A MULTIDIMENSIONAL APPROACH TO FOOD SECURITY AND NON-TRADITIONAL EXPORT AGRICULTURE: A CASE STUDY IN RURAL GUATEMALA

Josée Méthot
Department of Natural Resource Sciences / McGill School of Environment
McGill University
Montreal, Quebec, Canada
August 2013

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of

Master of Science

ABSTRACT

There are four important dimensions of food security: food availability, food access, food utilization and food system stability. However, although the concept of food security has come of age, food security remains difficult to measure across these dimensions. In the first chapter of this thesis, I review the concepts and indicators used to assess the four dimensions of food security at the household level, and argue that a multidimensional approach to food security analysis is fundamental to understanding the overall impacts of development strategies on the food security of households. This is an important area of research because many strategies to improve food security in the developing world focus on income (supposedly an indicator of food access) and neglect to consider the other three dimensions of food security and associated indicators. Food system stability, in particular, is often overlooked in assessments of food security.

In the second chapter of this thesis, I present a case study exploring the food security implications of farming broccoli for export in Guatemala, recognizing that broccoli, a non-traditional export crop, is widely promoted in this region as a means to increase smallholder incomes and food security. I use a multidimensional approach to explore the four dimensions of household food security, and compare the food security of broccoli farmers (*adopters)* and corn farmers (*non-adopters*) in the community of Chilascó, in Central Guatemala. Neither food availability nor food utilization differed significantly between adopters and non-adopters. Although adopters earned significantly higher income (40%) than non-adopters, income gains did not translate into improvements in food access according to outcome indicators. The majority of adopters and non-adopters alike were categorized as moderately to extremely food insecure according to the Household Food Insecurity Access Scale. Households in the top income tercile had significantly higher dietary diversity (an indicator of food access) compared to households in the bottom tercile. A nuanced conclusion from this work is that income *can* lead to positive food security outcomes, but does not *guarantee* them.

In terms of food system stability, adopters applied twice as much manure per hectare, three times more inorganic fertilizer per hectare, and had a higher environmental impact associated with pesticide use. Taken together, there are trade-offs among the different dimensions of food security, whereby some indicators improve (e.g. income), others remain unchanged (e.g., staple crop production), and others degrade (e.g. the ecosystem service of biological pest control) for adopters relative to non-adopters.

My results show that narrow, often income-oriented approaches to food security analysis may mask important differences among the four dimensions of food security. Future research into the food security implications of non-traditional export agriculture must move beyond the dualistic understanding of food security outcomes (better/worse) in order to better target interventions. This will require a systematic consideration of all four dimensions of food security in assessments and development planning.

RÉSUMÉ

La sécurité alimentaire comporte quatre dimensions importantes: la disponibilité des produits alimentaires, l'accessibilité, la qualité de l'alimentation, et la stabilité des systèmes alimentaires. Bien que le concept de la sécurité alimentaire soit maintenant établi, il demeure encore difficile à mesurer dans toutes ses dimensions. Dans le premier chapitre de cette thèse, je fais une revue des concepts et indicateurs utilisés pour évaluer les quatre dimensions de la sécurité alimentaire à l'échelle des ménages familiaux, et je mets de l'avant qu'une approche multidimensionnelle d'analyse et de mesure de la sécurité alimentaire est nécessaire pour comprendre les impacts des stratégies de développement sur la sécurité alimentaire des ménages. Ceci est un domaine de recherche important car beaucoup de stratégies visant à améliorer la sécurité alimentaire dans les pays en voie de développement se concentrent sur l'augmentation du revenu (considéré comme un indicateur de l'accès à la nourriture) et négligent souvent de considérer les trois autres dimensions de la sécurité alimentaire et les indicateurs associés à ses dimensions. Une dimension en particulier qui est souvent ignorée est la stabilité des systèmes alimentaires.

Dans le deuxième chapitre de cette thèse, je présente un cas d'étude de la culture de brocoli au Guatemala, destinée à l'exportation. J'explore les implications de cette culture non-traditionnelle d'exportation sur la sécurité alimentaire locale dans la perspective que cette culture est favorisée dans cette région en tant que moyen d'augmenter les revenus de petits exploitants et leur sécurité alimentaire. J'emploie une approche multidimensionnelle pour explorer les quatre dimensions de la sécurité alimentaire et je compare la sécurité alimentaire des producteurs de brocoli (*adopteurs*) avec celle des producteurs de maïs (*non-adopteurs*) dans la communauté de Chilascó, au centre du Guatemala.

J'ai constaté que la disponibilité des produits alimentaires et l'utilisation des aliments n'étaient pas différentes entre les deux groupes. Bien que les revenus gagnés par les adopteurs étaient significativement plus élevés que les non-adopteurs (40% plus élevé), les gains de revenus ne se traduisaient pas par une

amélioration de l'accès aux aliments selon les indicateurs utilisés. La majorité des adopteurs et des non-adopteurs confondus ont été classés comme modérément à extrêmement insécures face à l'alimentation selon l'Échelle de l'Accès déterminant l'Insécurité Alimentaire des Ménages. Ce travail démontre que le revenu *peut* améliorer la sécurité alimentaire, mais ne le *garantit* pas. Les ménages dans le tercile supérieur du revenu avaient une diversité diététique significativement plus élevée que les ménages du tercile inférieur.

En termes des indicateurs liés à la stabilité du système alimentaire, les adopteurs ont appliqué deux fois plus de fumier par hectare, trois fois plus d'engrais minéraux par hectare, et avaient un impact environnemental plus élevé associé à l'utilisation de pesticides. Dans l'ensemble, il y a des différences entre le succès des différentes dimensions de la sécurité alimentaire, où certains indicateurs s'améliorent (par exemple, le revenu), d'autres restent inchangés (par exemple, la production des cultures vivrières), et d'autres se dégradent (par exemple, le service écosystémique de la lutte biologique contre les ravageurs) pour les adopteurs comparés aux non-adopteurs.

Mes résultats démontrent que les approches étroites de l'analyse de la sécurité alimentaire, souvent axées sur le revenu, peuvent masquer des différences importantes entre les quatre dimensions de la sécurité alimentaire. Les recherches sur les implications de l'agriculture d'exportation non traditionnelle sur la sécurité alimentaire doivent aller au-delà du concept dualiste de sécurité alimentaire (meilleur / pire) afin de mieux cibler les interventions. Cela nécessitera une prise en compte beaucoup plus systématique des quatre dimensions de la sécurité alimentaire dans les évaluations et la planification du développement.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

This thesis is dedicated to the strength of my mother and to the curiosity of my father. I thank them both for their unwavering encouragement and love.

I wholeheartedly thank Dr. Elena Bennett and Dr. Nicolás Kosoy. As co-supervisors, they have jointly taught me how to ask interesting questions and dig for answers. I am fortunate to have supervisors that care about my development not only as a scientist, but also as a global citizen.

I also dedicate this to the people of Guatemala – for all they taught and shared with me. I am thankful for the openness and grace granted to me by the community of Chilascó. I am especially grateful for the support given to me by Byron Medina Fernández and the joint team from the United Nations Development Program and Guatemala's Ministry of Environment working in Salamá, Baja Verapaz. Your friendship and support made this work possible.

I thank Jhania Soberanis Bardales, my field assistant, Iliana Monterroso from the Latin American School of Social Sciences in Guatemala (FLACSO), Dr. Miguel Martínez-Tuna from the World Wildlife Fund (WWF) watershed program in Guatemala, Noel W. Solomons, MD and the entire team from the Center for Studies of Sensory Impairment, Aging and Metabolism (CeSSIAM), and Dr. Pablo Prado-Córdova from the Universidad de San Carlos de Guatemala. Your insights helped shape the evolution of this work.

I gratefully acknowledge principal funding from the Natural Sciences and Engineering Research Council of Canada. I also thank the McGill Institute for the Study of International Development (ISID) and the Canadian International Development Agency (CIDA) for granting me a '*Research to Practice Graduate Student Fellowship in Development Studies'*.

I thank Christiane Méthot and Jocelyne Méthot for their help revising the french text. I would also like to acknowledge all my wonderful peers from the Bennett lab for your friendship and for being so dedicated to your work. I give special thanks to Kate Liss and Genevieve Metson for their help along the way. I have truly enjoyed observing how our mutual curiosity for science manifests itself in so many different ways.

Last but not least, I thank Francis Dumas for making me happy to come home every day, drink a cup of tea, and keep working.

CONTRIBUTIONS OF THE AUTHORS

The candidate, Josée Méthot, is the sole author of this thesis. Her advisors, Dr. Elena Bennett and Dr. Nicolás Kosoy, have contributed equally in terms of guiding the research design and editing draft manuscripts. They will continue to provide guidance during the preparation of a subsequent article for journal publication.

The candidate was responsible for developing the ideas in the manuscript, the collection of primary data in Guatemala, the analysis of data, and writing the manuscript. A field assistant in Guatemala, Jhania Soberanis Bardales, helped to collect the data presented in Chapter 2.

