illnesses, loss of appetite, and severe headaches, which they attributed to use of agrichemicals and fertilizers (n= 10).

Negative environmental impacts were also perceived by smallholders, which they associate to agrichemicals and fertilizers. Deep concern was frequently expressed regarding contamination and algal blooms in Lake Atitlán (n= 14), and contamination of rivers (n= 2). San Juan la Laguna, a village near the shore of Lake Atitlán, cyanobacteria and water contamination was cited by 100% of farmers interviewed. Other negative indicators were mentioned such as poor soil (n= 2), increases in crop diseases (n= 2), less overall crop yields (n= 2), and less tasty food (n= 1).

6.5 PAR Inquiry: In-situ and Ex-situ Crop Agrobiodiversity Conservation

6.5.1 Perceptions of Drivers of Loss: Traditional Agricultural Practices and Crops

Cultivators were interviewed about their views regarding drivers of loss of traditional production practices and crops. As depicted in Figure 15, there is a wide degree of variance in responses, and only 7.5 % of smallholders do not perceive any loss of traditional practices and crops. The most widely recounted causes were lack of land (32.5%), lack of seed (22.5%), and economic influences (12.5%). Other reasons given included influx of other crops (7.5%), youth disinterest in agriculture and traditions (7.5%), use of agrichemicals and fertilizers (5%), and additionally a Tz'utujil farmer attributed these changes to the rising water table of Lake Atitlán.

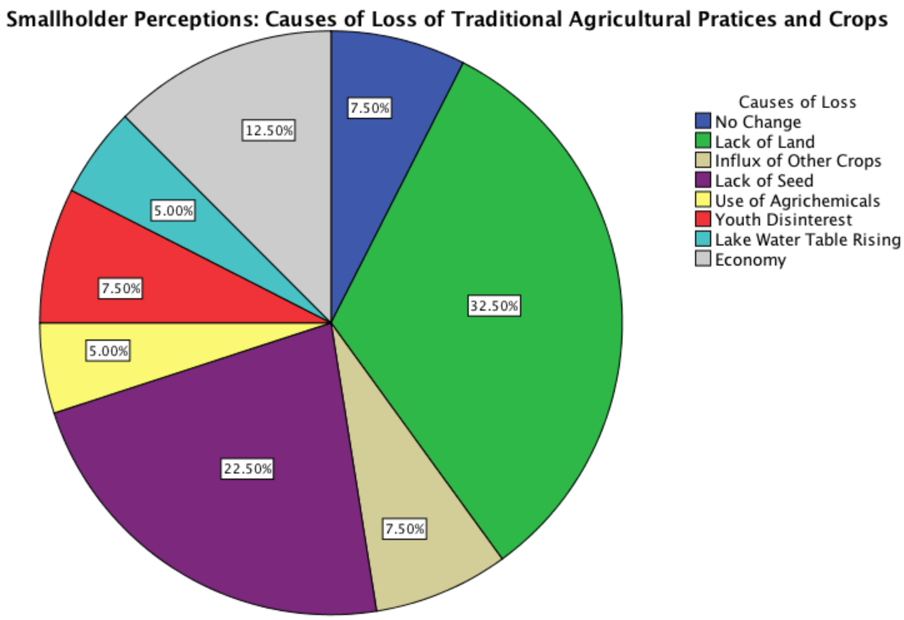

Figure 15: Smallholder Perceptions: Causes of Loss of Traditional Agricultural Practices and Crops

6.5.2 Seed: Spatial Flows, Conservation and Acquisition Trends

In order to gain insight into the current state of seed systems in Lake Atitlán, it was necessary to assemble an understanding of spatial flows of seed, seed conservation practices, presence of pre-existing seed banks, as well as challenges to seed acquisition by smallholder farmers. Overall interest in community-based seed exchange initiatives was also gauged.

Farmers revealed that they most frequently acquire seed from neighbors (55%), and are also very likely to source their seed from family members (20%). Only ten percent of farmers purchased their seeds from their local market. A few cultivators responded that they acquired their seed from other sources, which were primarily from the larger market in Sololá (n= 2) (Figure 16).

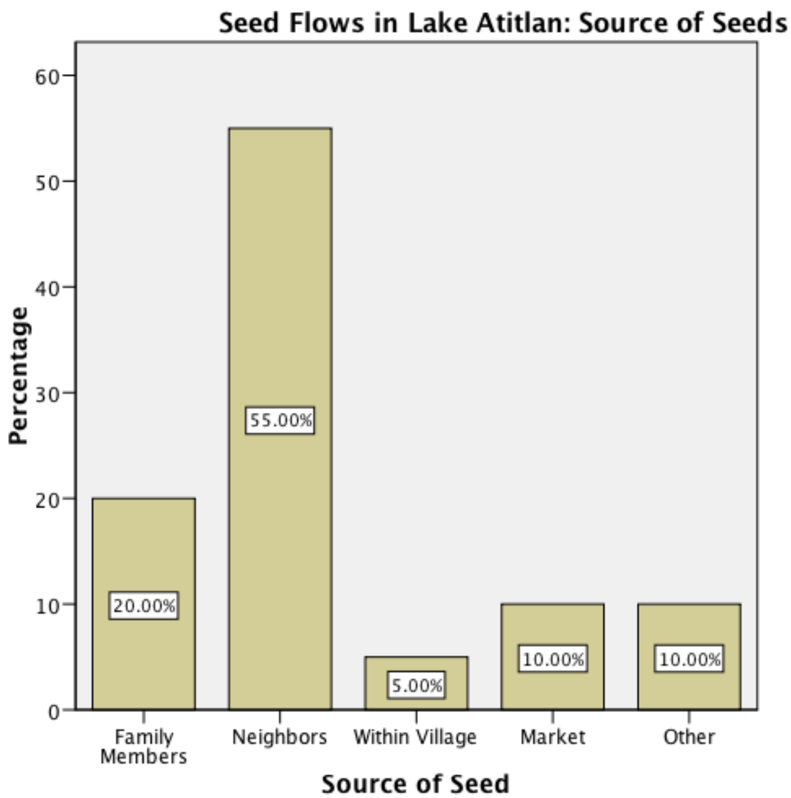

Figure 16: Seed Flows in Lake Atitlán

As evident in Figure 17, frequently cited challenges in regional seed acquisition included the overall expense of seeds (37.5%), followed by both loss of seed varieties (25%), and difficulties to locate seed (25%). A farmer in Santa Cruz la Laguna expounded upon the impact of fluctuating seed prices, "Sometimes the seeds are extremely cheap, and other times they are extremely expensive." Other difficulties were mentioned by 12.5% of farmers – a respondent from Panajachel explained, "It is especially difficult to find seeds to make milpa." Lucia Garcia, a Quiche farmer from Santa Cruz la Laguna described her challenges; "There are very few people who have good seed so it is difficult to find the good native variety like *sajquim* [maize]." Intriguingly, maize insufficient households were more likely to report overall difficulties in accessing seed than maize sufficient households.

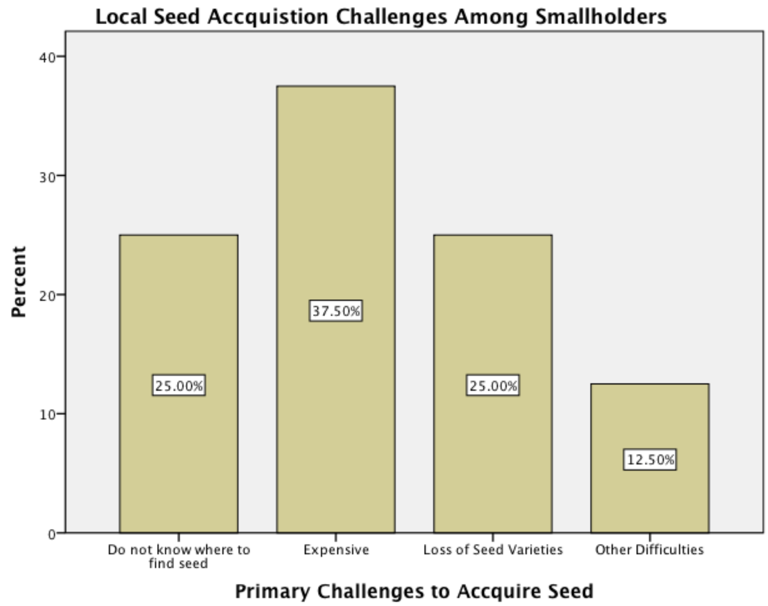

Figure 17: Local Seed Acquisition Challenges Among Smallholders

Farmers were also asked to indicate if they could locate any seed banks with the intention of identiying any existing seed repositories. The vast majority of respondents reported that they did not know of any seed banks. Respondents who did mention seed banks indicated shops in urban areas that sell industrial seed varieties. A woman in San Juan la Laguna indicated that village elders may keep some local seed varieties.

The practice of keeping seeds from previous crops was widely reported, at a rate of seventy-five percent. There did not prove to be any association between seed conservation practices by village, ethnicity, or gender. A farmer in Santa Cruz la Laguna said, “We used to always keep our seeds, but now we don’t so we must always continue to buy… it is better to keep our seed.” Farmers who keep seed are slightly more likely to also receive benefits, and also reported increased izote consumption (77.4 %).

6.5.3 Gauging Feasibility and Viability: Interest in Regional Seed Exchange

Sixty-five percent of smallholders were interested in regional seed exchange of indigenous crops. Among farmers who were not interested, Nicolasa Joi Bocel, a farmer from Panajachel said, “I don’t have confidence in seeds from outside this village.” Other farmers cited the excellent quality of their own seed for the cause of their disinterest (n= 3), and others mentioned concern for the quality of outside seed (n= 2). Disinterest in regional seed exchange may also indicate a positive trend: a sense of protectionism of native local crops from externally sourced genetic resources.

6.6 Smallholder Perceptions of Potentials and Constraints for Farm and Food System Development: SWOT Analysis and Future Visioning

6.6.1 Strengths

Farmers gave many varied responses in terms of strengths of their farm system. Farmers were likely to highlight that their land gave good yield (n= 8), was suitable for production of export crops (especially onions and coffee) (n= 15), and with good soil fertility (n= 15). Some considered the mere fact that they own land to be the biggest strength (n= 8), and mentioned other topographical features such as the location of the farm situated within a plain (n= 1), or high enough to be safe from the fluctuating water table of Lake Atitlán (n= 3). Others mentioned strengths such as knowledge (n= 1), possession of seed adapted to the local microclimate (n= 2), strong family network for work help (n= 1), and presence of a nearby water source (n= 2).

6.6.2 Weaknesses

The most commonly reported weaknesses were flooding (n= 5), lack of land (n= 5), and loss of soil fertility (n= 5). Similarly to loss of soil fertility, farmers often mentioned that the land requires chemicals (n= 4), as a female Kaqchikel farmer proclaimed, “My land already grows almost nothing now… and I always need to use more and more chemicals, it is very expensive now.” Other indicators of poor quality soil were indicated, with one farmer indicating rocky soil was his primary weakness, and another mentioning that her soil was too sandy. Extreme market distance was also mentioned repeatedly (n= 4). Plant disease, particularly roya (*Hemileia vastatrix)* in the coffee was mentioned (n= 4), and one respondent attributed his biggest weakness to a loss of harvest resulting from changing climatic patterns. One farmer cited the biggest weakness as a general lack of knowledge.

6.6.3 Opportunities

Although many farmers seemed to struggle with the question of opportunities for their faming system and gave fewer answers, the most common response was crop diversification (n= 11), followed buy desire to acquire or purchase more land (n= 8). Many farmers also wished to increase their export-led production and enter formal markets, citing hopes to grow NTX crops such as broccoli (n= 6). Lastly, two farmers aspired to gain more agricultural training.

6.6.4 Threats

Farm system threats were very diverse. Many alluded to the fact that their farmland was in some way marginal. Two farmers mentioned that their land was not flat and therefore prone to flooding, and an elderly farmer in Santa Cruz la Laguna cited that, "My land is so mountainous it is very dangerous to farm… it is so steep that I must be tied down or I will fall off." Likewise, landslides and soil erosion were indicated at a very high rate (n= 12). One farmer mentioned river flooding, and four others indicated that their land is situated within a flood plain (n= 4). Another four farmers mentioned the rising lake. While on one hand too much water (e.g. flooding and water table rise) was a major concern, paradoxically too little water is also a major issue in all villages. Many farmers situated high on the basin (above from the lake) mentioned that they have no nearby water source (n= 4), and likewise the foremost concern of three farmers was rain shortage. Two farmers cited agrarian challenges related to the unpredictable climate.

Three farmers mentioned distance to the market, and other market issues were also voiced. A respondent in Santiago Atitlán described, "Everything I produce seems to have little value now, many times I can find no one to buy my harvest even after I make the long journey to the market. I ask myself why I continue to produce [for the market] like this."

Tenure insecurity was also mentioned (n=2), and a Quiche woman in San Juan la Laguna elucidated the gravity of her situation, "My landlord… sometimes he tells me he will make me go away from my fields. If he makes me leave we will have nothing. I have a lot of fear of that, especially for my children."

Other on-farm problems that were mentioned included rocky soils (n=1), profound winter food shortage (n=1), pest problems (n= 2), and the fact that the land had ceased to produce maize for reasons unknown to the farmer (n= 1). Likewise, two farmers mentioned that their crop yields seemed to be "smaller and smaller" and were generally insufficient (n= 2). Coffee disease *Hemileia vastatrix* (roya) was mentioned by many farmers as their most weighty concern (n= 8). Lastly, one farmer cited simply "uncontrollable bad luck."

6.6.5 Farm System Future Visions

By far, the most commonly mentioned vision for a farm was to increase crop production (n= 14). Many farmers also specified they wanted to increase production of crops to sell at the market for the purpose of monetary gain (n= 7). Visions of agronomic development were mentioned widely: farmers envisioned improving their seed (n= 2), construction of a plant nursery (n= 1), gaining access to agricultural training (n= 2), and hope of receiving agricultural benefits from the government (n= 1). Many farmers also envisioned securing their property against flooding and landslides (n= 5).

Concern that children leave the land and agriculture in general was very strongly voiced throughout the case study villages, and this aspect was mentioned at least once per village (n= 5). An elderly Kaqchikel farmer said of his apprehension, “My vision for my farm is that my children and my grandchildren do not leave the farm and abandon farming.”

6.6.6 Village-Level Future Visions

Smallholders were asked to describe their visions for the future of their village. Answers depicted the distress of the current state of the regional food system. Many farmers mentioned a large lack of support for smallholders and overall decreased current food production, a situation that was altered in their future visions through further aid, education, and agricultural benefits. In Santa Cruz la Laguna, farmers were united in their dream for a future with a better road (n= 5).

A Kaqchikel farmer in Santa Cruz la Laguna said, “We really lack help, we are all very poor here and for this reason there are some children now who are malnourished.” Another farmer mentioned, “We need help to learn to produce more. We produce very little here now compared to the past.” A respondent from Panajachel stated, “I wish we could grow more and not have to buy as much food like before.” The most prevalent vision of the future for farmers around Lake Atitlán was a future of greater abundance through larger harvests (n= 10).