ETHICS

McGill University has an ethics review process for any research involving human participants. This study received full approval from the Research Ethics Board based in the Faculty of Agricultural and Environmental Sciences.

THESIS INTRODUCTION

PROBLEM OVERVIEW

Approximately 870 million people are hungry or undernourished worldwide; meaning that one in every eight people on Earth is food insecure (FAO 2012). Of these people, 97% live in developing countries (ibid), and, perhaps counter-intuitively, almost 80% live in rural areas, often living as small-scale food producers (Bailey 2011). Although smallholder farming plays an important role in global agricultural production and food security, in this thesis, I focus on how smallholder farming can contribute to the food security of those most proximately involved - the smallholder farmers themselves.

How can food insecurity be alleviated among smallholder farmers? Food security and rural agricultural development have frequently been pursued as twin, complementary goals. Many have argued that, in order to achieve these twin goals, smallholder agricultural households (henceforth smallholders) in developing countries need to transition from low productivity subsistence agriculture to high productivity commercial agriculture (Timmer 1988; Barrett 2008), through strategies aimed at market-oriented liberalization (Pingali 1997; Timmer 2000; Nissanke and Thorbecke 2007; FAO 2012). One particular type of smallholder agricultural commercialization –the farming of non-traditional export (NTX) crops for the international market– is the focus of this thesis.

There is considerable controversy surrounding the contribution of smallholder export agriculture to reducing domestic food insecurity in developing countries. At the macroeconomic level, this debate is polarized between those who argue that the commercialization of agriculture through trade is an important engine of economic growth (Pingali 1997; Timmer 1997) and others who argue that export models deepen existing socioeconomic inequalities (Carter and Barham 1996; Goldin 1996; Carletto et al. 2011). At the household level, an issue of concern is whether or not farming NTX crops brings about real improvements in the food security status of smallholder households, with some arguing that export agriculture fails to improve the food consumption and nutritional status of the poor (Immink and Alarcon 1991), and others arguing that gains in food security can come from this type of agriculture (von Braun et al. 1989a). Previous research on the issue highlights mixed results (von Braun and Kennedy 1986).

I hypothesize that one of the reasons for the mixed results of previous research exploring the relationship between NTX farming and food security has been the limited conceptualization of food security used to drive this research. Although we now understand food security to include four dimensions – food availability, food access, food utilization, and food system stability (FAO 2008) – most research tends to focus on a subset of these dimensions and thus fails to capture the implications of NTX farming across all four dimensions. For example, although smallholder export agriculture is often promoted as a strategy to improve the incomes – and by extension, the food access – of the rural poor in developing countries, there is evidence that income poverty reduction is not always synonymous with improving food security (Gentilini and Webb 2008). If improving income and food access is not synonymous with improving food security, then an important avenue of research is to explore the relationships among the four dimensions of food security.

In this thesis, I focus on how food security has been conceptualized and measured at the household level, particularly with respect to the four dimensions of food security. My research examines the relationship between agricultural commercialization and multidimensional food security. Using a case study approach, I investigate the implications of farming broccoli, an NTX crop, for the food security of smallholder households in rural Guatemala. I investigate differences in the food security status of smallholders who farm broccoli versus those who farm traditional subsistence crops, for each dimension of food security. This approach links the national-level agro-export debate to the household level, recognizing that food security is best assessed at the household level (Ericksen 2008). It also allows us to investigate how the changing conceptualization of food security might affect the results of research.

RESEARCH QUESTIONS AND OBJECTIVES

The specific objectives of this thesis are as follows:

1. To review the concepts and indicators used to assess food security at the household-level, specifically with respect to the four dimensions of food security.
2. To analyze the implications of farming non-traditional export crops for the multidimensional food security of rural households using a small community in Guatemala as a case study.

Taken together, the results of this research will provide a better understanding of how food security can be measured in a way that adequately captures all four dimensions. Within this scope, I make two primary contributions to the literature. First, while many authors have reviewed food security indicators writ large (see Gerster-Bentaya 2009a, 2009b; Maxwell and Frankenberger 1992; Pangaribowo et al. 2013), I discuss the more nuanced relationships between food security indicators and the four dimensions of food security at the household level. Importantly, I draw special attention to the oft-neglected dimension of food system stability, and introduce the ecosystem services framework as an entry-point to understanding social-ecological resilience, and by extension, lend insight into food system stability. Second, I link recent improvements in food security theory (notably the idea that food security is multidimensional) to the practical measurement of the multiple dimensions of food security within the scope of a case study. Notably, I also employ indicators of ecosystem services as an entry-point to understanding the dimension of food system stability at the household level. Overall, researchers and policymakers can use the results of this research to improve the design of future food security assessments and interventions. If policymakers can reorient existing (often reductionist) approaches to food security interventions towards a broader understanding based on some of the building blocks presented in this thesis, then hopefully the lives of the world's food insecure peoples also stand to benefit.

THESIS STRUCTURE

In **Chapter 1,** I introduce the concepts that form the backbone of this research. The chapter is presented in three parts. In the first part, I discuss the evolution of a conceptual framework for food security that reflects the four dimensions of food security – availability, access, utilization, and stability. In the second part, I discuss and compare methods and indicators used to assess food security at the household-level. In the final part of the chapter, I discuss NTX agriculture as a strategy to improve the well-being and food security of rural smallholder farmers, and present a literature review of the relationship between NTX farming and rural smallholder food security. As a whole, this chapter sets the stage for Chapter 2 by discussing the conceptual and methodological bases of household food security and by summarizing the academic debate about the value of NTX farming as an instrument to improve the food security of smallholders.

In **Chapter 2,** I examine how the production of broccoli for export by smallholder households in a rural Guatemalan community influences multidimensional food security, with an eye toward the implications of export-based development strategies for household food security in both the short and long-term. I also draw attention to the oft-neglected fourth dimension of food security – food system stability – by exploring the implications of NTX farming for agricultural ecosystem services. The chapter is based on data I collected in Guatemala. Chapter 2 will be prepared as a manuscript for submission to a peer-reviewed journal.

I then summarize the major conclusions of the thesis and the contributions to the literature in **Chapter 3.** As this thesis is an outcome of my participation in both the Department of Natural Resource Sciences at McGill University and the McGill School of Environment, it should be read through a lens of interdisciplinarity. Moreover, because this is a manuscript-based thesis, there is some necessary repetition across chapters.

CHAPTER 1. HOUSEHOLD FOOD SECURITY: CONCEPTS, INDICATORS, AND LINKS WITH NON-TRADITIONAL EXPORT AGRICULTURE

PART 1: WHAT IS FOOD SECURITY?

Over the last forty years, the concept of food security has evolved to reflect significant advances in food security theory. While food security was once thought to be merely an issue of food production, today's conceptualization also includes considerations of food access, nutrition, and vulnerability. In 1974, the World Food Conference officially defined food security as the "availability at all times of adequate world food supplies of basic food stuffs (…), to sustain a steady expansion of food consumption (…) and to offset fluctuations in production and prices" (UN 1975). However, in 1981, Amartya Sen's seminal work, '*Poverty and Famines: An Essay on Entitlement and Deprivation',* demonstrated that people often fall prey to food deprivation not so much because food is unavailable but rather because access to food is constrained. Sen's work fundamentally shifted the production-focused food security concept promoted by the World Food Conference to a definition that also included issues of food access. More recently, food security theory has evolved to reflect advancements in nutrition science, explicitly recognizing the need for different nutrients, calories and proteins as well as a healthy environment (Young 2001). While over two hundred definitions of "food security" have been put forth in the literature (Maxwell 1996), there is a general agreement on a working definition, which is that food security exists when:

> "All people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (World Food Summit 1996).

A USEFUL FRAMEWORK

Using the above definition as a departure point, food security is commonly thought to include four dimensions – *availability*, *access*, *utilization*, and *stability*

(FAO 2008). A food security framework based on these four dimensions is widely considered a solid starting point for conceptualizing and measuring food security, and has been adopted by numerous development and food security agencies. This framework implies that achieving food security requires that the *availability* of physical supplies of food is sufficient, that households have adequate economic and social *access* to food, and that the *utilization* of food supplies is sufficient to meet the dietary and nutritional needs of individuals (FAO 2008). Moreover, these must be *stable* through time (ibid).

FOOD AVAILABILITY

The dimension of food availability addresses the "supply side" of food security by referring to the physical presence of food, either produced or purchased. Food availability refers to the *existence* of enough food (Sen 1981) at the household, regional, or national levels (Weingärtner 2009). It is also often interpreted to mean dietary energy (calories). For many years, food availability was equated with food security, even though we now realize that availability does not ensure access to food, nor does it imply a healthy and nutritional diet.

FOOD ACCESS

An adequate supply of food does not in itself guarantee food security. We must also think about access to food, which refers to the *having* of enough food (Sen 1981). Food access is ensured when all households and all individuals within those households have sufficient resources to obtain the foods required for a nutritious diet (Weingärtner 2009). We can differentiate economic access from social access. Economic access to food is mediated by factors such as income, knowledge, and prices, where adequate access to food can be achieved without being self-sufficient in food production. Social access to food is also important, and is mediated by factors like class, education, and gender.

FOOD UTILIZATION

Food access is necessary but not sufficient for food security (Webb et al. 2006; Barrett 2010). We also care about how food is utilized to reach a state of nutritional well-being, as enabled by adequate diet, clean water, sanitation, and health care. Good food utilization requires a nutritionally diverse diet and a safe environment within which to produce, prepare, and consume food. A healthy environment depends on elements such as safe drinking water, adequate sanitary facilities (so as to avoid disease), good care and feeding practices, and clean food preparation, among other factors (Weingärtner 2009).

FOOD SYSTEM STABILITY

Achieving food security requires a combination of food availability, food access, and food utilization that is *stable through time*. Stability is influenced by conditions such as weather and climate, political upheaval, sudden changes in trade, and economic volatility, (FAO 2008; Pangaribowo et al. 2013). Interestingly, although food system stability is vital for long-term food security, the components of stability are seldom explored in any detail, and food security assessments typically focus on short-term trends (Stamoulis and Zezza 2003; Ingram 2011).

Maxwell and Smith (1992) provide one of the best reviews of this dimension, and contrast a conventional interpretation of stability with the emerging understanding that sustainability, sensitivity, and resilience are crucial to support food security in the long-term. In their words:

> "The conventional view is that […] variability, and the resulting risk of future food consumption shortfalls, must be dampened and insured against. In this view, sustainability means maintaining constant levels of consumption, and comes from stabilizing and making more reliable each of the proximate factors. […]. Stability means minimizing variability around the mean values of production levels, terms of trade, or assets and claims."

However, Maxwell and Smith (1992) go on to argue that this interpretation of stability may overlook important issues of social-ecological resilience. Although minimizing seasonal and cyclical variations in access to food is an important part of food security, in fact, the long-term sustainability of livelihood systems is supported by "resilience in the economic and social system, which allows the system itself to contract and expand in response to variations in resource availability and external shocks" (ibid). In other words, to support food system stability, we require *resilient* food systems - i.e., that tend to maintain their integrity when subject to disturbance and that can 'bounce back' following a disturbance (Holling 1973; Misselhorn et al. 2012).

MULTIDIMENSIONALITY

Having traced the progression of mainstream conceptualizations of food security, we can see that the focus has shifted from *availability* to *accessibility* and more recently to *utilization* (specifically nutrition). Moreover, a fourth dimension, *stability*, is sometimes included, though typically it is given much less attention. Altogether, this multidimensional conceptualization has the advantage of avoiding simplistic assumptions that consider food security to be solely a function of inadequate food supply or income. The framework is the product of many decades of research and I therefore adopt it as the conceptual starting point for this thesis. Although much more can be said about the evolution in thinking on food security over the years (see Maxwell 1996b), I have provided only a high-level summary of the key discursive shifts. I discuss some of the drawbacks of this framework in a later section of this chapter. In Part II of this chapter, I discuss how to transition from concepts to measurements, focusing on common indicators of food security at the household level.

PART II: ANALYZING FOOD SECURITY

How should household security be estimated? Food security is by no means an easily defined concept that lends itself readily to empirical measurement. Its ambiguity and complexity represent a challenge for researchers and practitioners, and yet many agencies are tasked with the practical problem of assessing needs, identifying at-risk households, targeting interventions, and evaluating the impact of those interventions. Recognizing the need to differentiate the "food secure" from the "food insecure" – or to situate people along some sort of food security continuum – there is a sense of urgency associated with the search for better measures and methods. In this section, I: i) briefly review some of the issues to keep in mind when planning a food security analysis; ii) summarize the key methods and indicators used by practitioners and researchers to assess household food security; and, iii) review some of the common statistical methods used to analyze collected data. I limit the scope of this discussion to indicators of household food security, although I briefly discuss issues of assessment across spatial scales.

THE CHOICE OF INDICATORS

What are food security indicators?

Measurement may take two forms, "*fundamental*" or "*derived*" (Webb et al. 2006). Where fundamental measurement "presupposes no other", derived measurement depends on a known empirical relationship with an established measure (ibid). According to Webb et al. (2006), food security measurement typically depends on derived measurement, where "proxy measures of household food insecurity, such as food consumption, or income, or assets, (…) are presumed to be closely related determinants or consequences of the phenomenon". Thus, we are not really dealing with measures *per se*, but rather with *indicators*. Indicators are intended to condense complex information, yet they do not require the direct and exact measurement of the condition or characteristic we are interested in (Schultink 2000). For example, if we are interested in soil fertility - commonly defined in terms of the ability of a soil to supply nutrients to crops and to promote production (Watson et al. 2002) - we may consider the concentration of phosphorus as an indicator of soil fertility, recognizing that this approach provides only a partial representation of the complex nature of soil fertility.

Indicators of food security have traditionally focused on specific, easily measured, aspects of a given dimension, such as current food supply, individual caloric intake, or income. However, food security indicators are far from standardized. Many indicators have multiple permutations, and over 450 indicators of food security have already been identified (Chung et al. 1997). A surge in interest in food security research in the last decade has only added to this list.

Food security indicators may be qualitative or quantitative, and come from a multitude of disciplines including economics, anthropology, nutrition, sociology, medicine, and ecology (Migotto et al. 2005). It is generally agreed that separate indicators and data collection methods are needed to assess each of the four dimensions of food security (FAO 2003a; Webb et al. 2006). Moreover, there is no gold standard or single benchmark for assessing food security (Migotto et al. 2005). Instead, researchers must rely on cross-referencing indicators and methods through a convergence of evidence approach (Coates et al. 2003).

What is the process for selecting indicators?

After defining a research problem, a researcher is interested in moving from concepts to indicators and then to results. To do so, the researcher must establish a systematized concept (e.g., the four dimensions of food security) and operationalize the concept by selecting appropriate and valid indicators. Some abstraction is needed to move from conceptualization to operationalization to analysis (Adcock and Collier 2001). While indicators must reflect the systematized concept, they should be selected and evaluated on the basis of several additional criteria, including: information use, relevance, cost, comparability, time sensitivity, and credibility (Riely et al. 1999).

First and foremost, indicator selection should be tailored to the intended *uses of information*, where the data required for developing baselines, targeting, monitoring, and evaluating programs will likely vary (Riely et al. 1999). Indicators should also be *relevant* with respect to local production systems and the food security context. For example, one should consider the issue of 'contextual specificity', where it is possible that an indicator that is valid in one context is invalid in another (Adcock and Collier 2001). Indicators should also be *cost effective* in terms of the design, collection, analysis, and monitoring of data. *Time sensitivity* is especially important for food security research involving household surveys, because as the researcher tries to cover a larger set of questions, the survey takes longer to administer and this risks triggering respondent fatigue. Simple indicators (or proxies) are often used in household surveys owing to the need to collect a range of information while avoiding respondent fatigue (Riely et al. 1999). Another important consideration is indicator *comparability,* which may not be important for case studies but is essential for cross-study comparisons. Finally, and most importantly, indicators should be selected on the basis of *credibility.* Riely et al. (1999) argue that credibility is enhanced when an indicator: (i) has a strong empirical basis in the literature, (ii) is more objective than subjective, (iii) can be measured accurately, (iv) can be measured with precision, and (v) can be measured while minimizing measurement error.

Conceptual and methodological challenges

Because food security is so complex, researchers will inevitably encounter some methodological challenges. I discuss some of these challenges below.

Issues with spatial scale: Food security is cross-scale, involving individuals, households, communities, nations, and international trade. While analyses typically focus on only one scale at a time, researchers should be aware of potential cross-scale relationships. For example, even when food is available in sufficient quantities nationally, it may not be available to marginalized rural groups at a meso scale. The indicators used to understand food security across the four dimensions also vary across scales (Weingärtner 2009).

Issues with temporal scale: A key question for food security analysis is how well indicators – and associated sampling protocols – capture the temporal nature of food insecurity. Food insecurity can be *chronic* or *transitory (*Weingärtner 2009). In turn, transitory food insecurity can be *cyclical* (e.g., due to hungry seasons that occur every year) or *temporary* (e.g., due to a short-term shock like a drought or civil conflict). Capturing this temporal nature of food insecurity is difficult because many indicators represent only a snapshot it time. While it is often desirable to assess food security through time, this is not always feasible.

Differentiating the "food secure" from the "food insecure: Is food security a binary state (i.e., secure/insecure) or is there some continuum of food (in)security that ranges from immediate hunger to sustained food security? Should we evaluate food security in relative or absolute terms? These remain open questions (Coates et al. 2003), and researchers and practitioners use a variety of means to identify and stratify the 'food insecure'. Benchmarks - for example, a minimum cut-off for the level of caloric intake of a person deemed to be food secure, can sometimes be defined to establish absolute levels of food insecurity, although their use is sometimes contested (Riely et al. 1999). For some indicators, there are widely used conventions for benchmarks (e.g., anthropometric indicators). For other indicators, appropriate benchmarks may not exist (Riely et al. 1999).