Two agronomic future visions stated pertained to soil erosion and seed conservation. “Every day the land erodes more, so I hope that we can still continue to cultivate in the future” explained a farmer from Santa Cruz la Laguna. A Quiche women in San Juan la Laguna said, “I hope we can work together and get help to better produce our own maize *sajquim*.”

Intergenerational succession and a heavily felt trends in migration to urban areas for off-farm work was mentioned frequently, as within farm system visions. For many farmers, their vision was simply that agricultural practices would survive and continue in Lake Atitlán in the future. A Quiche farmer said, “I hope we can still continue to cultivate more agriculture in the future… I hope that my children will not leave the land.”

Lastly, a farmer also noted that his vision for the future included greater respect given to smallholders, “I wish that people would give more validity to the important work of farmers.”

6.7 Farm System Results

The semi-structured interview was conducted with the Ronaldo Lec Ajcot, the Kaqchikel IMAP farm system stakeholder in order to allow for analysis between hierarchical levels of inquiry, as well as to gain more information about trends in the food system.

6.7.1 Economic and Socio-Cultural Dimensions

Primary drivers of loss of traditional practices and crops in Atitlán were emphasized by Ronaldo’s critique, “Agroindustry encouraged by globalized economy and promoted by governments and university.”

While no smallholders in the food system study mentioned relationships to social networks, IMAP indicated strong affiliation with a local organization that supports and promotes sustainable agriculture, Pura Vida Atitlán. Additionally, IMAP is involved with several national and international organizations that work with the issues of food sovereignty and seed conservation, such as Red Sagg, Guardianes de semillas, Campesino a Campesino, Via Campesina, to name a few. In similarity to other farm systems interviewed throughout the food system, benefits or aid from the government is slight. Ronaldo explained, “We do not benefit from any governmental program, in fact we train their agricultural extensionist to work with the schools.”

Social and cultural traditions of the Maya are well guarded at IMAP and in the hamlet of Pachitulul. “The Mayan calendar is our guide to daily life and agriculture is not a separate thing.” He highlights the spiritual value of maize to Kaqchikel people, “Maize is more than tortillas, it is life itself. The circle of corn is what shows us the life cycle every year.”

6.7.2 Environmental Change

Ronaldo explains his perceptions of environmental change, “There is less rainfall, but it is more intense. The temperature is higher and different bugs and animals have come to the highlands. Mosquito malaria, pelicans from the ocean. Also roya [*Hemileia vastatrix*] in the coffee was confined to lowlands but now is in the highlands.” These climatic changes have also altered cropping practices in Pachitulul hamlet, “Coffee production has been lost and there is a possibility of not being able to grow it.”

In regards to environmental impacts of use of agrichemicals in the food system, Ronaldo expounded, "The fertilizers have affected the water quality of Lake Atitlán, the main source of drinking water to the bigger towns. The soil fertility is the most obvious loss." Ronaldo believes that agrichemicals arrived in Lake Atitlán in the 1980's.

6.7.3 Crop Agrobiodiversity Conservation

In terms of access to local varieties of seed, the situation is also bleak in accordance with regional trends. "There are only a small amount of farmers that are not growing cash crops," Ronaldo explained. For this reason, IMAP primarily sources seed from its own producers, local Mayan farmers involved in the IMAP land exchange program. In regards to trends in regional seed loss, Ronaldo recalls historical situation of seed systems in the area, "In the past just about every hill and family had their own seed variety. Now seed is lost because of the loss of land, and because subsistence agriculture has been lost."

IMAP's networks also extend to knowledge of some other seed banks: Quachaloom, Rabinal Baja Verapaz, La hojita Verde, Guatemala City, ADICTA in San Marcos Department. It is however notable that none of these seed banks are located within the Lake Atitlán food system.

6.7.4 SWOT Analysis and Future Visions

The future vision of IMAP farm system is to be economically sustainable through educational services and seeds. IMAP's future vision for the Atitlán food system is to be a region where sustainable agriculture becomes the norm and is taught in schools.

Figure 18: SWOT Analysis of IMAP Farm System (Compiled from Semi-Structured Interviews from Ronaldo Lec Ajcot)

7. Discussion

7.1 Discussion Overview

The primary research question, "What are potentials and constraints for agroecological farm and food system development in Lake Atitlán?" will be compared and contrasted in through the themes emergent from Grounded Theory analysis at the hierarchical scale of the food system. Likewise, research sub-questions pertaining to crop agrobiodiversity conservation from the hierarchical scale of the farm system case study will be reviewed. Lastly, overall critique of methods and limitations to the study will be discussed.

Potentials and constraints of sustainable development were analyzed through the two themes taken from Grounded Theory Methodology: globalization and uneven development, as well as environment and agricultural adaptation. Research sub-focus also highlights the PAR research inquiry of crop agrobiodiversity conservation and seed dynamics.

Trends emergent from this study point to widespread change in Lake Atitlán farm systems, which are prevalent in all villages and linked to two primary causes: immense economic and environmental change. The impacts of neoliberal globalization and uneven development as well as and impacts of climatic and environmental change and caused a series of system perturbations, and the attempts of farmers to mitigate or lessen the negative impacts of these trends were documented in this study. Further information and comparison of the results of this study with review of published literature may also be found in the appendix. These relatively recent disturbances to the food system have caused a series of disturbances and shifts in overall agricultural production systems, but have also further impacted the fabric of daily life of inhabitants of Lake Atitlán basin, causing additional socio-cultural shifts.

7.2 Globalization and Uneven Development

7.2.1 Agrarian Reform

Land distribution in Guatemala is of crucial concern for the survival of smallholder agriculture and food security in a country where 60% of the population is dependent upon agriculture for survival: 88% of all farms, averaging 1.5 ha., occupy a meager 16% of agricultural land (Lastarria-Cornhield, 2003; IFAD, 2004). Trends in mounting population pressure and increasing resource scarcity are also prevalent in this study. On the whole, in this study farmers acknowledged that they fundamentally lack enough land to support their families. This may be supported by World Bank (2004) estimates that 8 out of 10 indigenous Guatemalan children face stunting due to chronic food and nutrition insecurity. A UN general assembly (2012) concluded that, "access to land is an essential element of the right to food. Extreme inequality in the distribution of land is a key factor in the persistence of hunger and poverty."

In fact, rural poverty in Guatemala is chiefly associated with lack of access to land, and one of the principle causes of the civil war was also attributed to struggle for more equivocal land tenure (IFAD 2004; Lastarria-Cornhield, 2003). Within Lake Atitlán case study, these grievances proved to be a palpable source of rural strife and hardship, usurping peasant smallholders of their power to support themselves. Given the already highly politicized ethnic divisions prevalent in the case study, if no attention is given to this epidemic of land insecurity violence could conceivably ensue again.

Farmers also expressed that land scarcity negatively impacts their ability to maintain on-farm agroecological practices. This study revealed that farmers have increased inability to allow land to fallow, as well as lack of land to support animals for compost or nutrition. Land scarcity coupled with the conundrum of prolonged food insecurity may decrease a farmer's ability to allow land to fallow, thereby decreasing soil fertility over time.

Peasant farmers from every village perceived that this prevailing lack of land is the single largest driver of loss of traditional agricultural practices and crops. Land deficit was reported a farm system weakness by many farmers (n= 5) in their SWOT analysis, and desire to acquire more land was also mentioned by smallholders as one of the largest opportunities for their farm (n= 8). Subsistence farmers in the case study were also less likely to own their land, and further thirty percent of smallholders in the food system rent their land. Farmers mentioned purchase of more land as their biggest opportunity for future development at a high rate during this study.

Among cultivators who owned land in this study, there was common evidence that nearly half of the farm systems in this study were also on land of marginal quality, situated on extremely steep land, within flood plains, with poor soil quality, or prone to landslides.

This study hypothesized to find some evidence of increased food security with increase in land owned, however no such quantitative parallel emerged. This may implicate a much more complex portrait of the drivers of food insecurity than solely the question of land ownership, however the profound importance of land access was aptly demonstrated by the smallholder's own observations.

Attention to land tenure is not a dismissible factor when attempting to upscale food security and agricultural sustainability, and remains a formidable impediment to development at the most general level. Land-use schemes targeted to promote smallholder access to land could conceivably increase crop agrobiodiversity conservation, and drastically increase household food and nutritional sovereignty.

7.2.2 Beneficent Economic Policy

Maize imports have caused tremendously negative impacts on Lake Atitlán food system, and indications that foreign maize competes with local maize varieties was evident in the case studies. Maize insecurity accounted for the bulk of farmers in this study, with an alarming 57.89% of farmers citing that they needed to purchase maize. The association between household maize security and household food security was not surprising due to the crucial role of maize in the Mayan diet. Nearly sixty percent of smallholders who were food insecure were also maize insecure. While this may not seem like a profound association at first glance, when considering the evolution of free trade agreements such as DR-CAFTA over the past decade, the profound importance becomes evident.

Before the implementation of free trade agreements such as DR-CAFTA in the 1990's, maize imports accounted for a meager 4 percent of national consumption, however since the implementation of free trade agreements maize imports constitute nearly one-third of the Guatemalan maize supply (Isakson, 2013). For these reasons, competition of cheap imported maize in regional markets now heavily competes economically with locally produced maize. These trends also lead to decreases in diversity and quantity of maize produced, which gradually undermine local food and maize security and sovereignty. Maize agrobiodiversity is also decreased in this process, which also implicates immense future repercussions. The decimation of vital global reserves of maize genetic diversity tremendously jeopardizes future food security worldwide.

Potential remedies for these alarming trends include at foremost economic and political protection from market flooding. Maize holds critical importance as a staple crop, thus the promotion of market flooding of foreign maize on Guatemalan markets through agreements such as DR-CAFTA decrease national food security.

7.2.3 Food System Re-Localization

The high levels of production of crops for sale at the market implicate a huge amount of local food production is now exported while at the same time, malnutrition and food insecurity remain a component of daily life in Lake Atitlán. Interestingly, farmers who cultivate solely for the purpose of selling their products on market were found more likely to be food insecure in this study, suggesting volatile and weak local markets. This development is likely to increase in the future: farmers in this study revealed that they consider market production and production of crops for export a very strong future opportunity for the development of their farms. The most commonly cited vision for the future of farming systems in this study was the dream of increasing crop production, followed by the vision of selling more crops on the market for economic gain.

A strong example of the correlation between market liberalization polices and the manifestation of agricultural practices chosen by smallholder farmers may be considered through production trends in non-traditional crops. The impact of economic trends profoundly shifted the hegemonic production model in Guatemala over the last decades, as may be elucidated by Isakson (2013) "between 1985 and 2010, the quantity of land dedicated to non-traditional agricultural exports from Guatemala has increased by some 280 percent."

Analogously, the adoption of non-traditional export crops in Guatemala has required increasing applications of synthetic pesticides that have contributed to rampant soil degradation, and been correlated with the growing incidence of cancer and many other health problems (Carey 2009; Isakson 2013).

Potentials include the promotion of increased food system re-localization, a concept that would involve devolving the quantities of export-led production towards local buyers, consumers, and economic platforms. This concept holds immense potential within the Atitlán food system, as the basin is the second most visited tourist destination in all of Guatemala. As such, there is an enormous flux of tourists and businesses that cater to travelers. In this way, local agricultural markets could find ample business. Other promising possibilities include direct sales, on-farm value addition of agricultural products, creation of local farmers markets, regional product labeling, cooperatives, agritourism, and use of fair trade labeling could immensely improve the opportunities of smallholders in the Atitlán basin and simultaneously invigorate the local economy, stimulating creation of local sustainable livelihoods.

7.3 Agricultural Cropping Systems, Environment, and Adaptation

7.3.1 Climate Change Adaptation Research

While perception of climatic change was extremely high (85%), and subsequent agricultural adaptations were widely reported (~ 70 %), household maize sufficiency was reported to be lower among farmers who had delayed planting, which was the most commonly chosen climatic adaptation in all villages and among all ethnic groups.

Ninety-five percent of farmers interviewed in this study perceived some form of climatic change, including temperature increase, less rain, more rain, and delayed onset of winter. Farmers adapted a variety of approaches in order to mitigate losses from these environmental changes. Resultantly, the bulk of farmers chose to delay planting their crops, a choice which later implicated a larger propensity towards household maize insecurity (61.50%). This may highlight the truly complex and uncertain challenges faced by farmers worldwide in the face of climatic change and adaptation. It also magnifies the importance of ensuring that the best possible agronomic adaptations are defined and disseminated in the future.

Francis and colleagues (2013) explain that these trends are likely to continue, "Future food production will be constrained by the scarcity of fossil fuel and fresh water as well as increasing intensity and unpredictability of weather events and climate changes." These developments also highlight the immense importance of increased research of appropriate climate change adaptation techniques within the agricultural sector. The agency demonstrated by farmers in their choice of adaptation decision-making processes are also extremely important for future research agendas to ensure that appropriate climatic change adaptations are accepted and implemented in practice. The perceptions and agency demonstrated by smallholders in this study implicates value in merging research with participative inquiry and traditional knowledge for climate change adaptation studies.

7.3.2 Promotion of Marginal Traditional Crops

Colossally high levels of household food insecurity were reported throughout farmers in this study (55%), and prevalence of household maize insufficiency (57.89%) also reaches incredibly elevated levels. This is consistent with literature on the subject, whereby chronic undernutrition rates among indigenous children in Guatemala remain at 69.5%, and stunting rates due to malnutrition impact a shocking eighty percent majority of indigenous Guatemalan children (World Food Programme, 2014). Also consistent with the findings of this study, a recent study by MAGA (2013) concluded that there is a chronic malnutrition rate of 60.4%, suggesting that the figures of this study are somewhat low.

While there are likely many drivers inducing and perpetuating these indices, one notable potential highlighted in this study was a case study of nutritious traditional agricultural crops that were once commonly consumed within the case study region. In order to highlight the correlation between crop agrobiodiversity of traditional crops and indigenous nutrition, this study included questions pertaining to the consumption and cultivation of traditional crops that were historically cultivated and consumed Lake Atitlán food system. Because of time constraints, a sample of a few crops was chosen: maize, chipilin, izote, chaya, chia, and amaranth. Smallholder farmers were questioned pertaining to their practices of cultivation and consumption of these crops. Sample crops were chosen via the following criteria: (1) they are all traditional Mesoamerican agricultural crops, (2) all crops were historically cultivated within the food system, (3) exhibit high nutritional value, (4) and are crops already promoted by local organizations.

Knowledge of traditional crops and agricultural practices seems to have been lost at an alarmingly rapid rate. Among the case studies of key nutritious crops that were cultivated in the area in the past, only 2 out of 5 crops were consumed or cultivated. This suggests immense potential for increasing food and nutrition security through promotion of locally viable crops. Chia, amaranth, and chaya held tremendous potential to increase regional food and nutritional security, while izote and chiplin are already central to the diet of most smallholders, with reported consumption rates of 77.50% and 95% respectively.

Therefore, promotion of the production and consumption of these key crops is very likely to positively benefit regional food and nutritional sovereignty within the food system case study. Food insecure households were also more likely to consume these crops, suggesting that foraging of these crops are already a pre-existing survival strategy among food insecure households. More information regarding crop genetic erosion, the importance of agrobiodiversity for regional food security, and the nutritional values of crops mentioned are highlighted in the appendix.

Other potentials emergent from this study insinuate that the promotion of agricultural benefits, agroforestry systems, and milpa systems may also increase the likelihood of household food security.