Measurement: to what end? Although it may seem a heterodox question, one may ask whether measuring food insecurity in the hopes of identifying the food insecure even matters. The FAO estimates that around 870 million people were undernourished in 2012, and this represents approximately the same number of undernourished people as in 1970 (FAO 2012). Although researchers have gotten better at measurement, food insecurity at the global scale has not gotten better in absolute terms. According to Alcock (2009), there is a risk that measurement may not lead to any real change in the status quo, as structural inadequacies or power imbalances within the food system remain unaddressed. Another issue is that, even when equipped with a rather holistic conceptual framework of food security, there is a risk that academic interpretations of food security may not match individual or cultural *experiences* of food insecurity. In the book *Anthropology of Food: The Social Dynamics of Food Security* (1999), Johan Pottier argues that policy-makers all-too-often "opt for a minimalist approach to culture" (p. 15) whereby we fail to adequately account for local knowledge, social norms, and general social conditions when assessing food security.

Overall, despite the potential challenges and shortcomings associated with food security assessment, policymakers nevertheless need to understand who is at risk and how best to reach them through appropriate interventions (Becquey et al. 2010). It follows that we must use indicators even as we try to remain mindful of their potential inadequacies.

KEY INDICATORS

In the following section, I describe a set of household food security indicators that are commonly used in food security assessment, including those I will use in Chapter 2, and distill the literature to describe the advantages and disadvantages of each (see Table 1.1 for a summary). I do not cover food security indicators that are are less relevant to my thesis. Noteworthy references for those seeking more information include Haddad et al. (1992), Maxwell and Frankenberger (1992), FAO (2002), Gerster-Bentaya (2009a, 2009b), and Pangaribowo et al. (2013). Building off of FAO (2003a), I identify four general sets of indicators, covered briefly here and in more detail below:

1. Indicators of food intake: These measure the amount of food actually consumed at the individual or household level. Food intake may be measured directly using techniques including dietary histories, 24-hour recall surveys, the actual weighing of food eaten, and food frequency questionnaires (Migotto et al. 2005). It is also possible to use data collected as part of household expenditure surveys to estimate food intake, although this method is less direct (Smith and Subandoro 2007).
2. Indicators of economic access to food: The concept of access to food can be proxied by wealth status, as measured by total consumption, expenditures, or income. Access-to-food indicators – particularly income – are typically the main food security indicators reported at the country-level and household level (Migotto et al. 2005).
3. Indicators of nutritional status: The most common indicators of nutritional status are those related to dietary diversity and the anthropometric measurements of children.
4. Indicators of self-assessment: These indicators provide a more direct representation of food security based on the perceptions and experiences of individuals (Barrett 2002). Households are classified along a food security continuum based on responses to survey questions representing different domains of food insecurity.

Table 1.1. Key indicators of food (in)security at the household level (Source: adapted from Pérez-Escamilla and Segall-Correa 2008 to include additional indicators, advantages, and disadvantages).

Method	***Purpose(s)***	***Advantages***	***Disadvantages***
1. *Indicators of food intake*			
Dietary Intake	• *Inputs:* 24-hour recalls, food frequency questionnaire, food composition tables • *Outputs*: Individual's food group intake counts, nutrient intake	• Addresses both dietary quantity and quality • Measures actual food consumption	• Typically high measurement error • Costly and time-consuming • Nutrient benchmarks often uncertain
2. *Indicators of economic access to food*			
Income	• *Inputs:* Income from agricultural and non-agricultural wages, crops, livestock, self-employment, transfers, and miscellaneous income • *Outputs:* Net annual household income	• Identifies vulnerable households; informs poverty analysis • Monetary units are well understood and comparable	• Measurement error associated with under-reporting/ recall bias • Seasonal variations difficult to capture • Data and time intensive if done well
Household Expenditure Survey	• *Inputs:* money spent on food and other expenditures, foods consumed and market value, food composition tables • *Outputs*: caloric intake per capita per household; dietary variety score	• Identifies vulnerable households • Can help understand household/intrahousehold patterns of food access	• Expensive and logistically tough • Food acquired (as measured) does not necessarily represent food consumption • Lack of standardized methodology
3. *Indicators of nutritional status*			
Anthropometry	• *Inputs*: body dimensions (weight, height), age • *Outputs*: indicators of	• High level of standardization • Inexpensive	• Reflects joint impact of food insecurity and health

Method	*Purpose(s)*	*Advantages*	*Disadvantages*
	stunting, wasting, and underweight	• Well-established normative growth cut-offs	• Does not properly account for obesity
Dietary Diversity	• *Inputs*: food items and or/groups consumed over a time period; possibly including frequency of consumption • *Outputs*: Household Dietary Diversity Score (HDDS), Food Consumption Score (FCS)	• Positive association with more complicated indicators (good proxy) • Low cost and straightforward method	• Difficult to compare across studies; • Benchmarking in development • Recall error of participants
4. *Indicators of self-assessment*			
Subjective Surveys – Household Food Insecurity Access Scale	• *Inputs*: Responses to standardized survey questions • *Outputs*: Food insecurity status (range 0-27); Categorical classification (food secure; mildly, moderately, and severely food insecure).	• Direct measure: experience-based • Captures physical and psycho-emotional elements • Low cost and straightforward method	• Difficult to standardize cut-off points • Potential for participant "benefit" bias
Coping Strategies	• *Inputs*: types and frequency of strategies employed over reference period; community weighting of strategy severity • *Outputs*: Coping Strategies Index	• Captures elements of vulnerability and seasonality • Low cost and straightforward method • Useful for monitoring	• Relative rather than absolute indicator • Recall error and "benefit" bias • Cannot be compared across regions

1. Indicators of food intake

Dietary Intake

Dietary intake methods estimate an individual's food group and nutrient intake, lending insight into both food availability (caloric intake) and food utilization (dietary quality). An individual's dietary intake may be estimated using 24-hour recall surveys, food frequency questionnaires, or individual food journals (Johnson 2002; Pérez-Escamilla and Segall-Correa 2008). While 24-hour recall surveys and food frequency questionnaires rely on the memory of participants, the food journal method is done in real time.

Advantages: A major advantage of dietary intake methods is that they measure food consumption directly. These methods can also: 1) estimate both dietary quality (macro and micronutrients) and dietary quantity (caloric intake); 2) shed insight into patterns of intrahousehold food consumption; and, 3) be used to compare recent and longer-term dietary intake (Pérez-Escamilla and Segall-Correa 2008).

Disadvantages: The 24-hour recall and food frequency questionnaires are subject to memory recall bias and substantial measurement error. Associated methodological challenges, such as estimating portion sizes, may lead to an unacceptably high measurement error (Pérez-Escamilla and Segall-Correa 2008). Applying these methods is also costly, requires skilled personnel (for both application and analysis), takes a significant amount of time (20 to 30 minutes per survey), and requires repeated visits to form a reasonable estimate. Finally, it is difficult to evaluate dietary intake data because benchmarks for assessing intake adequacy are evolving and vary across cultures (ibid).

2. Indicators of economic access to food

Income

Income is the indicator most commonly used to measure food access because direct measures of food insecurity have been found to be strongly associated with income (Tarasuk 2001). There are many ways one can measure household income. For example, it may be estimated based on a household head providing a lump sum estimate of income over the past month, or it might be based on the aggregate income of individual household member activities and individual recall.

McKay (2000) and Covarrubias et al. (2009) discuss the challenges involved in measuring household income, and provide thorough guidelines for developing appropriate questionnaires. Covarrubias et al. (2009) suggest calculating rural income on the basis of seven categories (see equation below), where the required data is collected using household survey questions designed to capture the income associated with each category over a 12-month period.

$$\boldsymbol{Income} = (Agricultural\ wages) + (Non\text{–}\ agricultural\ wages) + (Crop\ production) + (Livestock\ production) + (Self\text{–}\ employment) + (Transfers) + (Other\ Income)$$

Advantages: One major advantage of measuring income is that policymakers readily understand a monetary definition of poverty based on income. McKay (2000) argues that there are three main arguments for collecting income data: 1) it can be used to measure or understand household living standards; 2) it can be used to understand the determinants of poverty; and 3) it can be used to estimate household savings. Income is an important risk factor for household food insecurity, and it is therefore important to understand income sources and income levels. From a logistical standpoint, although consumption-based standard of living measures are usually considered preferable to income based measures, income data is easier to collect than consumption or expenditure data (although that does not mean it is simple to do) (McKay, 2000).

Disadvantages: Household income is neither a specific nor sensitive indicator of food insecurity (Rose 1999; Tarasuk 2001) because there is not a simple linear relationship between income and food insecurity and hunger (Rose 1999). Within any given income bracket, there is typically a mix of food insecure and food secure households (Alaimo et al. 1998; Bickel et al. 2000). Although the relative proportion of food insecure to food secure households generally falls as income rises, food insecurity may persist in households with higher incomes. Similarly, household income provides only a crude indication of the available food resources within a household; these resources are also a function of other variables, such as shelter costs, debts, food prices, and support from social networks. Income-based measurements also fail to take into account the consumption of subsistence food that does not appear on the market, the existence of informal markets, or non-monetary food transfers (Tarasuk 2001).

Additionally, collecting high quality income data is challenging (McKay 2000). Seasonal variations in income may be difficult to measure accurately, and many researchers prefer to measure expenditures, which do not fluctuate as much as income over the course of a year and are generally more accurate (ibid). Income is also subject to under-reporting. Some participants may deliberately under-report income if they perceive a program benefit linked to poverty, or the measurement method may not adequately account for income from the private and informal sectors (ibid). Moreover, income analyses typically do not take into account the terms on which that money was obtained, and in particular, of the time spent working and the labour environment (Falkingham and Namazie 2002).

Household Food Expenditures

Household food expenditure surveys (HESs) may be used to gather data for indicators of both dietary quantity and dietary quality. Specifically, participants are asked about: (i) the quantity of food bought (or expenditures) associated with different foods consumed within and outside the household for a given reference period, (ii) foods received as gifts or as payment for work, and (iii) foods grown for consumption by the household (Pérez-Escamilla and Segall-Correa 2008).

HESs are often used as a cheaper alternative to direct methods of measuring dietary intake (e.g., the food consumption surveys discussed earlier), as they are able to estimate the calories consumed on average per household member per day, albeit with lesser precision than dietary intake methods (Smith and Subandoro 2007). Where food consumption surveys measure the amounts of foods actually eaten by households (typically over a 24-hour period), HESs measure the amounts of foods acquired by households over a period of one to two weeks. HESs may also be used to assess indicators of dietary quality, such as dietary diversity or the percentage of dietary energy available from food staples (ibid).

Advantages: HESs are viewed as a cheaper, more practical, alternative to the dietary intake methods previously discussed, because data collection focuses on foods acquired rather than on the actual quantities of food consumed (Smith and Subandoro 2007). HESs are also useful because they serve as the basis for calculating indicators of dietary quantity, dietary quality, and economic vulnerability to food insecurity and may help identify both determinants and consequences of food insecurity (ibid).

Disadvantages: Although less costly than food consumption surveys, HESs are believed to give less accurate and less precise estimates (Smith and Subandoro 2007). The methodological limitations of HESs include: (i) the method measures the amount of food available but not necessarily the amount of food consumed, (ii) it is difficult to include estimates of foods eaten outside the household, (iii) participants have a difficult time bounding estimates of food acquisition within the timeframe of interest inviting recall error, (iv) survey questions are highly variable and resulting data is often incomparable across regions, (v) there is a large measurement error associated with converting estimated food available into caloric intakes, (vi) and the method relies on interdisciplinary teams with significant expertise for implementation (Smith and Subandoro 2007; Pérez-Escamilla and Segall-Correa 2008).

3. Indicators of nutritional status

Anthropometry

Maxwell and Frankenberger (1992) distinguish between "process indicators" – which reflect food supply and food access – and "outcome indicators" – which describe nutritional status. Anthropometric indicators are outcome indicators, and reflect the joint impacts of food insecurity and health status on the nutritional status of individuals by measuring the size, weight, and proportions of the human body (Pérez-Escamilla and Segall-Correa 2008). Common indicators are based on the weight, height, or length of people across age groups, and may examine height-for-age (stunting), weight-for-age (underweight), and weight-for-height (wasting) (de Haen et al. 2011). Reference levels are based on well-established normative growth standards; values below 2 standard deviations from the mean of the population (i.e. a Z score of <-2) may indicate that an individual is stunted, underweight, or wasted (Payne 1990).

Advantages: Anthropometry is a popular method for measuring food insecurity owing to the low cost and high standardization of the method. The interpretation of anthropometric indicators is aided by a strong evidence base, and this method is generally viewed as less problematic than interpreting the adequacy of nutrient intake through other methods (Pérez-Escamilla and Segall-Correa 2008; de Haen et al. 2011). The availability of three different child anthropometric indicators gives an indication of both chronic and acute undernutrition, and anthropometry is therefore well suited for monitoring and evaluating interventions (de Haen et al. 2011). Anthropometric indicators also lend insight into the trends, determinants, and consequences of malnutrition at the individual level (ibid).

Disadvantages: Since anthropometry is a joint reflection of both food (in)security and health status, anthropometric indicators are indirect, non-specific indicators of food security. Organizing fieldwork around anthropometry may be difficult, owing to the need for a stricter ethical review process (due to physical contact with human participants) and a trained field staff. Interestingly, interpreting anthropometric indicators is also becoming more difficult as obesity becomes an increasingly common outcome of mild to moderate food insecurity (Pérez-Escamilla and Segall-Correa 2008).

Dietary Diversity

Dietary diversity is often used as an indicator of dietary quality, and can be defined as the number of different foods or food groups consumed over a reference period (Ruel 2003). It is commonly measured using a simple count of food items (food variety score) or food groups (dietary diversity score) over a given reference period (ranging from one to fifteen days). Although there is some debate about whether dietary diversity reflects energy intake or dietary quality, it may actually reflect a combination of both (Ruel 2003).

In terms of food utilization, dietary diversity is positively associated with nutrient adequacy and dietary quality. An increase in dietary diversity is typically associated with an increase in energy, fat, protein, carbohydrates, and the number of vitamins and minerals consumed (Ruel 2003). Dietary diversity may also be a good indicator of food access, owing to a positive association with caloric intake (Hoddinott 2002).

One indicator of dietary diversity is the one-day Household Dietary Diversity Score (HDDS) used by the FAO. The HDDS is the sum of the number of 12 distinct food groups consumed in the household in the previous 24 hours (range 0-12) (Swindale and Bilinsky 2006). Households consuming a more diverse diet (as assessed by the HDDS) have been shown to have greater access to food (Hoddinott and Yohannes 2002). Another indicator is the seven-day food consumption score (FCS) used by the World Food Programme (WFP 2008). The FCS is a composite score based on dietary diversity, food frequency (the number of days the food is consumed per work), as well as the weighted nutritional importance of eight food groups (WFP 2008). The number of times each food group is eaten in the previous week (within the household or by an individual) is multiplied by a standard weight developed according to the nutritional density of the food group (WFP 2008). Food group scores are then summed to give the FCS (ibid). Data on dietary diversity and food frequency have proven to be reliable proxy indicators of diet quality across a range of settings (Ruel 2002; Wiesmann et al. 2009). Moreover, the FCS is strongly correlated with energy intake (Hoddinott and Yohannes 2002; Wiesmann et al. 2009).

Advantages: Dietary diversity is an attractive indicator of food security both in its own right and because it is positively associated with birth weight, anthropometric status, and caloric intake (Hoddinott, 2002). It is an important indicator of dietary quality (i.e., food utilization) (Ruel 2003), and can be used as a proxy measure for some other indicators with which is associated, given that these indicators are typically more difficult to measure (e.g., measuring caloric availability from 7 day recall of food acquisition) (Kennedy et al. 2010). Measuring and analyzing dietary diversity is also relatively straightforward. The costs of collection are low, and answering the survey questions takes less than 10 minutes per person. Moreover, dietary diversity data can be collected at both the individual and household level.

Disadvantages: Despite the apparent simplicity of dietary diversity methods, there is a lack of consensus on how to measure and operationalize dietary diversity (Ruel 2003). For example, there is still confusion about which indicator performs best, the FCS or the HDDS (Kennedy et al. 2010). Actually, the FCS may be a better indicator of food utilization, whereas the HDDS may be a better indicator of food access (Wiesmann et al. 2009). A key measurement challenge is that researchers tend to focus on different food groups while using different classification systems and reference periods (Ruel 2003). There are also measurement challenges relating to: i) the aggregation of food items into food groups based on differing criteria (e.g., should we select food groups based on nutrient composition or economic value?); ii) portion sizes (e.g., do small quantities of fish powder in porridge count as fish intake?), iii) scoring systems (e.g., should we weight foods based on frequency of consumption or nutrient density, if at all?), iv) recall error of participants, and v) cutoff points. Although cutoff points are needed to define high and low diversity, international cutoff points are generally meaningless, which means that cutoff points must be defined locally (although this can also be considered an advantage) (Ruel 2003).

4. Indicators of "self-assessment"

Coates et al. (2006) argue that "household food insecurity in developing countries is still commonly measured through income, consumption and even anthropometric indicators that are only distantly, or partially, related to the concept." In turn, there have been calls to shift from "second generation" indicators (e.g., income and consumption) toward "third generation" indicators (Barrett 2002; Coates et al. 2006). Although still nascent, so-called "third generation" approaches reflect a broader conceptualization of food insecurity, and focus on the felt experience of food insecurity (Barrett 2002). Breakthrough research by Radimer et al. (1990), which analyzed the accounts given by individuals of their experiences of food insecurity, identified several aspects of food insecurity that were common to those accounts: 1) the quantitative aspect of not having enough food, 2) the qualitative aspect concerning the types and poor diversity of foods, 3) a psychological aspect including feelings of deprivation, restricted choice, and anxiety; and 4) a social or normative aspect whereby an individual considers the food situation in terms of generally accepted social norms, such as eating three meals a day or having enough food without having to rely on charity. These third generation measures help identify households that regard themselves as food insecure, even if there are no recognizable signs of undernutrition or if income levels and other second generation measures appear adequate.