7.3.3 Crop Diversification

The erosion of traditional agricultural practices and crops became magnified during this study; therefore smallholders were questioned regarding their views regarding the drivers of these changes. Over ninety percent of respondents perceive overall loss of traditional agricultural practices and crops. Lack of land, lack of seed, and economic influences are the most prominent causations of loss mentioned by farmers. Notably, lack of land may impact varieties of maize cultivated, as space is needed to separate open-pollinated maize.

One simplified solution to this increasingly loss is to promote greater crop diversification throughout the food system. Ironically, the results of the SWOT analysis reveal that farmers cited crop diversification as their largest opportunity for the farm system (n= 11). Therefore, promotion of crop diversification would also likely be implemented and adopted among smallholders. Additional information regarding the multitude of ecological and nutritional of crop diversification can be found in the appendix. Likewise, food system relocalization, policies that protect local markets from flooding, and more equitable land tenure policies are also hugely likely to conserve traditional production systems and crops.

7.3.4 Promotion of Organic Agriculture

Over sixty percent of farmers indicated that they perceived negative human health or environmental impacts from agrichemicals and fertilizer application. Frequently cited health impacts included severe headaches, higher rates of infant mortality, and generally less healthy children. Commonly cited environmental impacts included contamination of water sources, cyanobacteria in Lake Atitlán, decreased soil quality, more crop diseases, loss crop yield, and less tasty food.

The immense scale of adoption of Green Revolution technologies in Lake Atitlán may well understood through the simple fact that 38 out of 40 farmers interviewed apply agrochemicals or fertilizers to their crops. Farmers often cited that agrochemicals have been used within the food system for about twenty years, representing a very short time to ignite such a scale of adoption.

Correspondingly, 37 out of 40 respondents were enthusiasm and interested about training and possible adoption of organic agricultural practices, citing a myriad of perceived benefits for human and environmental health. Some such perceived benefits of organic methods include: improved soil fertility, better food quality, better maize quality, and because of the negative impact of agrichemicals on water sources. Additional benefits of organic practices were considered to be better for human health, and lastly to decrease the expenses of agricultural inputs.

Organic agriculture holds immense potential as a form of watershed management targeted to decrease agricultural inputs from Lake Atitlán, which is plagued by cyanobacteria blooms that will likely continue without attention. Organic agriculture may truly hold remarkable sway in this regard, as many studies have concluded that management of phosphorus remain critical to maintenance of water quality, and with few exceptions management of phosphorous inputs has led to recovery of watersheds facing threat of eutrophication (Rejmankova et al., 2011). Because of these factors and the widespread interest indicated by farmers throughout the Lake Atitlán basin, incentives and promotion of organic agriculture may hold a great deal of future promise.

7.4 PAR: Crop Agrobiodiversity Conservation

7.4.1 Community-based Seed Conservation Initiatives

Overall, indications of seed spatial flow suggest that traditional seed varieties may still exist: farmers are most likely to source their seeds from neighbors or family members. The low frequency rate of purchase of seed from the market highlights that although traditional seed systems were reportedly somewhat eroded, the systems are not extremely flooded by externally sourced seed: only 10% of farmers interviewed reported purchase of seed from the market. The mere fact that genetic materials are exchanged is notable, and as an indicator of the levels of agrobiodiversity perpetuated and maintained on farms throughout the food system. The ways in which farmers obtain their seed was investigated in this study is best summarized by a recent study in Peru on agrobiodiversity conservation (Stromberg, Pascual, & Bellon, 2010), "Farmers' ways of obtaining seed generate temporal and spatial seed flows… these seed flows are mediated by social relations that entail different types of rules and have an important associated knowledge base."

Additionally, practices of keeping seed from previous harvests are widespread in the food system, at a rate of 75%, however some respondents indicated that the practice might be declining. These existing seed systems exhibit notable importance, because within the act of saving seed genetic diversity are continuously passed between generations (Stromberg, Pascual, & Bellon, 2010). Further, additional studies indicate that in the Global South, "farmers rely on themselves for their own seed or obtaining it from others who saved it (Stromberg, Pascual, & Bellon, 2010)."

The largest challenges in regional seed acquisition identified through this research include the expensive cost of seed, followed by loss and difficulty to locate seed. Increased price volatility of seed and food resources caused by market speculation was perceived by one farmer who cited that the price of seed can change significantly within a short period of time. This trend may also be curbed by increasing protection from market flooding of imported products. Overall lack of access to appropriate seeds and loss of locally appropriate genetic resources may imply major ramifications on food security, and in fact the evidence may already be implied in the indices of food and maize insecurity found in this case study. Farmers also mentioned seed improvement as one of their dreams for the future vision of their farm systems.

No community-based seed banks or indigenous seed conservation initiatives in this study apart from the seed conservation initiative at the case study farm, IMAP. This question was posed with intention to attempt to identity possible conservation networks to collaborate with the case study farm, IMAP. The fact that no seed saving networks or initiatives were identified highlights the importance and immense potential of upscaling efforts in all villages throughout Atitlán to increase efforts of in-situ and ex-situ seed conservation. Most alarmingly, farmers reported difficulties to acquire seeds to produce milpa, which is perhaps the most crucial indigenous agricultural system of Mayan people today. Further information regarding the titanic importance of milpa systems can be found in the appendix.

Sixty-five percent of farmers were interested in exchange of plant genetic resources within the Atitlán basin. Farmers who were disinterested in participation in such initiatives cited lack of confidence in the quality of seeds from other villages (which also largely correlates to increase sharing of genetic resources between Kaqchikel, Quiche, and Tz'utujil ethnic groups). Because of these responses, as well as the associations between ethnic identity and crop genetic diversity among

Mayan groups, community-based seed conservation strategies should largely take the approach of village-level conservation strategies. Insularity and disinterest in regard to seed exchange may also be seen as a defense mechanism and strength against contemporary forces of market flooding and against saturation of foreign seed.

The only food system level seed-sharing scheme identified in this study is hosted by the case study farm system (IMAP), in which indigenous seed varieties have been distributed to over 20 elementary schools from villages and hamlets throughout the Atitlán food system as part of IMAP's "Sustainable School Gardens" project. Notably, this initiative includes multiple practical training sessions covering permaculture and organic farming practices for one teacher and one governmental agricultural extensionist from each school pilot project. Through this initiative, local children are now receiving basic training in sustainable agricultural practices as well as permaculture design principles. This project includes the formation of a training manual, and is anticipated to be upscaled to other areas of Guatemala in the future.

In light of the current situation of seed systems assessed in Lake Atitlán, at foremost the promotion of in-situ and ex-situ agrobiodiversity conservation schemes should be promoted. Given the characteristics of the case study, community and village-based conservation schemes may be the best option. Further potentials include policies which promote the conservation of agrobiodiversity, protection against market flooding, crop diversification, seed exchange fairs, and educational and capacity building for greater importance of the importance of crop agrobiodiversity conservation.

7.5 Viability and Limitations of the Study

One notable discernment of this study was the use of multiple methodologies, however these methodological frameworks proved to be quite complementary overall. However, it remained a notable weakness that there was no other studies found which implicated a use of Soft Systems Methodology and Participatory Action Research in tandem, therefore methodological guidance was lacking and possibly inappropriately approached at times. Overall, Soft Systems Methodology and Participatory Action Research were found to be very useful in regards to field research conducted in the Global South, and were especially effective at ensuring a research approach that was grounded in both culturally and ecologically appropriate inquiry.

Following the steps of SSM also ensured that the research corresponded with the actual situation of the farm and food systems. This was demonstrated when the first project attempt proved unviable just before implementation. Soft Systems inquiry requires comparison between "real world" and "conceptual world" frameworks at multiple times, and this fact aided immensely in assessing the viability of research conducted.

Principles of adaptive management were also very useful in accommodating the preliminary "failed inquiry", and in combination with the work previously done for Soft Systems Methodology and PAR, it was possibly to simply slightly backtrack the research process without loss of structural integrity to the thesis inquiry. The use of these methodologies in unison proved to be a good combination for inquiry that included holons and holarchies (farm and food system), allowing for SSM to guide the largest scale of inquiry, and PAR to tailor the research process with key stakeholders from the locale. The combined use of SSM and PAR also has implications on maintaining the aspect of agroecology as a social movement by magnifying voices of those generally marginalized in mainstream discourse.

The union of these methodologies provided a strong orientation throughout the course of the study. However, it must also be noted that the inclusion of participative research was extremely time intensive. Other limitations of combined usage of SSM and PAR processes may include the relative complexity and burden of adhering to multiple methodological frameworks. Additionally, PAR processes and inquiries are highly dependent upon emergence: upon the production of research sub-questions in tandem with stakeholders. This also required that subsequent research methods were chosen in order to gather and analyze these emergent research sub-questions. In this case, because large-scale data collection of farmers from around the food system was necessary, Grounded Theory Methodology was chosen.

Grounded Theory Methodology proved to be an excellent tool to conduct interviews at the food system level, as it allowed theories to be generated from the data collected. This process was very useful when compiling and streamlining the vast amounts of data collected. The use of parallel qualitative and quantitative analyses was also enormously effective in gaining insight into the phenomenological aspects of this study. The use of quantitative and qualitative research frameworks within Grounded Theory allowed for triangulation of data, and further triangulation of data was also processed through Grounded Theory, PAR, and SSM processes. Resultantly, the use of multiple methods may be therefore more likely to produce data of higher validity.

Limitations of this study included a small sample size as well as remarkable time and funding constraints. Participation was also limited at the food system level to only one interview per farmer, although ideally follow-up interviews might have also been conducted. The quandary of language plurality was also a notable limitation, as this study was carried out across five languages. Likewise, some agricultural practices proved to be extremely difficult to explore due to translation difficulties in Quiche language, and were therefore marginalized from this report. Formulation of focus groups would have also been very useful in this situation in order to upscale participation, however the immense task of multi-lingual translation and facilitation became enormously limiting.

Other limitations may include that the fact that data was gathered using self-reported metrics. During food system interview processes, participant observation revealed a tendency for farmers to sometimes appear shy or embarrassed when questioned about household food security. Because of this, the actual rate of food insecurity is suspected to be somewhat higher than actual responses.

8. Conclusion

Participative research was undertaken with Mayan smallholders in order to highlight constraints and potential for future agroecological development in Lake Atitlán, Guatemala. The study was set in a context of extremely high indices of poverty, food insecurity, and malnutrition in an area characterized by weak governance and ecological discordance. The research was also located with a region of vast socio-cultural and biological diversity, characterized by enormous wealth of natural resources as well as opulent cultural and agricultural heritage.

Spatial scales of household, community, and regional hierarchical systems were studied in order to highlight interrelationships and manifestations between macro, meso, and micro causalities. The largest spatial scale of the study was limited to the greater "food system" a socially constructed spatial level which was in this instance demarcated by the boundaries of the caldera basin of Lake Atitlán. A key farm system and school, IMAP was focused upon in order to facilitate participatory action research, and likewise the resulting potentials concluded from this study will later be expounded upon and possibly acted upon by the same organization, concluding the full cycle inquiry constituent of participatory action research.

Semi-structured interviews were then gathered in four villages in Lake Atitlán: Panajachel, Santiago Atitlán, Santa Cruz la Laguna, and San Juan la Laguna, with consultancy of smallholder farmers from the three unqiue Mayan ethnic groups living within the food system: Kaqchikel, Quiche, and Tz'utujil. This process again highlighted the spatial hierarchical components of this study, representing 41 unique farm systems component of the greater Atitlán food system. Efforts to include the voices of indigenous small-scale farmers were made at all points possible during the research process in order to identify pathways for change as acknowledged by farmers who contend with these challenges on a daily basis. Resultantly, a myriad of valid and thoughtful insights were gathered and synthesized in this report. The plenitude of factors constraining sustainable development in the Atitlán basin as emergent from this study are prodigious, however emergent potentials hold promise for a more prosperous future.

Conclusions of this study indicate that some of the most notable constraints to agroecological development in Atitlán are perpetuated by current political and economic policy, thereby indicating that much of the power for change lies within the hands of few. With high corruption indices, Guatemala's agrarian policy will continue to be constricted by weak governance at the national level without immense changes. Most notably, protection of the agricultural sector must include market protection against flooding of imports, which cannot be pursued under the statues of the DR-CAFTA free trade agreement. The impacts of these policies upon rural development have been demonstrated to be tremendous hurdles for indigenous smallholders in this case study, indicating correlations between these trade agreements and the prevalence of poverty, food insecurity, erosion of crop agrobiodiversity, and decrease in traditional agricultural practices undermining the fabric of indigenous livelihoods and communities. Further research is needed to shed light onto impacts of neoliberal globalization and market liberalization upon smallholders and environment in in the Global South.

Additionally, the prevalence of land scarcity among indigenous smallholders in this study and the notable fluctuation of land scarcity amongst subsistence farmers indicates that agroecological land stewardship cannot be maintained under conditions of dire resource scarcity. Trends in poor resource management are again exacerbated by weak governance and magnified by the domination of cartel control in this case study, rendering deforestation and distressed land-use strategies status quo, while simultaneously instigating economic inequalities throughout the regional agricultural value chain.

All of these factors in combination speak volumes and imply that enormous shifts within current economic and political policy must be made. Speculation of this study indicates that political and economic policies currently serve to undermine food sovereignty from Guatemalan smallholders at the regional level, and upon further research may also hold implications for rural indigenous communities throughout all of Guatemala.

The secondary research query of this study was determined in tandem with the rural Mayan farmer's organization and farm school, IMAP, a progression which led to the study of potentials for both in-situ and ex-situ prospects for crop agrobiodiversity conservation within the Atitlán basin. Results indicated high loss of local genetic resources has already occurred within the food system, which smallholders perceived to be caused by lack of land, loss of seed varieties, and the high expenses and fluctuating costs of seed on regional markets. Results also signified that traditional networks for seed conservation and stewardship are still intact albeit rapidly dwindling, with the bulk of farmers indicating sourcing seed from neighbors, family members, or within their own village.

The most compelling potentials identified for future development at farm and food system levels are composed of both external factors and internal factors to the food system. External potentials include attention to land tenure policy and land distribution, revision of current economic policy and trade agreement stipulations, and an urgent need for increased research on viable climate change adaptation strategies for smallholder farmers. Internal potentials include promotion of the consumption and cultivation of marginal traditional crops for increased food and nutritional security, food system relocalization strategies, crop diversification, promotion of organic agriculture, and community-based seed conservation initiatives.

In the face of climatic change and a rapidly globalizing economy concerted efforts should be made to abridge the chasm between academia, policy, and the every day experiences of resource-poor farmers in the Global South in order to collectively mitigate negative repercussions of these tribulations. Without collective action, amplification of adverse impacts will likely continue to be exported to the poorest echelons of the globe, perpetuating vast devastation to human societies and the environment.

Overall, it is notable that while the highlighted potentials were the most noteworthy platforms for change emergent from this study, these options represent only a fragment of beneficent potentials available to the development of the food system. Potentials for agroecological development in Lake Atitlán may only be truly constricted by socio-ecological appropriateness and the limits of imagination.