Subjective Surveys

Subjective food security surveys are based on an individual's perceptions and past experiences of food (in)security. These surveys are constructed around assessing not only aspects of the availability, access, and utilization of food, but also how a person feels about it (e.g., anxiety or worry), what a person thinks about it (e.g., perceptions of social acceptability), and how frequently different perceptions or experiences occur. Wolfe and Frongillo (2001) argue that these surveys directly measure food insecurity, and are thus preferable to other indirect indicators. Although different surveys exist, most stem from the U.S. Household Food Security Survey Module (US HFSSM) (Radimer et al. 1990; Radimer et al. 1992; Carlson et al. 1999). The US HFSSM is designed to measure the severity of household food insecurity through responses to validated survey items that are then transformed into a continuous linear scale. The 18 standard survey questions address aspects of food insecurity including the physical sensation of hunger, the experience of anxiety, and the lack of choice regarding the foods to eat, among others. Field validation studies of the US HFSSM indicate that it is strongly correlated with common indicators of poverty and food consumption (Webb et al. 2002; Coates et al. 2003).

One increasingly popular subjective survey – and derivative of the US HFSSM – is called the Household Food Insecurity Access Scale (HFIAS) (Coates et al. 2007). The HFIAS, an indicator of food access, consists of nine questions relating to worry, availability of, and accessibility to foods for a household during the previous 30 days. Some of the questions relate to *perceptions* of food stress or vulnerability (e.g., did you worry that your household would not have enough food?) and some relate to *behavioural* responses to insecurity (e.g., did you or any household member have to eat fewer meals in a day because there was not enough food?) (ibid). If a respondent answers yes to a question, it is followed by a question asking about the frequency of occurrence (rarely, sometimes, often). Questions are directed to an individual who is in charge of or well informed about food acquisition within the household. A score is assigned to each answer: zero is attributed if the event never occurred, 1 point if it occurred 1 or 2 times during the previous 30 days (rarely), 2 points if it occurred 3-10 times (sometimes), and 3 points if it occurred 10 times or more (often). The HFIAS score is then tallied as the sum of these points, and can range from 0 (food security) to 27 (maximum food insecurity) as a continuous score (ibid). Cut-off points on the scale enable the categorical classification of households as either food secure, or mildly, moderately, or severely food insecure.

Advantages: Subjective surveys like the US HFSSM and the HFIAS are advantageous because they: (i) directly measure food insecurity, (ii) include both physical and psychosocial domains of food security, (iii) lend insight into the causes and consequences of food security, (iv) are fairly easy to administer at low cost, and (v) may be used across social-ecological contexts (Deitchler et al. 2010).

Disadvantages: Disadvantages associated with subjective surveys include: (i) the scale may not be valid if used to determine eligibility for social assistance due to exaggerated responses, (ii) the cut-off points to determine levels of food insecurity may vary across regions, (iii) the scale does not capture the food safety dimension of food security, and (iv) it may be necessary to use different timeframes for the survey (e.g., 30 days, 3 months) depending on the frequency and intensity of food insecurity across regions (Pérez-Escamilla and Segall-Correa 2008).

Coping Strategies

The strategies that people use for dealing with insufficiency of food at the household level (henceforth 'coping strategies') may be employed as indicators of food access (Maxwell 1996a). Coping strategies are behavioural responses to food insecurity or perceived food insecurity. In periods of food stress, there is typically a sequential use of coping strategies by a household (Corbett 1988, Maxwell 1996a). Methods to assess food insecurity based on coping strategies examine the frequency and severity of strategies used by households relating to changes in food consumption (e.g., reducing meal frequency, quantity, or quality) or to the household resource base (e.g., seeking food aid, migrating for work). Survey questions are first constructed around a set of strategies that have been identified as locally important through initial focus groups and weighted in terms of their severity (Barrett 2002). Survey respondents are then asked whether or not (and the frequency) they have used a given coping strategy over a reference period. The identified strategies are then simply tallied or combined into relative frequency scale.

Advantages: One major advantage of the coping strategies method is that it begins to capture an element of household vulnerability when assessing food insecurity (Maxwell 1996a). It also pays attention to the agency of household through their choices, thus reflecting human intentionality and the subjective judgment of food sufficiency (Maxwell 1996a). The data for the indicator is also relatively easy to collect and analyze, can be collected quickly and can be collected on repeated visits for monitoring purposes (ibid). The method also has a longer and representative recall period (e.g., over several months), although this does involve some trade-offs regarding the reliability of the data (ibid).

Disadvantages: Disadvantages of the coping strategies approach include: (i) difficulties in assigning severity weightings to each strategy that apply equally across households or contexts, (ii) a focus on short-term strategies implies that the indicator is descriptive but cannot be applied for predictive value, (iii) there may errors associated with recall, especially as the recall period increases, and (iv) there may be a deliberate respondent bias if the survey is linked to any offers of social assistance (Maxwell 1996a). Moreover, coping strategies provide a relative rather than absolute indication of food security.

MULTIDIMENSIONALITY

Clearly there is no single, best measure of food security. Any single indicator may only partially capture an element food security (Maxwell 1996a) and for any given measurement or indicator, there are advantages and disadvantages. As a result, researchers are forced to make choices as to how best to operationalize the food security concept using indicators across a broad set of criteria, where the "best" indicator(s) will likely change across contexts and depending on the question at hand.

Given this, an important issue remains how to better address food security as a multidimensional phenomenon. Pangaribowo et al. (2013) argue that assessing food security requires more systematic approaches to assessing food availability, access, utilization, and stability. This will require using indicators that provide complementary information across all four dimensions (FAO 2002). Researchers will need to carefully consider how well the indicators they have chosen capture food security; while remaining cautious about overstating claims of assessing "food security" when really they are assessing a particular dimension or subset of dimensions. As an entry-point to this important work, Table 1.2 summarizes the relationship between the major methods and indicators discussed herein and the four dimensions of food security. The table shows that many indicators address more than one dimension of food security. Nevertheless, indicators have typically been designed to address one dimension in particular. While many indicators have been developed to specifically explore food access, there are fewer options available for assessing food utilization. Importantly, of the indicators covered here, none address food system stability as a focus area. This table is a useful starting point for designing a systematic approach to food security measurement at the household level. This approach would entail selecting multiple indicators of all four dimensions, and working to ensure that the indicator suite captures the breadth of food security while also measuring each dimension in a valid and robust way.

Table 1.2. Dimensions of food security and corresponding indicators at the household and individual levels. Although indicators may address more than one dimension, boxes highlighted in grey represent the dimension best captured by each.

Indicator	Availability	Accessibility	Utilization	Stability
Dietary Intake	Yes	Yes	Yes	No
Household food expenditure	Yes	Yes	No	No
Income	No	Yes	No	No
Coping strategies	Yes	Yes	No	Yes
Subjective scales	No	Yes	No	No
Anthropometric	Yes	Yes	Yes	No
Dietary Diversity	Yes	Yes	Yes	No

Note: This table does not attempt to provide a comprehensive list of indicators and methods; it gives examples of commonly used indicators for food security assessment.

FOOD SYSTEM STABILITY

Notably absent from the discussion on indicators thus far is any mention of how to operationalize the dimension of food system stability. Unfortunately, this dimension is often under-represented in food security analyses (Wood et al. 2010; Ingram 2011; Pangaribowo et al. 2013). To my knowledge, there is no literature that addresses operationalizing food system stability in food security analyses in any depth. Where indicators of stability are suggested, they typically focus on comparing an indicator trend over a short-to-medium term period (e.g., comparison of pre- and post- harvest food availability) and attempt to identify whether food insecurity is of a chronic or transitory nature (Weingärtner 2009; Pangaribowo et al. 2013). Examples of indicators used in this way include food price fluctuations (at the macro level), rainfall levels (at the meso level), or employment migration (at the micro level) (ibid).

Food system stability requires resilient food and social systems that can maintain integrity in the face of disturbances (Maxwell and Smith 1992; Misselhorn et al. 2012). Risks associated with social, economic, or ecological disruptions threaten food availability, access, and utilization (Pangaribowo et al. 2013). How might we choose indicators that reflect the social and ecological resilience of food systems? Biggs et al. (2012) argue that although the indicators needed to monitor trends in resilience are generally not well developed, there are some indicators that correspond to generic principles for enhancing resilience. For example, connectivity in social networks enhances social resilience, as high levels of connectivity among groups encourages information sharing, builds trust, and fosters the reciprocity necessary for collective action (Brondizio et al. 2009; Biggs et al. 2012). It is then possible to design indicators associated with social connectivity as an entry-point to understanding social resilience (Pingali et al. 2005).

From an ecological standpoint, scientists now recognize that ecosystems and the specific services they provide (e.g. pollination, water regulation, pest control) are necessary for long-term food provision (MA 2005), and that diverse bundles of ecosystem services – defined as the benefits humans receive from nature (ibid) – enhance social-ecological resilience. In fact, Bennett et al. (2005) argue that the best indicators of ecological resilience may actually be slowly changing ecological variables, including “slow” regulating services such as erosion regulation and nutrient cycling. Although social-ecological systems produce a bundle of ecosystem services, including provisioning (e.g., freshwater, crops), regulating (e.g., flood and climate regulation), and cultural services (e.g., recreation, spiritual values), indicators developed to reflect changes in the status of regulating services are a promising new avenue for assessing social-ecological resilience (Biggs et al. 2012).

INTERPRETING RESULTS

Once indicators have been selected and data have been collected, a researcher must analyze the data using appropriate methods and interpret the results. In this section, I review some of the most common statistical tests used in food security analysis, review the assumptions underlying each test, and suggest non-parametric analogues where applicable. I focus on the methods that I employ in Chapter 2, including the Student’s t-test, the two-way analysis of variance (ANOVA), and cross-tabulations of categorical variables. Although there are many other statistical methods commonly used in food security analyses (e.g., Multiple Linear Regression, Principal Components Analysis), I do not discuss them here because they do not form part of my analysis. I begin by discussing different types of data and measures of dispersion.

TYPES OF DATA

Data can be categorized according to four different measurement scales: nominal, ordinal, interval, and ratio (Sokal and Rohlf 1969). The type of variable then informs the types of statistical methods that may be used for data analysis. Even simple descriptive statistics (e.g., measures of central tendency) vary by variable type (Table 1.3).

Table 1.3. Summary of statistical measures by type of variable (Adapted from the World Food Programme's *Comprehensive Food Security and Vulnerability Analysis Guidelines*, 2009, p. 159).

	Categorical		**Continuous**	
	Nominal	**Ordinal**	**Interval**	**Ratio**
Description	Describe a name or category, without "natural ordering".	Order (or rank) data based on a natural order, without equal intervals.	Order data based on a natural order, with equal intervals. Arbitrary zero point.	Same as for interval data, but the scale has a clear zero point.
Example	Country (Guatemala, Mexico, Belize)	Food consumption scores: "good", "acceptable", "poor"	Year of birth	Weight (kg)
Okay to compute				
- Frequency distribution	Yes	Yes	Yes	Yes
- Median and percentiles	No	Yes	Yes	Yes
- Add or subtract	No	No	Yes	Yes
- Mean, standard deviation, standard error of the mean	No	No	Yes	Yes
- Ratio, or coefficient of variation	No	No	No	Yes

Measures of dispersion

Common measures of variation around the mean of a continuous variable include the variance and the standard deviation. Although both are measures of variation, the variance is measured in units that are the square of those of the variable itself, while the standard deviation – calculated as the square root of the variance – has the same unit as the original data (Sokal and Rohlf 1969). In a normal distribution, the majority of cases fall within one standard deviation of the mean (68.26%), while 95.46% of all cases fall within two standard deviations of the mean (ibid). Generally speaking, as sample size increases, the standard error decreases as the estimator is based on more information (ibid). The standard deviation (SD) should not be confused with the standard error of the mean (SEM). While the SD describes the spread of values in a sample relative to an average, the

SEM represents the standard deviation of the sample mean and describes its accuracy as an estimate of the true mean.

COMMON STATISTICAL ANALYSES

Statistical tests can help a researcher discern whether differences or relationships exist among different variables, and are often used to test a scientific hypothesis (Sokal and Rohlf 1969). Tests of significance can be used to help identify differences that are real (i.e., significant) versus those that occur simply by chance or sampling error (i.e., non-significant), where the value that helps distinguish between significance and non-significance is referred to as the p-value (probability value). Most researchers rely on published probability values of 0.05, 0.01, or 0.001 (ibid). In simple terms, researchers typically reject the null hypothesis (which states that differences occur at a chance level only), when the probability of this being true drops below the probability value (with 0.05 being the most common). This is also called the 5% significance level (Coolican 1994).

Table 1.4 provides guidance on how to choose statistical methods based on the type of data. For all the tests shown, there are fundamental assumptions that need to be met in order for the test to be valid. For example, many common tests assume that continuous variables are normally distributed. If the data are non-normal, and they cannot be made normal using data transformations, then non-parametric tests of significance that do not assume normality should be used.

Independent t-test

An independent t-test is used to determine if the mean scores of two groups differ significantly for a single, continuous variable. The assumptions underlying the t-test include: 1) the dependent variable is normally distributed, 2) equal variances of the two samples, 3) the samples are independent, and 4) both samples are simple random samples (Sokal and Rohlf 1969). If the data are non-normal, and they cannot be made normal using data transformations, then a non-parametric Mann-Whitney U-test may be used (ibid). This test is used to assess whether one of two samples of independent observations tend to have larger values than the other, based on a method that ranks all observations from smallest to largest in a single group. Sokal and Rohlf (1969) provide an excellent review of both the t-test (and variants) and the Mann-Whitney U-test. In Chapter 2, I frequently use either the independent t-test or the Mann-Whitney U-test to compare the means of a continuous variable across two groups of households.

Analysis of Variance (ANOVA)

An ANOVA is a technique used to test significant differences between the means of three or more groups (identified by the categories of the categorical variable) (ibid). I employ a two-way ANOVA in Chapter 2. There are two independent variables (or factors) in a two-way ANOVA, and each factor has two or more levels within it. An ANOVA has the following assumptions: 1) the population from which the samples were obtained must be normally or approximately normally distributed, 2) the samples must be independent, and 3) the variances of the samples must be equal (Sokal and Rohlf 1969). An ANOVA produces a test statistic that compares the means of variables – this is called the F-ratio. If the F-ratio indicates a significant main effect or interaction effect, post-hoc tests are used to check which differences are statistically significant ($p<0.05$). I use the Tukey HSD as a post-hoc test in Chapter 2, although other post-hoc tests (e.g., REGWQ, Games-Holwell) may also be used.

Correlation

Correlation analysis is used to measure the strength of association observed been any two continuous variables (Sokal and Rohlf 1969). The strength of a correlation is measured by the correlation coefficient r (also called the Pearson product moment correlation coefficient, or Pearson's r). Correlation denotes positive or negative association between variables in a study, and is measured using values between -1.0 and +1.0. Values close to zero indicate little or no relationship, and values close to +1.0 (or -1.0) indicate strong positive (or negative) relationships (Frankfort-Nachmias and Nachmias 2007). Both parametric (Pearson's r) and non-parametric (Spearman's Rank) correlations may be calculated. In Chapter 2, I use correlation analysis to check for convergent validity among indicators of food access and food utilization. Convergent validity refers to the degree to which two measures of a given systematized concept are empirically associated and thus convergent, where theory would suggest that the two measures are in fact related (Adcock and Collier 2001).

Cross-tabulations and the chi-square test of association

Cross-tabulations are commonly used in the social sciences, and are used to display the relationship between two categorical variables in a single table. Each column in the table corresponds to a category of the independent variable (two or more) and each row corresponds to a category of the dependent variable (two or more). Once displayed, it is possible to test whether there is a statistically significant association between the two variables (nominal or ordinal) using a chi-square test. To conduct a chi-square test, two assumptions must be met: 1) the two variables must be categorical, and 2) each variable should consist of two or more categorical and independent groups. If the test finds that there is a significant association between the two categorical variables, then we can measure the strength of the association (effect size) using different measures of association (Frankfort-Nachmias and Nachmias 2008). One measure of association, Phi, is used for cross-tabulations involving two nominal variables, each of which has only two categories (2 X 2 nominal tables). Another measure of association, Cramer's V, is used to measure the strength of the association between one nominal variable with another nominal variable, or with an ordinal variable (ibid). Both of the variables may have more than two categories. Phi and Cramer's V vary between 0 and 1. I conduct several chi-square tests as part of categorical data analysis in Chapter 2.

Table 1.4. Examples of significance testing for different types of variables (Adapted from the World Food Programme's *Comprehensive Food Security and Vulnerability Analysis Guidelines*, 2009, p. 171).