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Appendix

1. Literature Review: Globalization and Uneven Development

Land Tenure

According to the World Food Programme (2014), Guatemala is one of the most unequal countries in the world, with a Gini index of 53.7. Access to land is tremendously important in Guatemala, as sixty percent of the population are dependent upon agriculture for livelihood – the highest rate in all of Central America (Lastarria-Cornhiel, 2003). Indeed, trends in land ownership are marked by a decidedly slanted distribution: "2.5 % of the country's farms control 65 % of agricultural land, while 88 % of all farms, with an average size of 1.5 ha., occupy a mere 16 % of arable land" (IFAD, 2004).

The origins of this extremely unequal land tenure pattern may be traced through streams of historical trends primarily formed by colonial and neocolonial imperial forces. It is important to note that the sheer ideological concept of land ownership is also a by-product of colonization, as private property did not traditionally exist among the Maya and land was not commoditized in any manner. In fact, for the pre-Colombian Mayans, "private and individual ownership of the land was as meaningless as private ownership of… the weather" (Holley, 1997). Carey (2009), explains the Mayan regard for land, "differences in local agroecology aside, most Maya consider the land sacred; each time before they begin a cycle of work in the fields, they make an offering to the *rajawal* (spirit of the land)."

Since the early invasions by Spanish conquistadors, the commodification of land has been both ideologically and physically imposed upon Mayan groups, a process which has caused a large amount of violence and discord that can still be tangibly felt in Guatemala today. Holley (1997) elucidates, "with colonial rule came the imposition of private property regimes and the logic of marketplace production of commodities which dictated that land be concentrated in fewer and fewer hands and be devoted more and more to export crops. At the hands of colonizers, the Mayans have suffered genocide and exploitation, gradually being driven from their fertile lowlands to live in remote pockets of the less fertile highlands and inaccessible jungles."

These historical events have contributed to the formation of contemporary social, economic, and political structures of present-day Lake Atitlán. Cumulatively, "indigenous peoples are consistently the poorest members of states because settler societies continue to discriminate against them and, in particular, continue to usurp the lands they have traditionally depended on for survival" (Holley, 1997). In present-day Guatemala, roughly 40% of the able-bodied rural population does not own land, therefore the bulk of peasants simply lack enough land to support rudimentary substance needs (IFAD, 2004; Lastarria-Cornhiel, 2003).

Abject rural poverty in Guatemala is largely linked with lack of access to land, and in fact the chief causes of the civil war were also largely associated with the disparity of land concentration and distribution (Holley, 1997; IFAD, 2004; Lastarria-Cornhiel, 2003). Therefore, more equitable agrarian reform could conceivably increase national production of staple crops exponentially and promote food security for Guatemala's most vulnerable and marginalized groups. Smallholder harvests account for approximately sixty percent of total maize production in Guatemala, while they control a meager 16 % of total arable land (Isakson, 2013).

The myriad of impacts imposed upon the peasant population of Guatemala due to the dearth of access to arable land simply cannot continue to be overlooked. Attention to land tenure is not a dismissible factor when attempting to upscale food security and agricultural sustainability, and remains a formidable impediment to development at the most general level.

Guatemala in a Neoliberal Era

David Harvey (2005), defines and overviews key elements of neoliberalism, "Neoliberalism is in the first instance a theory of political economic practices that proposes that human well-being can best be advanced by liberating individual entrepreneurial freedoms and skills within an institutional framework characterized by strong private property rights, free markets, and free trade." Neoliberalism first began to emerge as a global hegemon of political-economic perspectives in the 1970's. Carey (2009) highlights processes of early adoption and integration of neoliberal logic in Guatemala, "In the 1980's, the IMF, World Bank, US government, and some Guatemalan elites pressured the government to adopt neoliberal economic reforms, which (among other austerity measures) discouraged government intervention in the economy in an effort to liberalize markets."

The transition to neoliberal frameworks served to increase tangible economic disparities between the poor and the rich as well as between ethnic groups (MacNeish and Rivera, 2009). MacNeish and Rivera (2009) stress the subsequent manifestations of these impacts on Guatemalan society, "Although the richest segment of the population saw their share of national GDP grow from 62.7 percent in 1989 to 64 percent in 2002, the poorest sector of the population saw their share decrease from 2.7 percent to 1.7 percent." While early impacts of neoliberal globalization clearly contributed to the exaggeration of national patterns of uneven development, the trends were steadily overlooked and Guatemalan markets have continued to become increasingly liberalized.

Markedly, in 2006 the Dominican Republic- Central American Free Trade Agreement (DR-CAFTA) was ratified by the Guatemalan government with the United States (Isakson, 2013). The multifarious impacts of neoliberal globalization policies and trade agreements on smallholder Mayan agriculture have been truly profound, and will be further explored in this study.

Uneven Development

Although neoliberal economic perspectives remain hegemonic in global economic discourses and policies, there have been widespread criticisms to this approach. In the Global South, these political-economic perspectives have been documented to cause widespread ramifications on the populace and environment, constituting a form of structural violence for a variety of reasons.

MacNeish and Rivera (2009), explain, "by setting the context for new forms of economic exploitation (no ownership of the means of production, low wages and poor labor conditions), neoliberalism can be seen to have further contributed to the existing structural conditions for violence in the country, and not only at the macro-level." Isakson (2013) also posits that liberalization of agrarian markets has served to widely aggravate the poverty of peasant farmers.

Overall, elimination and liberalization of trade barriers has encouraged importation of subsidized, cheap staple grains which then compete on local markets at lesser prices than locally produced harvests – slowly competing with smallholders until their products are not marketable, thereby impelling rural to urban migrations (Isakson, 2013; MacNeish and Rivera, 2009). "In sum, the neoliberal restructuring of Guatemalan's agrarian sector has exacerbated economic inefficiently… the agrarian transformation has compounded food insecurity in a country that has one of the highest indices of poverty and malnutrition in Latin America" (Isakson, 2013).

Neoliberal globalization and export-led development acutely impacts indigenous Guatemalans, as evident by trends in peasant dispossession of land and livelihoods. For example, fluctuation of commodity prices has been heavily felt in the coffee industry, where the decreasing value of coffee coupled with intensive integration in capitalist networks has left people without livelihood and land (MacNeish and Rivera, 2009). Overall, neoliberal restructuring has largely diminished the economic autonomy and increased vulnerability of the rural Guatemalan population (Isakson, 2013).

Export-led Development: Production of Non-Traditional Crops

A robust example of the correlation between market liberalization polices and the manifestation of agricultural practices selected by smallholder farmers may be considered through production trends in non-traditional crops (NTX). Smallholder farmers first began to receive loans in the early 1970's through USAID, however as a stipulation to obtain these loans farmers were essentially obliged to cultivate export crops (Carey, 2009). The impact of these economic influences greatly shifted the hegemonic agrarian production model in Guatemala over the last decades, as may be understood through Isakson's (2013) observation that, "between 1985 and 2010, the quantity of land dedicated to non-traditional agricultural exports from Guatemala has increased by some 280 percent." Resultantly, NTX production remains predominately the only pursuit in which rural smallholders can obtain formal credit – contemporary USAID loans are composed of loan guarantees for the purchase of agrochemicals and inputs for export-led production (Carey, 2009; Isakson, 2013).

A study on agrarian restructuring in Guatemala by Isakson (2013) gives insight into the complex and largely obscured interactions between political actors and agricultural corporations, as well as the vested economic gains to be held by promotion of NTX crops in Guatemala:

> "USAID's promotion of NTX agricultural exports was not necessarily well intentioned. [Researchers] maintain that if the agency was genuinely concerned with economic stability in Guatemala and the food security of its citizens, it would have dedicated its resources towards improving employment opportunities and the productivity of domestically oriented food crops. By law, however, USAID is prohibited from promoting agricultural activities that would compete with agricultural exports from the US. In other words, the development agency cannot support food sufficiency in Guatemala because, averaging nearly 400,000 tones of maize per year since 1990, the country is heavily dependent upon imports of US grain. Such policies were pushed by a coalition of powerful agricultural interests in the US and were instrumental to the emergence of the US as the hegemon in the global food economy."

From an agroecological perspective, cultivation of non-traditional crops does not always cogently align either in regards to agricultural production or environmental health. One example of the many trade-offs embedded in this shifting production model may be explicated through a comparison of labor efficiency between Mayan milpa systems and production of non-traditional crops upon the same land. A study by Isakson (2013) concluded that an enormous disparity exists:

production of broccoli and cauliflower were established to demand 228 percent and 360 percent more labor time respectively; and cultivation of snow peas requires an astounding 1,000 percent more labor days than cultivation of a milpa system. In sharp contrast,

> "Most peasant systems are productive despite their low use of chemical inputs. Generally, agricultural labor has a high return per unit of input. The energy return to labor expended in a typical highland Mayan maize farm is high enough to ensure continuation of the present system. To work a hectare of land, which normally yields 4,230,692 calories requires some 395 h; thus, an hour's labor produces about 10,700 calories. A family of three adults and seven children eat about 4,830,000 calories of maize per year, thus current systems provide food security for a typical family of 5 or 7 people (Altieri, 2000)."

Analogously, the widespread adoption of NTX crops has also mandated increasing applications of synthetic agrochemicals that have also perpetuated rampant soil degradation, and been correlated with the raising prevalence of cancer and various additional health problems (Carey 2009; Isakson 2013).

Transition from Indigenous Food Systems to Green Revolution Practices

The shift from traditional Mayan agricultural systems to conventional agricultural practices characteristic of the Green Revolution can be largely traced to the 1960's. At that time period, USAID began promoting Green Revolution fertilizers and pesticides in Guatemala (Carey, 2009).

In the 1990's, the implementation of DR-CAFTA was marked by the saturation of local markets with cheap grains from the North, and was also simultaneously coupled with a time period in which conventional farming inputs were exorbitantly high for smallholder farmers throughout Latin America (Tetreault, 2012). A study by Carey (2009) summarizes subsequent agricultural trends during this time period,

> "Since the costs of fertilizer and pesticides increased faster than the price of corn, profits diminished. Through PL 480 program, for example, the US sent surplus subsidized corn to Guatemala, which it sold for a price lower than the cost of producing corn in Guatemala. Under such circumstances, Mayan farmers could not compete. As a result of indirect

technological determinism, the cycle of synthetic fertilizer prices out-competed small agriculturists in favor of large ones and thereby usurped land from the Maya."

The Political Ecology of Maize

The complex interface between macro, meso, and micro-level interactions that cause tangible impact in the contemporary agriculture of Guatemala today can greatly obscure understanding of cause and effect in both farm and food systems. Therefore, maize was chosen as an example to highlight these interactions because of the pivotal importance of maize in traditional agricultural systems in regards to food, seed, and nutritional sovereignties of Mayan people.

Despite the profound importance of maize on food and nutritional security among Guatemalan's most marginalized and vulnerable groups, the crop was subjected to immense challenges under economic reforms over the past decades. "Between 1961 and 1990, maize imports accounted for less than 4 percent of total consumption… since then, however, imports have increased dramatically, such that they now account for one-third of the domestic supply (Isakson 2013)."

Under the stipulations of the DR-CAFTA free trade agreement, the Guatemalan state is obligated to expand quotas and jettison import tariffs for foreign-produced maize, which is then sold on local Guatemalan markets in competition with local maize harvests, thereby driving down overall value of maize in Guatemalan markets. Under current economic policy, these processes are scheduled to continue well into the future, "specifically, the [DR-CAFTA] agreement requires that import quotes for yellow maize varieties increase by a minimum of 25,000 tones per year until their eventual elimination in 2016; the initial quota for white maize was set at 20,400 tones, a quantity that was ore than double its 2003 imports from the US, and will increase to a minimum of 400 tones per year" (Isakson, 2013).

While the DR-CAFTA free trade agreement was implemented in 2006, by the following year the impacts of these importation quotas were already dauntingly apparent, and the conditions of the free trade agreement had successfully created a captive maize market for US agribusiness. Isakson (2013), highlights these trends, "By 2007, a mere one year after the implementation of the free trade agreement, Guatemala was importing 36 % of its total maize consumption… Nearly all of Guatemala's maize imports are from the US: the US supplies 100 percent of its yellow maize imports and 71 percent of its white maize imports" (Isakson, 2013). In light of these statistics, the implementation of DR-CAFTA has palpably decreased maize sovereignty and food sufficiency in Guatemala by increasing local and national dependencies on external markets.

2. Literature Review: Agrobiodiversity and Importance of Traditional Crops for Food Security and Sovereignty in Guatemala

As previously stated in this research, chronic undernutrition rates among indigenous children in Guatemala remain at 69.5%, and stunting rates among indigenous children in the country reach a shocking 80 percent (World Food Programme, 2014). This may be seen as a rampant public health concern, as well as a violation of the basic human rights, defined by the United Nations (2002) as:

> "The right to food is… the right to have regular, permanent and free access, either directly or by means of financial purchases, to quantitatively and qualitatively adequate and sufficient food corresponding to the cultural traditions of the people to which the consumer belongs, and which ensures a physical and mental, individual and collective, fulfilling and dignified life free of fear."

Upon rudimentary analysis, regional food insecurity trends are not as much a question of food scarcity, but of food quality and nutrient diversity. According to the World Bank (2004), "for most households in Guatemala, access to calories is not a problem, however there is limited access to nutritious food."

Traditional Mesoamerican agronomic practices historically included high levels of plant diversity, therefore in parallel the present dearth of dietary diversity may be seen as a comparatively novel phenomenon. Indeed, historically the Aztec diet comprised up to 229 diverse plants (Ayerza and Coates, 2005). An FAO report (1994) expounds: "most of the crop displacement seems to have take place in modern times, especially since the second half of the nineteenth century, by which time the former Spanish and Portuguese colonies were independent countries and capitalism and commercial agriculture were expanding."

Before the arrival of European conquistadors, even the lowest stratums of Mesoamerican societies ate nutritionally more balanced and healthier overall diets than are consumed today by the people of Mexico and Peru (Ayerza and Coates, 2005). Universally, micronutrient deficiencies have emerged as a critical public health issue largely as a result of the colossal loss of nutrient dense food crops from local food systems in favor of monoculture production of staple food crops (IAASTD, 2009; Zander, 2014). This process of decreased dietary diversity is rampant throughout Latin

America; "economic transitions from subsistence to market-based economies have led to an increased availability of westernized processed foods, which are calorie-dense but nutrient-poor" (Nagata et al., 2011).

Globally, micronutrient deficiency directly impacts over 40% of the population, and is felt primarily among women and children in low-income countries (Zander, 2014). Nagata and colleagues (2011) explain, "The movement away from local farming diets to diets consisting of highly processed foods decreases both dietary diversity and nutritional status, and leads to deficiencies in macro and micro nutrients, which can adversely affect health through growth, physical and cognitive development, reproduction, and the immune system." Generally, increased diversification of diets emerges as a cheap however indispensable long-term approach to achieve better quality rural diets, thereby crop agrobiodiversity may be understood to improve nutrition security (Zander, 2014).

It is also crucial to consider that food and nutritional insecurity in Guatemala must also be considered as a direct result of greater structural problems, including political and economic inequalities and systematic marginalization (Pine and de Souza, 2013). Indices of poverty, malnutrition, and access to food among indigenous people in Guatemala imply widespread privation, and the gravity of the situation may also be understood as a violation of food sovereignty. Via Campesina (a global social movement), has defined food sovereignty as 'the right to produce food on our own territory' (Demarais, 2002). Pimbert (2010) explains, "one of the clearest demands of the food sovereignty movement is for citizens to exercise their fundamental human right to decide their own food and agricultural policies." Further expounding upon this notion, Via Campesina has made clear delineation between the concepts of food security and food sovereignty,

> "Food is a basic human right. This right can only be realized in a system where food sovereignty is guaranteed. Food sovereignty is the right of each nation to maintain and develop its own capacity to produce its basic foods respecting cultural and productive diversity. We have the right to produce our own food in our own territory. Food sovereignty is a precondition to genuine food security" (Desmarais 2002).

The ontological origins and impacts of larger structural causes of food insecurity will be explored in the following sections.

Crop Agrobiodiversity in Guatemala

The definition of agrobiodiversity used within this study largely refers to, "the variety and variability of living organisms that contribute to food and agriculture in the broadest sense, and the knowledge associated with them" (Jackson et al., 2007). Whereas planned agrobiodiversity signifies, "the biodiversity of crops and livestock chosen by the farmer" (Jackson et al., 2007). Within this scholarship, primary focus was placed upon analysis of planned agrobiodiversity of crops because of the fact that livestock farming is not a common practice among smallholder farmers in the periphery of Lake Atitlán principally due to acute land scarcity.

Indigenous farmers have domesticated 5,000 crop species and have also contributed over 1.9 million varieties of plants to global crop genetic resources (Altieri et al. 2012). Indigenous Mesoamerican populations have bequeathed numerous significant crops to contemporary agriculture, such as maize, beans, squash, tomatoes, cacao, avocadoes, agave, and cotton (Ross-Ibarra and Molina-Cruz, 2002).

Apart from notable contributions to increasing dietary diversity and thereby promoting a more nutritious diet, crop agrobiodiversity provides an abundance of ecological benefits. In addition to nutritional gains, crop genetic diversity increases the stability of cropping systems, thereby allowing farmers to exploit a greater variety of ecological microclimates (Altieri et al., 2012). In the face of climate change uncertainties, the value of crop genetic diversity maintained in-situ by indigenous farmers globally is becoming increasingly valuable, and even moreso by observations that on-farm biodiversity is closely connected to resiliency of farm systems faced with extreme climatic events (Altieri et al., 2012; Swiderska et al., 2011). The vast genetic diversity of traditional landraces and crop varieties also enables the crops to better endure immense environmental stresses, such as drought or nutrient deficit (Swiderska et al., 2011).

IAASTD (2009) describes, "In both local and national food systems, policies and programs to increase crop diversification and dietary diversity will help achieve food security." In light of these manifold benefits, crop agrobiodiversity conservation both on-farm and at the regional levels have been hypothesized as an important route towards increasing agroecological production through increasing beneficent ecosystem services and ecological resiliency, with overall less harmful cumulative environmental impacts (Jackson et al., 2007).

Marginalization and Genetic Erosion of Indigenous Crops

As summarized by the recent IAASTD Report (2009):

> "Loss of biological diversity results from repeated use of monoculture practices; excessive use of agrichemicals; agricultural expansion in to fragile environments; excessive land clearance that eliminates patches of natural vegetation; and neglect of indigenous knowledge and local priorities."

Among indigenous societies, farmers frequently maintain a variety of cultivars for a single species, therefore the concept of genetic marginalization should also be magnified to include perception of loss of traditional cultivars - including by replacement of a small number of variants of that same species (FAO, 2004). System marginalization of traditional Mesoamerican crops is not a novel occurrence, and may first be attributed to the arrival of the Spanish in 1493, which marked the commencement of the colonization of indigenous food systems.

During early colonial occupations, even staple Mesoamerican crops were replaced with plants brought by the conquerors, and over time sustenance partialities of indigenous populations were so influenced by European food habits that demand for traditional crops waned considerably (Ayerza and Coates, 2005; FAO, 2004). Additional factors that contributed to the relegation of many traditional plants that were once commonplace can also be attributed as direct result of, "the destruction of hydraulic infrastructure, the annihilation of local populations, the development of livestock rearing, etc. (FAO, 1994)."

Maize, Milpa and Nutrition

In several Mayan languages Guatemala is referred to as *Iximulew*, or "The Land of Maize", alluding to the vast significance of maize in the territory (Isakson, 2013). Maize domestication is hypothesized to have occurred around 7000 BC. in Oaxaca (Mexico) from the forbearers of Mayan farmers, who developed several thousand varieties of maize adapted to a wide range of microclimates from Mexican annual teostinte (van Etten, 2006; Isakson, 2013).

The great importance of this staple crop is illuminated by the fact that the Mayan calendar and worldview bases the year around the cycle of planting and harvesting milpa (Carey, 2009). Maize has been venerated throughout the ages in Mayan religious and cultural ceremonies, and sacred Mayan religious texts such as the Popol Vuh clearly express the notion that maize is a vital component in terms of ethnic identification, mythological origins, and even the very existence of Mesoamerican people (Carey 2009; Staller, 2010). Maize has also been considered a deity among many Mayan and Aztec groups, and further Staller (2010) expounds, "as a cultural marker, in the Yucatan a man's identity is defined by his milpa."

The singular importance of the milpa system on securing both food and nutritional sovereignty in Guatemala is truly singular, as is best summarized by Isakson's (2013) analysis of the milpa system:

> "On average, rural Guatemalans consume more than 1 pound of maize per day (454 grams), generating 72 percent of the calories and 82 percent of the protein ingested. The traditional preparation process known as nixtmalization, which entails soaking the dry maize kernels in a solution of alkaline limestone, adds calcium to the diet and releases niacin and amino acids that would otherwise be indigestible. Consuming nixtamizalized maize in conjunction with other milpa crops such as legumes (that provide complementary amino acids) tomatoes and chilies (that provide vitamins A and C and fruity acids) and avocadoes (that provide fats), the milpa diet is a healthy, nutrient-complete package. Moreover, given that the milpa crops are endemic to Mesoamerica, they require few inputs and are remarkably resilient to local environmental stresses, and are a reliable source of food underlying the otherwise precarious livelihoods of the rural poor."

In Guatemala maize represents the cheapest source of calories available to the rural poor, and thus the Guatemalan diet also derives its largest share (46%) of caloric intake from maize and maize products (World Bank, 2004). It is therefore not wholly surprising that a recent study in Guatemala found that although most smallholders appreciate that export crops may return economic profit, 99 % of households interviewed believed that maintaining the practice of milpa was an imperative component of household food security (Isakson, 2009; Altieri et al., 2012).

Chaya

A nutritious leafy vegetable commonly known as "chaya" or "tree spinach" *Cnidoscolus chayamansa* was researched in this study for its vast historical use and nutritional value in the Sololá region. Domesticated in Pre-Colombian times, chaya was part of a staple diet and was the chief dietary source of leafy vegetable for the indigenous people of both Guatemala and Mexico (Kuti and Torres, 1996; Ross-Ibara and Molina-Cruz, 2002). Historically, chaya has been used in Mesoamerica as a food, a living fence post, and an ornamental plant by at least ten Mayan ethnic groups (Ross-Ibarra and Molina-Cruz, 2002).

Edible portions of chaya plant closely resemble the taste of spinach when cooked, however the plant also contains substantially greater amounts of nutrients than spinach leaves including several essential mineral micronutrients (Kuti and Torres, 1996). "Chaya can be considered as an excellent regional nutritional source, containing protein, vitamins (A and C), minerals (calcium, iron, phosphorous), niacin, riboflavin, and thiamine… However some precaution is necessary: chaya leaves contain hydrocyanic glycosides, a toxic compound that can easily be destroyed by cooking" (Kuti and Torres, 1996). Because of this inherent toxicity, the practice of boiling chaya is the default method of preparation among the Mayan Kaqchikel and Tz'utujil who prepare this dish.

Additionally, chaya holds immense potential for promotion of rural nutrition in the face of climate change because it is both drought and disease resistant (Kuti and Torres, 1996; Ross-Ibarra and Molina-Cruz, 2002). Hence, chaya is a superlative addition to Neotropical smallholder systems.

Amaranth

Amaranthus hypochondriacus (commonly known as 'amaranth') was one of the staple and most important crops of Pre-Columbian Mesoamerica, constituting one of the five most essential plants in the basic diet of early civilizations (FAO, 1994; Tucker, 1986). Historically, amaranth was widely cultivated in Mesoamerica, used as a both staple food as well as for religious ceremonies until the early sixteenth century when Spanish conquistadors banned the crop because of its sacred role in Aztec religion (FAO, 1994; Tucker, 1986).

The repercussions historical ban on the cultivation of amaranth can be felt profoundly among the largely malnourished indigenous population of Guatemala today: amaranth's unique and plentiful nutritional properties make it a precious food resource among malnourished populations. Amaranth is an, "almost 'perfect' protein, comparable in nutritional quality to eggs, and meets virtually all the body's protein requirements", also containing high dietary fiber, vitamins A and C, riboflavin, and folic acid (Tucker, 1986). While the most common use of amaranth is for grain, the indigenous people of Sololá have historically also consumed amaranth leaves, as a preparation similar to spinach and the leaves may also be consumed raw.

Izote: *Yucca guatemalensis*

The Yucca family includes approximately 40 perennial shrubs and trees; they are dense, upright, and rhizomatous evergreen shrubs (Brown and Cooprider 2012). In Guatemala, the most abundant variety is *Yucca guatemalensis*, commonly known as “izote” (Chizmar, 2009).

Yucca are incredibly resilient plants which may have many benefits for farmers during periods of food scarcity of climate irregularities: they are easily propagated, have low nutritional requirements, high drought tolerance, high salt tolerance, wind tolerance, and additionally tolerate both dry and sandy soils (Brown and Cooprider, 2012; Chizmar, 2009; MacVean, 2009).

The tough fibrous stems and leaves of the yucca were commonly used by the aboriginal peoples in basketry, pottery making, for clothing and footwear, and diuretic tea can also be made from the leaves (Brown and Cooprider, 2012; MacVean, 2009). The plant may also be used to make a living fence, the inner part of the trunk can be used in a decoction to treat kidney problems, and the roots can be used to produce soap (MacVean, 2009).

In Guatemala, the white flowers of *Yucca guatemalensis* are commonly consumed in rural areas. Among the Maya Kaqchikel the white yucca flowers are prepared by first boiling for twenty minutes to reduce bitterness, and are then fried with onions and tomatoes. Izote flowers have a flavor similar to artichoke.

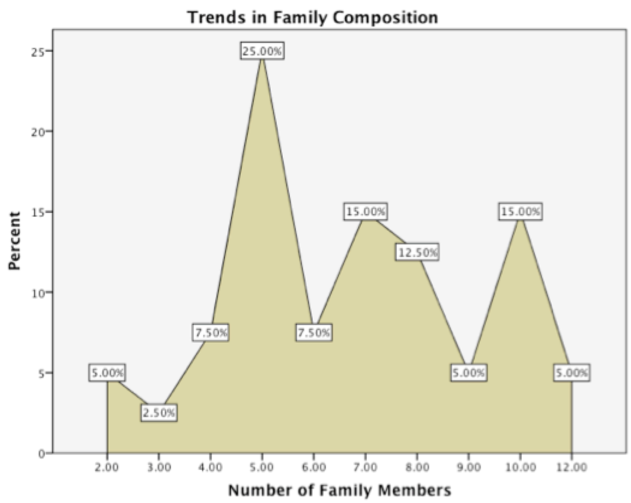
Chia *Salvia hispanica L.*

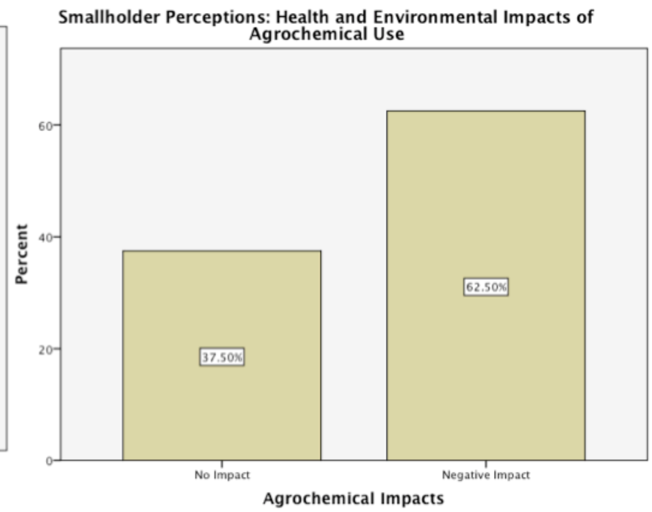
Chia (*Salvia hispanica L.*) was one of the four main Aztec crops at the time of Columbus’ arrival in the New World (Ayerza and Coates, 2005). According to Ayerza and Coates (2005), “chia seeds contains oil with the highest omega-3 fatty acid content available from plants, and is an excellent source of calcium, magnesium, potassium, iron, zinc, and copper.” This crop has been largely lost from Mayan food systems in the Guatemalan highlands.

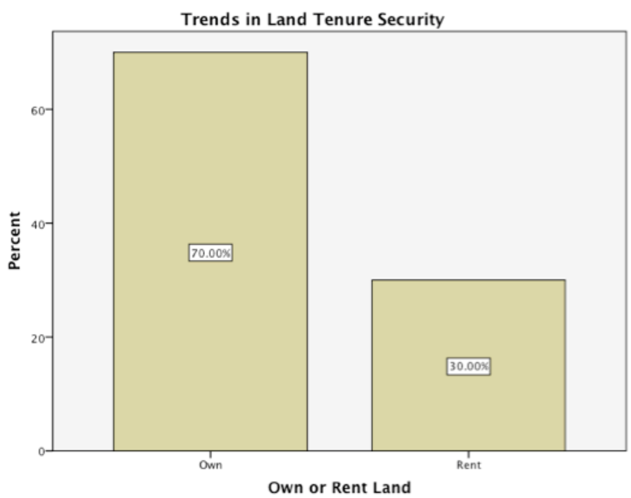
Chipilin *Crotalaria longirostrata*

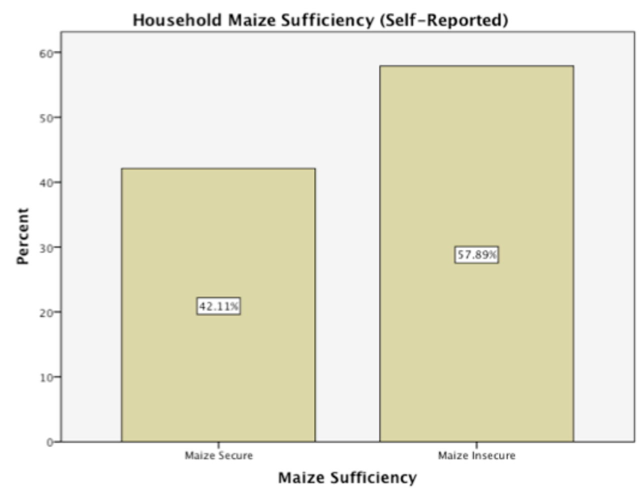
Chipilin (*Crotalaria longirostrata*) is a staple Mesoamerican crop because it can be farmed inexpensively as part of agroforestry systems, and additionally it is densely nutrient rich in protein, carbohydrates, fiber, calcium, iron, as well as vitamins A, B1, B2, and C (Isidoro and Messier, 2009). The leaf matter is edible and is often traditionally prepared in soups and tamales. Even today, this crop is still widely consumed among the Mayan people of Lake Atitlán, although it holds low market value due to its abundance in regional agroforestry systems. This crop is commonly consumed during food shortages, as can be easily foraged.

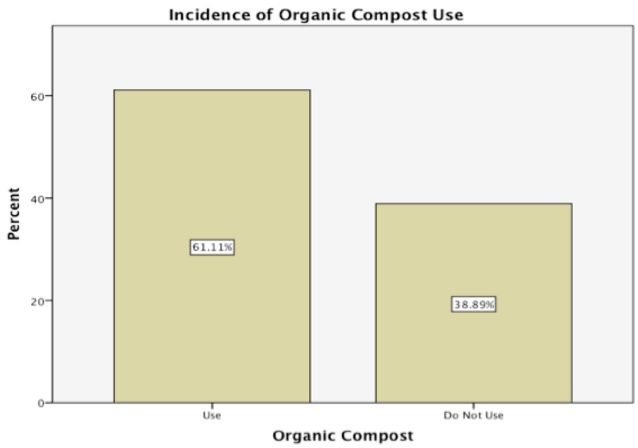
3. Additional Data Tables (Food System Results):

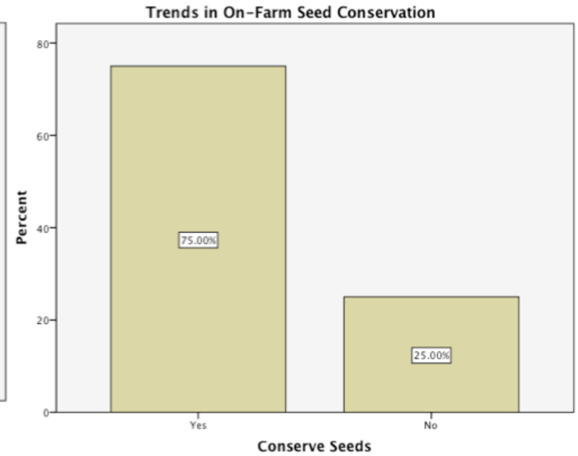









Incidence of Organic Compost Use
Percent
0
20
40
60
61.11%
38.89%
Use
Do Not Use
Organic Compost


Trends in On-Farm Seed Conservation
Percent
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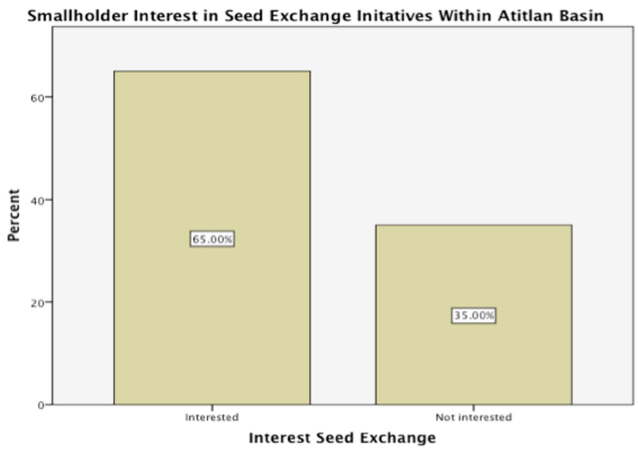
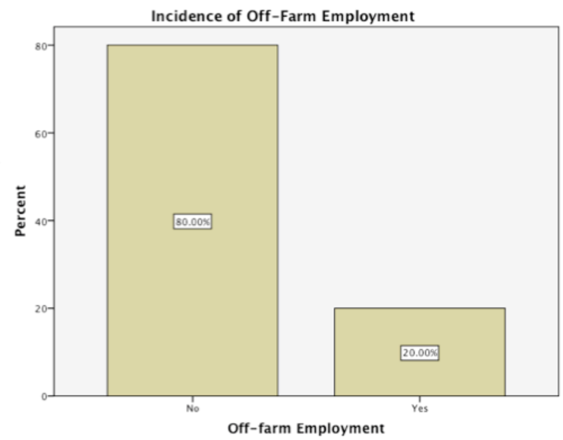
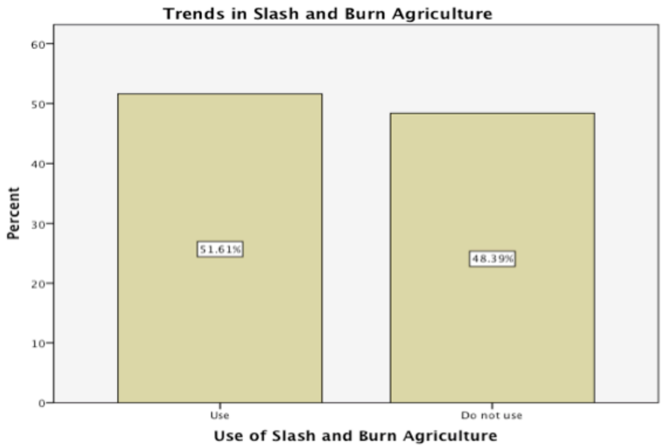
20
40
60
80
75.00%
25.00%
Yes
No
Conserve Seeds


Smallholder Interest in Seed Exchange Initatives Within Atitlan Basin
Percent
0
20
40
60
65.00%
35.00%
Interested
Not interested
Interest Seed Exchange


Incidence of Off-Farm Employment
Percent
0
20
40
60
80
80.00%
20.00%
No
Yes
Off-farm Employment


Trends in Slash and Burn Agriculture
Percent
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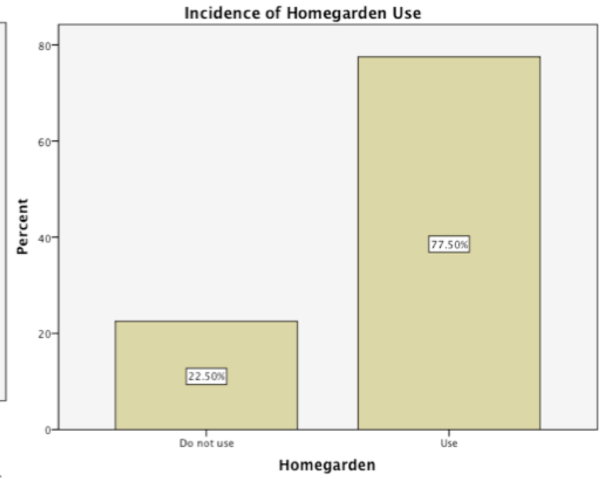
48.39%
Use
Do not use
Use of Slash and Burn Agriculture


Incidence of Homegarden Use
Percent
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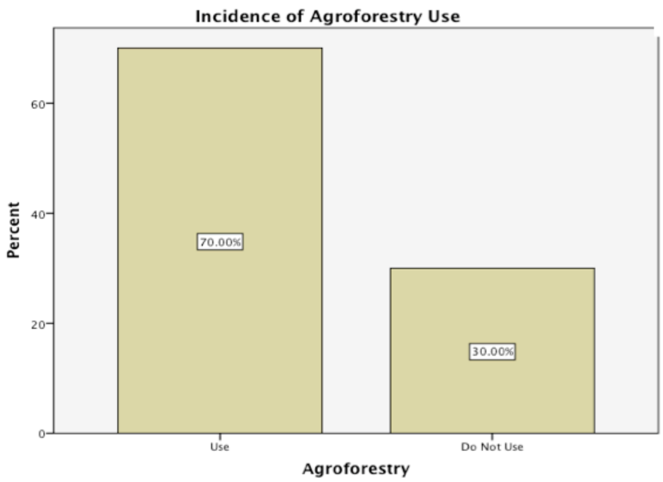
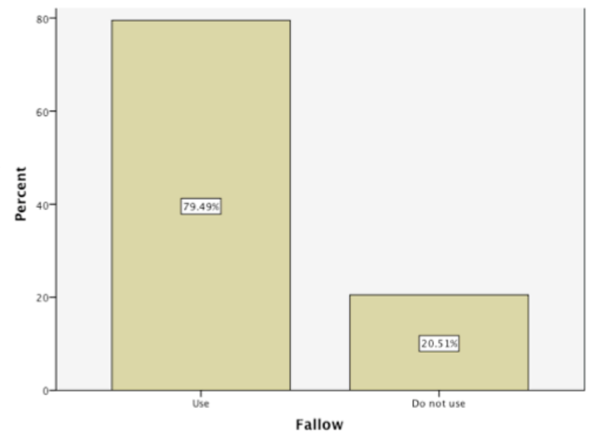
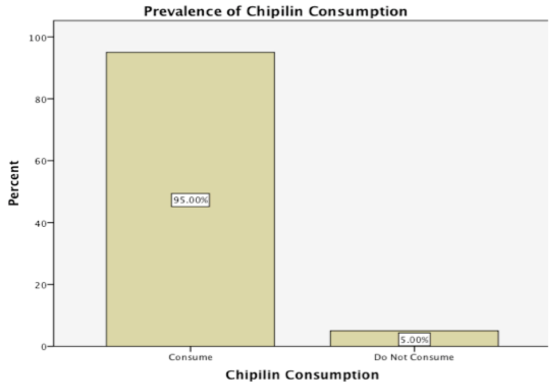
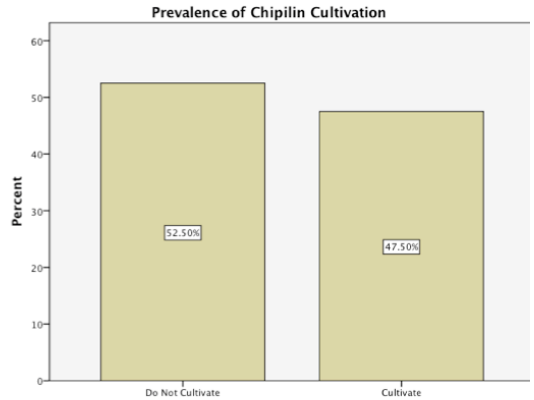
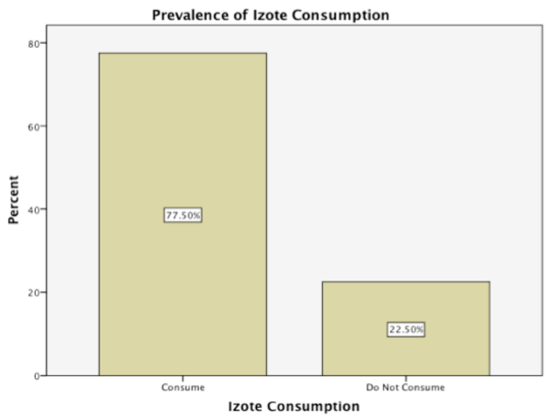
77.50%
Do not use
Use
Homegarden

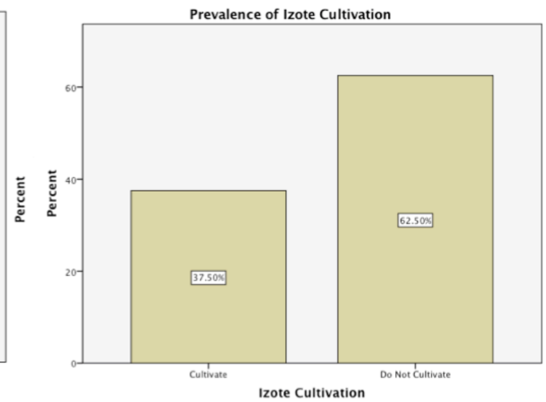

Incidence of Agroforestry Use
Percent
70.00%
30.00%
Use
Do Not Use
Agroforestry


Percent
79.49%
20.51%
Use
Do not use
Fallow









4. Additional SSM Processes

4.1 Soft Systems Root Definitions

The general rubric for finding a soft system root definition is: A system to do **X** (what), by (means of) **Y** (how), in order to do **Z** (why).

1) A system to identify sustainable cropping systems and practices by means of survey/interview, in order to increase implementation of sustainable agricultural practice.
2) A system to conserve native and heirloom seed, by means of in-situ and ex-situ conservation and seed dissemination in order to increase seed sovereignty/access and conserve agrobiodiversity.
3) A system to decrease malnutrition, by means of increased local food consumption and increased subsistence gardens in order to increase food security/sovereignty.
4) A system to decrease agricultural pollution by means of organic agriculture in order to increase soil fertility and watershed management strategies.

5) A system to increase re-localization of food consumption, by means of direct sales and regional marketing, in order to decrease foodshed malnutrition and increase food security.
6) A system to increase small-holder access to arable land, by means of farmer organization "seed for land" exchange programs and land-use redistribution schemes, in order to increase agricultural production and increase food sovereignty of poorest families.
7) A system to identify most abundant and nutrition-rich local agricultural products, by means of observation and research, in order to promote cropping practices that may increase local food nutrition quality and thereby promote nutritional security.
8) A system to decrease land-use pressure on unused lands, by means of adopting a program of land-use food/share (sharecropping?), in order to increase access to arable land by small-holder farmers.
9) A system to combat lake eutrophication, by means of agricultural nutrient-use strategies and promotion of composting toilets (and hu-manure applications), in order to reduce amount of nutrients seeping into Lake.
10) A system to mediate agricultural disputes, by means of communicative and conflict-mitigating strategies, in order to reduce tensions.
11) A system to preserve traditional knowledge systems, by means of education, in order to promote culturally and ecologically appropriate agricultural technologies.
12) A system to develop agricultural resiliency, by means of cultivating biological diversity, in order to develop resiliency to climatic and socio-cultural change.
13) A system of knowledge of sustainable agricultural practices and methods, by means of education, in order to promote agroecological practices.

4.2 CATWOE Analysis

Clients: smallholder farmers and the farmer's organization: IMAP
Actors: governments, private sector, NGO's, public sector, civil society, researchers, farmer's organizations
Transformation: capacity building for participatory crop agrobiodiversity conservation
World view: biocultural conservation and sustainability
Environmental constraints: Rising lake, climate change, poor infrastructure, ethnic tensions, highly unequal land tenure, market flooding, policy and economic climate, lack of access to native seed, poverty, weak governance, economic market demand for NTX products

4.3 Series of Issues that Inhibit and Promote Food System Development

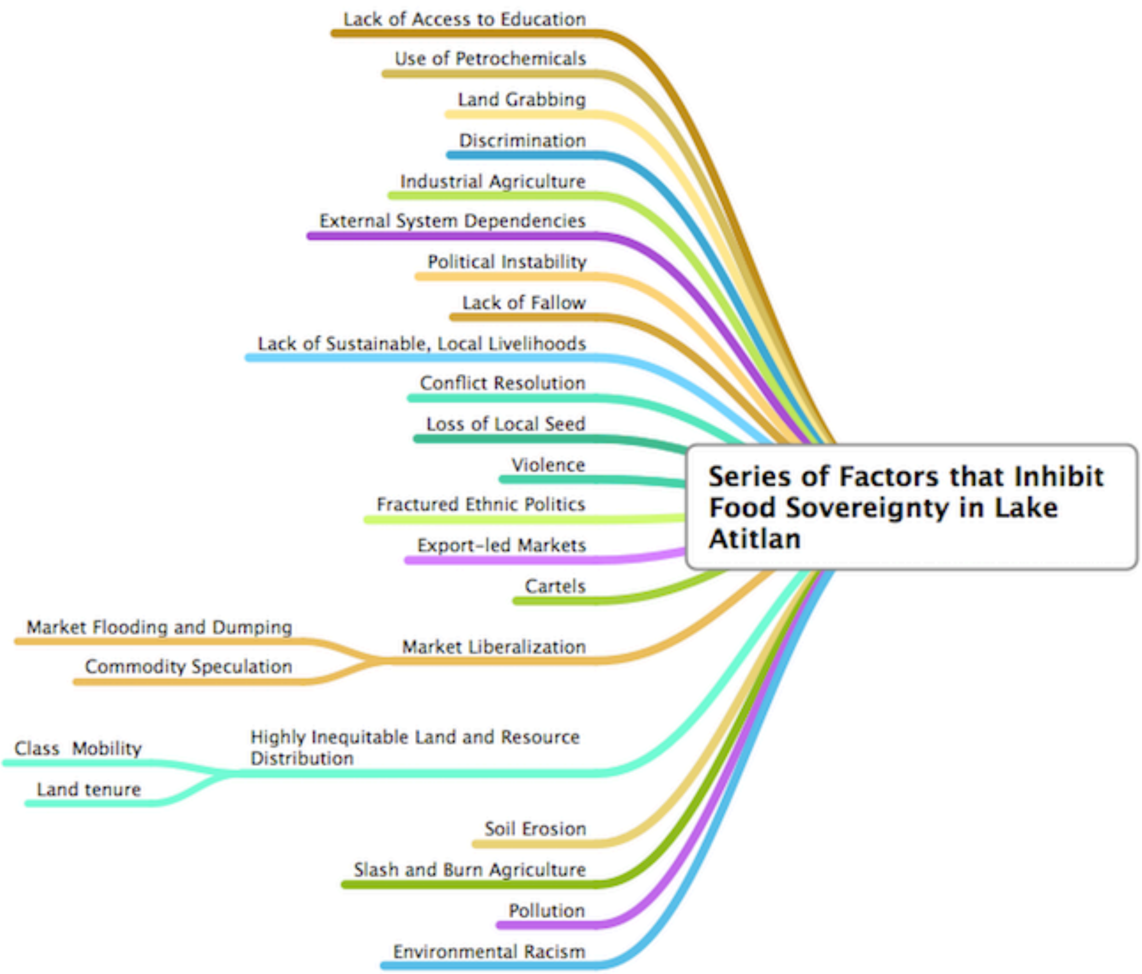


Figure: Mind Map of Series of Issues that Inhibit Food Sovereignty in Lake Atitlán

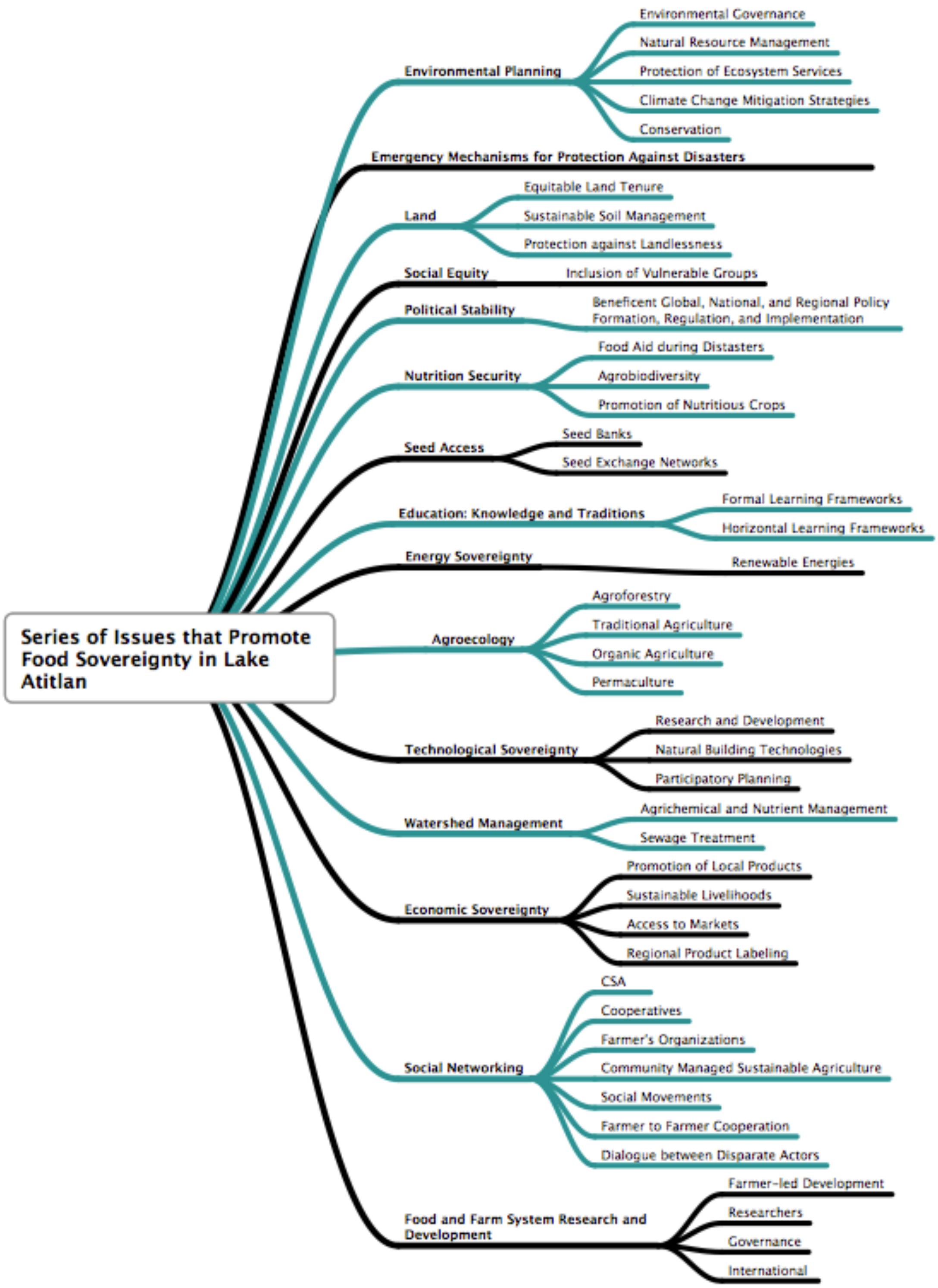


Figure: Mind Map of Series of Issues that Promote Food Sovereignty in Lake Atitlán

5. Secondary Semi-Structured Interview Guide for IMAP Farm System Stakeholder Rony Lec Ajoct

Name:	**Ronaldo Lec Ajcot**
Is it okay if I publish this?	**yes**

Environmental Impacts

Do you know when chemical fertilizers first began to be used around Lake Atitlán?	1980's
What impacts have you observed regarding the health of people of the environment relating to these chemical fertilizers?	The fertilizers have afected the water quality of lake Atitlán, the main source of drinking water for the bigger towns. The soil fertility lost is the most obvious loss.
What changes, if any, have you observed in the climate here (change in temperatures, in the quantity of rainfall, etc.)?	There is less rain fall, but it is more intense. The temperature is higher and different bugs and animals have come to the highlands. Mosquito malaria, pelicans from the ocean. Also roya in the coffee was confined to the low lands but now is in the highlands.
Have these climatic changes affected your farming or cropping practices? Please explain.	Coffee produccion has been lost and there is a possiblility of not being able to grow it here again.

Networks

Are you a member of any organizations, cooperatives, or social movements (e.g. Campesino a Campesino, Via Campesina, Women's organizations). If so, please list any networks:	I am part of a local organización that supports and promote sustainable agriculture, and we belong to several national and international organizacions that work with food sovereignty. (Red Sagg, Guardianes de semillas,)

Do you currently benefit from any agricultural extension program from the government or an NGO? If yes, please list any programs:	We do not benefit from any govermental program, in fact we train their agriculture extencionits to work with the schools.

Maya

Please explain the role of the Mayan calander in relation to IMAP's agricultural practices.	Mayan calendar is to guide our daily life and agriculture is not a separate thing.
What is the spiritual value of maize to Kaqchikel people?	Maiz is more than tortillas, it is life itsef. The cicle of corn is what show us the life cicle every year.

Seed Sovereignty

Which crops that were cultivated here in the past are no longer cultivated? Please provide a list:	**Amaranth, Chia, Jicama, chaya**
What difficulties did you encounter to find or access local varieties of seed?	**There is only a small amount of farmers that are not growing cash crops.**
Do you know of the existence of any other seed banks in your community, or in communities in	**Quachaloom, Rabinal Baja Verapaz.** **La hojita Verde, Guatemala City**

the region? If so, where are these seed banks located? (Please be as specific as possible):	**Perhaps, ADICTA in San Marcos Departamente**
From whom do you get your seeds?	**We get some seeds from Quachaloom but mainly from our own producers**
In your opinion, what are the primary causes of the reduction of traditional cultivation practices and crops?	**Agroindustry encourage by a globalized economy and promoted by governments and university.**

Maize

Number of varieties of maize that IMAP produces?	Just 3: Negro Cerro de oro, Amarillo Pachitulul, Blanco Obispo
If there are varieties of maize that you no longer cultivate, what are the reasons you have stopped (for example: loss of seeds, lack of land, changes in climate, etc.)?	In the past just about every hill and family had their own seed varity. Now becouse the lock of land, and subsistance agriculture has been lost.

Strengths, Weaknesses, Opportunities and Threats

In your opinion, what are the strengths of IMAP?	Local base, has its own seed bank, does not really depend on outside fund.
What are the weaknesses of IMAP?	Not enough produccer or land to produce seeds.
What are the greatest opportunities for IMAP?	There is more interest in sustainable agriculture and indigenous knowledge

What are the biggest threats to IMAP?	Losing more land and the new laws on pattet on seeds.

Visions

What are your goals and dreams for the future of IMAP?	To be economiclly sustainable through our educational services and seeds.
What are your goals and dreams for future of the region?	To be a region where sustainable agriculture is the norm and schools are teaching it.

Is there anything you would like to add?	

6. Semi-Structured Interview Guide for Food System Stakeholders

Encuesta:

Introducción, Explicación del propósito del estudio, y autorización de la persona a entrevistar – 5 mins

Fecha	
Encuesta # (ejemplo: 1,2,3 etc.)	

Demografía

Nombre:	1) Nombre: 2) Anónimo:

Pueblo:	
Identidad Étnica: (Más de una es posible)	1) Kaqchikel 2) Tz'utujil 3) Ladino 4) Quiche 5) Otra (especifique):
Idioma de la entrevista:	
Género:	
Lugar de nacimiento:	
Personas que habitan en la residencia	

Tenencia de la Tierra – 5 mins

¿Cuánta tierra posee o alquila su familia para propósitos de siembra? **¿Posee las tierras que siembra o las renta?**	Cantidad de las tierras: **Propia o alquilada:**
¿En que maneras ha cambiado la cantidad de tierra poseída por su familia en los últimos años?	1) Ningún cambio 2) Hemos adquirido más tierras 3) Hemos vendido parte de las tierras 4) Hemos perdido tierras debido a inundaciones 5) Hemos perdido tierras debido a deudas 6) Otras razones, especifique:
¿Cuánta tierra considera necesaria para ayudar a mantener a su familia?	

Cambios en el ambiente: 5-10 mins

¿Sabe cuándo los fertilizantes químicos comenzaron a ser utilizados en el Lago de Atitlán?	1) No sé 2) Si la respuesta es sí, ¿cuándo?:

¿Qué impactos ha observado en la salud de las personas debido a los agroquímicos?	1) Ninguno 2) Otros (especifique):
¿Qué impactos ha observado en el ambiente (como la tierra o el lago) debido a los agroquímicos?	3) Ninguno 4) Otros (especifique):
¿Qué cambios ha observado en el clima (aumento de temperaturas o cambios en las cantidad de lluvia que cae) en la zona con el paso del tiempo?	1) Ningún cambio 2) La temperatura ha aumentado 3) La temperatura ha disminuido 4) Retrasos del invierno 5) Llueve menos 6) Llueve más 7) Otros:
Si la repuesta fue "Sí" en la pregunta previa: ¿Estos cambios han afectado la manera en la que lleva a cabo sus siembras?	1) No 2) Atrasos en la siembra 3) Atrasos en la cosecha 4) Cambié de cultivo 5) Otros:

Perfil de la Granja: 10 mins

¿Cuáles son los principales cultivos que produce *durante el año*?	1) Café 2) Milpa 3) Cebollas 4) Repollo 5) Todos los cultivos primarios, por favor, provea una lista:
Cuál es la razón por la que produce esos cultivos?	1) Para consume propio 2) Para venderlos en el mercado 3) Otros, por favor específique:

¿Qué tipo de frutas y vegetales cultiva en el jardín de su casa, en caso de hacerlo?	1) No tenemos jardín en la casa 2) Sí A) Lista de frutas: B) Lista de vegetales:
¿Qué tipo de preocupaciones, si las hay, tiene usted por la hambruna o malnutrición de los miembros de su familia? ¿Durante qué períodos del año siente esas preocupaciones?	1) Ninguna preocupación **2) Otros (Por favor, especifique):** **Períodos del año:**

Prácticas de cultivo: 5-10 mins

¿Qué tipo de prácticas de cultivo utiliza? ¿Cambio de cosecha? (Changing the crops in different seasons?) ¿Agro forestación? (Do you use trees for wood, fruits, nuts, or medicine on your farm?)	Tipos: 1) Cambio de cosecha: Yes/No/ Other: 2) Agro forestación: Yes/ No/ Other:

¿Qué tipo de campo en barbecho usa? (Do you sometimes leave the field empty with no crops for the soil to be stronger?) ¿Tala y quema? (Do you burn your land with fire?)	1) Campo en barbecho: Si/No, Other; 2) Tala y quema: Si/No, Other:
¿Hace uso de pesticidas o fertilizantes químicos? Cuantos, y que tipo?	Sí/No **Otro:**
¿Hace uso de compuestos orgánicos u otro método de fertilización orgánica?	Compuesto Orgánico: Sí/No Métodos orgánicos: Sí/No
¿Tiene algún interés en el uso de una agricultura orgánica (agricultura sin fertilizantes químicos)? Por favor, explique ¿Por qué sí? ¿Por qué no?	

Dimensiones Sociales 5 mins

¿Es usted un miembro de alguna organización, cooperativa, o movimiento social? (Como por ejemplo Federación de Campesino a Campesino, Café Co-Op, Organización de las Mujeres, Vía Campesina).	1) Ninguna 2) Otras: **3) Sí** A) Lista de redes:
¿Ha recibido entrenamiento en agricultura sustentable, manejo integrado de las pestes, agricultura orgánica? ¿Qué tipo de entrenamiento le gustaría recibir en agricultura?	1) Ningún entrenamiento **2) Sí** A) Lista de redes:
¿Está usted siendo beneficiado por algún programa de extensión de la agricultura del gobierno o de una ONG (como algo de MAGA o Cero Hambre)? Si la respuesta es sí, por favor explique cuáles/es programas.	1) No **2) Sí** A) Programas:

Dimensiones Económicas (5-10 mins)

¿Cuánto trabajo hace afuera de sus propiedades? ¿Durante que temporadas?	1) No hago ningún trabajo fuera de mis

	propiedades **2) Sí** A) Temporadas:
¿Cuánto maíz compra en el mercado para el consumo de hogar?	
¿Cuáles son los desafíos que encuentra al momento de vender sus productos en el mercado?	1) Ningún desafío 2) Distancia del mercado 3) Poca demanda 4) **Otras, especifique:**

Conservación del cultivo y tradiciones: 5-15 mins

¿Qué parte de su propiedad es milpa? Si no cosecha milpa, ¿cuáles son las razones?	1) No cosecho milpa 2) Porcentaje de mi propiedad dedicado a la milpa: 3) He descontinuado la siembra, **razones**:
¿Consume o cultiva:	**1) Chipilin:** A) Consume: Sí/No B) Cultiva: Sí/No **2) Chan:** A) Consume: Sí/No B) Cultiva: Sí/No **3) Chaya:** A) Consume: Sí/No B) Cultiva: Sí/No **4) Amaranto:** A) Consume: Sí/No B) Cultiva: Sí/No **5) Izote (Flores):** A) Consume: Sí/No B) Cultiva: Sí/No

¿Cuáles cosechas eran cultivadas aquí en el pasado pero ya no lo son? **Por favor, provea una lista**:	1) No lo sé 2) Sí, especifique:
¿Qué dificultades encuentra para encontrar/acceder a las variedades locales de semilla?	1) Ninguna 2) Sí, especifique: A) No sé dónde encontrarlas B) Muy caras C) Escasez D) Otras, especifique:
¿Almacena semillas de su propia cosecha para las siguientes temporadas?	
¿Conoce usted de la existencia de un banco de semillas (semillerio) en su comunidad o comunidad vecina? Si la respuesta es sí, ¿Dónde queda?	1) Sí/ Ubicación: 2) No sé
¿Está interesado en participar en un intercambio de semillas criollas con otros agricultores del lago de Atitlán?	
¿De quién obtiene sus semillas?	1) Miembros de la familia 2) Vecinos 3) En mi mismo pueblo 4) En el mercado local 5) En el mercado de Sololá 6) Otro lugar, especifique:
En su opinión, ¿Cuáles son las principales causas de la reducción de los métodos tradicionales de cultivo y cosechas como milpa, amaranto, chaya, etc.?	1) No sé 2) Razones: A) Falta de tierras B) Afluencia de otras cosechas C) Otras, especifique:

Para los productores de maíz: Diversidad del Maíz actual y las causas de pérdida (5-10 mins)

¿Cuál es el número de las variedades de maíz que produce?	1) No produzco maíz **2) Número de variedades:**
Si hay tipos de maíz que usted ha dejado de producir, ¿cuáles son las razones por las cuales dejo de hacerlo (por ejemplo; pérdida de semillas, escasez de tierra, cambios en el clima, etc.)?	1) Ningún cambio **2) Por favor, especifique las razones:**

Debilidades y Fortalezas, Obstáculos y Oportunidades de las propiedades ~ 10 mins

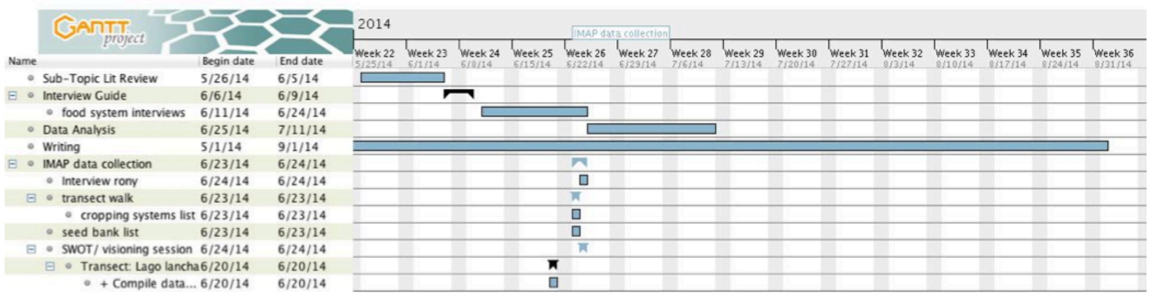
En su opinión, ¿Cuáles son las **fortalezas** de su granja (farm)?	
¿Cuáles son las **debilidades** de su granja?	
¿Cuáles son las **oportunidades** más grandes que tiene su granja?	
¿Cuáles son las **amenazas** más grandes que tiene su granja?	

Visión para la propiedad y sistema de alimentación (~ 5 mins)

¿Cuáles son los objetivos y anhelos para el futuro de ***su granja*?**	

¿Cuáles son los objetivos y anhelos para el futuro de ***su pueblo*?**	
¿Tiene algún comentario adicional que le gustaría agregar?	

7. Thesis Schedule: Tentative Planning Using GANTT Projection Software



8. Figure: Ideological Framework of Adaptative Management Used in Tandem with Soft Systems Methodology as used within this thesis process

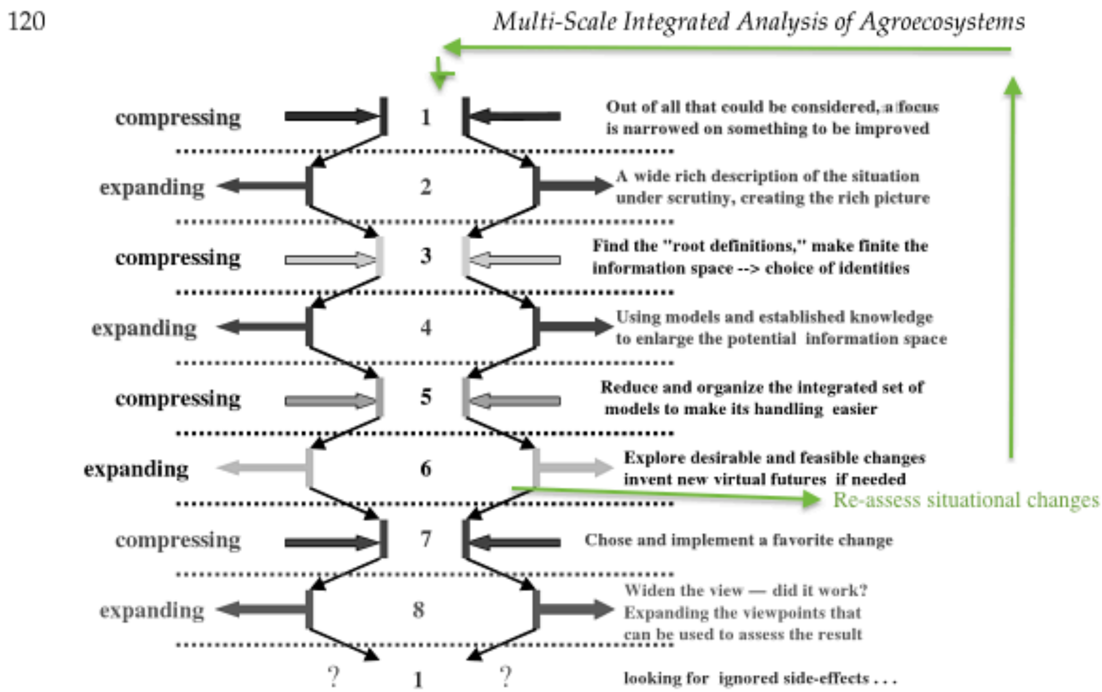


FIGURE 5.9 The iterative process suggested by Checkland. (Adapted from Allen, T.F.H. and Hoekstra, T.W., *Toward a Unified Ecology*, Columbia University Press, New York, 1992.)

Figure: Conceputal Use of Adaptive Management in Conjunction with SSM. Adpated From (Giampietro, 2003).

9. Proposed Initial Research Questionaire: Disregarded Analysis Guides for Two Mayan Villages (Emergent Sub-Methodology # 1)

Rapid Farm Assessment Survey Methodology

Adapted from: Nicholls, C.I., Altieri, M.A., Dezanet, A., Lana, M., Feistauer, D., & Ouriques, M. (2004). A Rapid, Farmer-friendly Agroecological Method to Estimate Soil Quality and Crop Health in Vineyard Systems. Science and Ecology. 33-40.

The idea is to use this survey methodology in tandem with the secondary questionnaire to compare farms between Pachitulul/ Cerro de Oro (two Mayan villages).

My hypothesis is that it will be possible to track the dissemination of agroecological practice from what I hypothesize is a “lighthouse farm” (IMAP), to be able to tangibly measure the sustainability/practices between Pachitulul village, where farmers have mostly participated in some type of agroecological trainings, and the nearby village Cerro de Oro, where farmers have not had access to these trainings. I hope to be able to see trends between permaculture (organic) farms, traditional Mayan agriculture, and conventional agriculture within these two villages.

For these interviews, I hope to find 5-15 farms from each village. I will conduct these interviews and surveys with my translator. I will ask each farmer for permission to interview, and permission to walk around their farm to do the survey with them before the interview. I’m concerned that I will not be able to get a very large sample size from Pachitulul village because there are very few people and much of the agricultural land is now underwater (due to rising waters of Lake Atitlán).

I have adapted this survey methodology from the attached study. The study has a rubric for assessing indicators of soil health, and then a separate rubric for assessing indicators of crop health. For the sake of time and feasibility, I compiled some of the indicators from the two rubrics into one quick survey. To make the survey more appropriate to the climatic/agri-cultural situation here I have made some sustainability indicator adaptations (and further adaptations may be necessary). I also added some of my own sections to formulate questions that are more appropriate to my research query.

Indicators of Farm System Health	**Established Value**	**Characteristics**
Soil Cover	1	Bare soil
	5	Less than 50 % soil covered by residues or live cover
	10	More than 50 % soil covered by residues or live cover
Erosion	1	Severe erosion, presence of small gullies
	5	Evident, but low erosion signs
	10	No visible signs of erosion
Microbiological Activity	1	Very little effervescence after application of water peroxide
	5	Light to medium effervescence
	10	Abundant effervescence
Appearance	1	Chlorotic, discolored foliage with deficiency signs
	5	Light green foliage with some discoloring
	10	Dark green foliage, no signs of

		deficiency

Crop Growth	1	Uneven stand; short and thin branches; limited new growth
	5	Denser, but not uniform stand; thicker branches; some new growth
	10	Abundant branches and foliage; vigorous growth

Disease incidence	1	Susceptible, more than 50 % of plants with damaged leaves and/or fruits
	5	Between 25-45% plants with damage
	10	Resistant, with less than 20% of plants with light damage

Insect Pest Incidence	1	More than 15 **leafhopper nymphs** per leaf, more than 85% damaged leaves
	5	Between 5-14 leafhoppers per leaf, or 30-40% damaged leaves
	10	Less than 5 leafhopper nymphs per leaf, and less than 30 % damaged leaves

Weed Competition and Pressure	1	Crops stressed, overwhelmed by weeds
	5	Medium presence of weeds, some level of competition
	10	Vigorous crop, overcomes weeds

Actual or Potential Yield	1	Low in relation to local average
	5	Medium, acceptable
	10	Good or high

Vegetational Diversity	1	Monoculture
	5	A few weeds present or uneven cover crop
	10	With dense cover crop or weedy background

Natural Surrounding Vegetation	1	Surrounded by other crops, no natural vegetation
	5	Adjacent to natural vegetation on at least one side
	10	Surrounded by natural vegetation on at least 2 sides

Management System	1	Conventional
	5	In transition to organic with IPM or input substitution ***(Cori Possible Amendment: Traditional/Conventional Mixed Management or Permaculture/ Conventional Mixed)***
	10	Organic, diversified with low external biological inputs ***(Cori Amendment: Traditional / Organic / Permaculture)***

(How to categorize?)

Cori Category: Agrobiodiversity (by cultivated species richness annually)	*1*	*More than 15 species*
	5	*Between 15-25 species*
	10	*More than 25 species*

(I don't have a realistic understanding of how many species are cultivated on an ordinary farm; perhaps my numbers are too high or too low. I chose arbitrarily, but I intend to adjust the numbers after preliminary interviews.)

Cori Category: Presence of Milpa	1	None
	5	Only maize
	10	Intercropped, traditional milpa

Cori Category: Intercropping	1	None
	5	Some application
	10	Abundant application

Cori Category: Soil Management Strategy	1	No strategy
	5	Slash/burn, some fallow
	10	Composting, animal poo, fallow, cover crops

Cori Category: Size of farm	1	Less than 1 cuerda
	5	Less than 5 cuerdas
	10	More than 5 cuerdas

**** (1 cuerda = 25 varas (~25x25 meters))**

Farmer/ Farm System Semi-structured Interviews:

(This part will be done verbally with my translator in 2 Mayan languages: Kaqchikel and Tz'utujil. Interviews will be conducted with farmers at IMAP as well as in Pachitulul and Cerro de Oro villages.)

Name: (optional)

Gender:

Ethnicity:

Number of family members:

Training: Have you participated in a PDC, agricultural trainings, or the seed exchange program at IMAP? If so, what programs?

If yes: What are the best permaculture practices that you have implemented in your fields? Which were the least useful practices? What could be improved in the permaculture trainings?

If not: are you interested in receiving IMAP trainings or are you satisfied with your current management system?

Land Tenure/Access
Has the amount of land you owned changed drastically in recent years (if yes: how so?) (Including land tenure and rising water table which has recently submerged a good deal of arable land).

Economic
Do you grow enough food for your family, or do you also have to buy food? (If so, how often/much?)

Do you buy fertilizer, seed, or pesticides?
If so: what products/ with what frequency?

Do you receive any economic support (such as grants or subsidies) from the government or any organization?

Do you sell your agricultural products?
If so: where? Is it difficult to sell your products?

Do you work on other farms?
If so: when and where?

Agrobiodiversity and Cropping
Do you use a fallow system or slash and burn agriculture?

Do you cultivate or consume Chaya? Izote? Chia? Amaranth? Chiplin? (among the most nutritious indigenous crops)

Do you perceive agrobiodiversity to be decreasing? (Yes or No)

Where do you get your seeds?

Do you have access to heritage/native seeds? (Yes/No)

Which seeds are most difficult to find?

How have agricultural practices changed in this village over the last 50 years?

Environmental Perceptions
When did chemical fertilizers and pesticides first appear in Lake Atitlán?

How do you feel about the use of agrochemicals?

What are your perceptions of the health of Lake Atitlán now? In the past?

Do you feel that agricultural practices have impacted Lake Atitlán?

What are your perceptions of wildlife health now, and in the past (land and aquatic animals?

What are your perceptions of climatic change (by temperature change/ rainfall changes)?

Socio-cultural
Do you use the Mayan calendar to know when to plant and harvest?

Do any religious or spiritual values from the land, harvest, or lake impact your farming practices?

Are you a member of any (farming) groups, associations, or organizations?
If so: which?

SSMethodology

SWOT Analysis
What **strengths** do you perceive of your farm?

What **weaknesses** do you perceive of your farm?

What **opportunities** do you see for the future of your farm and community?

What **threats** do you perceive for your farm and the environment?

Visioning
What is your dream for the future of your farm and community in 10 years?

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