	Dependent variable	Independent variable(s)	When to use	Example	Procedure
Independent t-test	Continuous	Categorical (binomial)	To test whether there is a significant difference in the means of two groups ($p<0.05$)	Compare the mean weights of male and female children	Run the test; Report the two means; Check if the t value is statistically significant ($p<0.05$).
Two-way ANOVA: Post-hoc multiple comparisons	Continuous	Two categorical variables	To examine the influence of different categorical independent variable on a continuous dependent variable. To identify whether there is a main effect (from each independent variable) or a significant interaction between the independent variables.	Compare the mean weights of children by residence (urban, peri-urban, rural) and sex (male, female).	Run the Two-Way ANOVA; Check if the categorical variable explains in a significant way some of the observed variation through the F-test. Check which differences (main effects) are statistically significant ($p<0.05$) through post-hoc tests (e.g., Tukey HSD).
Chi-square	Categorical	Categorical	To detect whether there is a statistically significant association between two categorical variables	Explore the association between ethnic groups and land ownership (yes/no)	Report the chi-square value; Check if the value is statistically significant ($p<0.05$); Determine effect size using appropriate measures of association (e.g., Phi, Cramer's V).
Correlation	Continuous	Continuous	To assess the strength of association between two variables (i.e., one variable increases/decreases when another increases/decreases)	Correlation between children's height and weight	Report the Pearson Correlation Coefficient; Check if the correlation is statistically significant (two tailed test) ($p<0.05$). Check the strength of the correlation.
Simple linear regression	Continuous	Continuous / Categorical binomial	To measure how the dependent variable changes with a one-unit increase in the independent variable	Regressing food consumption score by income	Report R^2 adjusted, B value Check and report if B is statistically significant ($p<0.05$)

PART III: NON-TRADITIONAL EXPORT AGRICULTURE AND SMALLHOLDER FOOD SECURITY IN DEVELOPING COUNTRIES

CONTEXT

There are roughly 870 million chronically undernourished people in the world, 97% of whom live in developing countries (852 million people) (FAO 2012). Perhaps counter-intuitively, approximately 80% of these people live in rural areas, and the majority are small-scale food producers – farmers, fishers, herders, and labourers (Bailey 2011). Finding ways to alleviate and eliminate food insecurity among these groups is a critical element of global development, however, progress has been inconsistent (FAO 2012).

Smallholder-centred agricultural growth may be a particularly effective strategy for reducing hunger and malnutrition (FAO 2012). Thus, the increased commercialization of agriculture and diversification into non-traditional export crops (NTXs) by smallholders has been advocated as a growth-oriented strategy to reduce rural poverty and combat food insecurity. However, it remains unclear whether the farming of NTXs by smallholders in developing countries actually leads to real improvements in the food security status of the smallholders involved (von Braun et al. 1989a). In this section, I discuss the growing importance of smallholder NTX agriculture in developing countries, generally, and in Guatemala, specifically. I also present a literature review of the relationship between the farming of NTXs and household food insecurity. Throughout, I focus on NTX vegetables rather than on NTX fruits, since this helps set the stage for the case study presented in Chapter 2, where I explore the implications of farming broccoli, an NTX vegetable, for the food security of smallholders in a Guatemalan community.

Smallholder market participation and commercial agriculture

Rural agricultural development and food security have frequently been pursued as twin, complementary goals. Many have argued that, in order to achieve these twin goals, smallholder agricultural households in developing countries need to transition from low productivity subsistence agriculture to high productivity commercial agriculture (Timmer 1988; Barrett 2008). For over half a century, there have been continual calls to put smallholder agriculturalists "on the growth path" through strategies aimed at the commercialization of agriculture and market-oriented liberalization (Pingali 1997; Timmer 1997; Timmer 2000; Nissanke and Thorbecke 2007). The emphasis on smallholder market participation as the keystone strategy for poverty reduction and food security traces its origins to Adam Smith and David Ricardo (Barrett 2008). The basic argument is that, given the choice between agricultural production for household consumption and agricultural production for exchange, a household that holds a comparative advantage for a given crop should produce for exchange and then trade for other goods and services. The argument is that market-oriented agricultural trade can provide a more diverse consumption bundle to households and, consequently, is uniquely equipped to propel the rural poor out of poverty while alleviating food insecurity (*ibid*).

In developing countries, the commercialization of agriculture has often been accompanied by calls for smallholders to begin growing NTX crops, defined as high-value, labour intensive, fruits and vegetables not part of the customary diet of the local farming population, and in demand globally but not traditionally farmed for export in that country (Singh 2002; Carletto et al. 2011). In Central America, traditional crops consumed locally include beans and maize; traditional exports include sugar, coffee, and banana; and NTXs include broccoli, snowpeas, and baby carrots, among others.

Between 1992 and 2001, the worldwide trade in non-traditional vegetables rose sharply, from 7.6 million tonnes in 1992 to 13.9 million tonnes in 2001. By 2001, 63% of these exports came from developing countries and this share is growing quickly, driven by a recent upsurge in production in Central America and the Caribbean (Hallam et al. 2004; Carletto et al. 2009). Developing countries in Central America and the Caribbean nearly tripled exports of non-traditional vegetables between 1992 and 2001, accounting for approximately 37% (3.3 million tonnes) of all NTX vegetable exports originating from developing countries (8.8 million tonnes) (Hallam et al. 2004).

Much of the literature on non-traditional exports focuses on their potential to improve national economic performance (Barham et al. 1992; Collier 2002; de Pineres et al. 1997; Timmer 2000; Stanley and Bunnag 2001). At this scale, the increased commercialization of agriculture and the diversification into high-value NTXs is promoted as a viable strategy for developing countries to stimulate growth in the agricultural sector, lower unemployment, and stabilize or repay foreign debt (Carletto et al. 2009). National economic growth, however, is only one part of the development promise of NTXs, because export promotion policies also propose to reduce rural poverty (Little 1994). NTXs have been heralded as a way for smallholder agriculturalists to work their own lands, integrate into international markets, and increase household income through the sale of specialty export crops (Barham et al. 1992). Altogether, these purported cross-scale benefits have helped frame NTX production as a 'win-win' strategy for development in that it improves the incomes and livelihoods of smallholders while simultaneously boosting local, national, and international economies (Barham et al. 1992; Timmer 2000).

However, despite these broad claims, some argue that the NTX development narrative offers more hype than hope (Carletto et al. 2011). A growing body of literature has documented challenges to the potential poverty-reducing and distributional benefits of NTX production. These challenges include environmental degradation, income insecurity, and land loss, among others (Barham et al. 1992; Carter and Barham 1996; Carletto et al. 2011). There is also considerable controversy surrounding the contribution of NTX agriculture to issues of national and household food security. At the national level, Pomereda (2008) argues that the engineering of food systems to emphasize trade and comparative advantage tends to neglect the important role of domestic production as an element of food security (Pomereda 2008). Indeed, in recent decades, many

Latin and Central American countries have become more food dependent, and have changed from being net exporters to net importers of staple foods (de Janvry and Sadoulet 2010). Recognizing that staple foods account for a majority share of the energy intake in many developing countries, this shift could, in principle, threaten to aggravate existing problems of food insecurity (ibid). At the household level, it is unclear whether NTX cultivation can be expected to improve the food security of smallholders, owing to contradictory findings in the literature. Several case studies show that the benefits of NTX crops for rural development, in general, and food security, specifically, have been inconsistent and unevenly distributed (von Braun et al. 1989a; Barham et al. 1992; Carletto et al. 2011). I will revisit this controversy in more detail later in the text.

GUATEMALA

As smallholders in developing countries shift into the NTX sector, there is a compelling need to understand whether or not farming NTX crops can be expected to improve the food security of smallholders. Guatemala is a challenging and appropriate place to explore this relationship. In Guatemala, poverty affects a staggering 71% of the rural population (INE 2011) and 72% of the rural poor engage in farming (World Bank 2009; de Janvry and Sadoulet 2010). Guatemala is also home to the fourth highest rate of chronic malnutrition in the world, as 49.8% of children under five suffered from chronic undernutrition in 2008 (Kothari and Abderrahim 2010).

In recent decades, Guatemala's NTX sector has grown by leaps and bounds (Carletto et al. 2011). Beginning in the early 1980s, the expansion of small-scale NTX production was a central component of U.S. economic assistance policy and was supported through the establishment of favourable trade rules for NTXs and a steady flow of foreign development aid to export-related agencies (Barham et al. 1992; Carletto et al. 2009). Many smallholders began farming NTX vegetables including snow peas, cauliflower, and broccoli, and later diversified in the 1990s to farm French beans, mini-zucchinis, berries, and other exotic crops. Today, NTX production is one of Guatemala's top export earners (Hamilton and Fischer

2003), and Guatemala has become a leading producer of NTXs in Central America. For example, Guatemala's exports of NTX vegetables rose from only 42,000 tonnes in 1992 to 271,000 tonnes in 2001 (Hallam et al. 2004). This upward trend in production later continued as exports of fresh vegetables to the United States increased fivefold between 2001 and 2009 (Carletto et al. 2011).

Prior to the introduction of NTXs, agro-export booms in coffee, bananas, sugar, and cattle fundamentally shaped Guatemala's economic development (Barham et al. 1995). However, these agro-export booms tended to exclude smallholders (thus reinforcing Guatemala's inequitable agrarian and economic structures). In contrast, NTX cultivation in Guatemala has been more inclusive of smallholders (Carletto et al. 2010), as contract farming has helped incorporate small farms into the NTX sector (Mannon 2005). Interestingly, this relative inclusivity is not the norm in other developing countries, as large-scale operators increasingly control NTX production in many other regions (Singh 2002).

NTX PRODUCTION AND FOOD SECURITY

The links between NTX production and the four dimensions of food security remain understudied. From a food security perspective, there is concern that an assumed positive relationship between income gains and household food security does not necessarily hold (von Braun et al. 1989a; Immink and Alarcon 1993, Immink et al. 1995), implying that while NTX production may be a strategy for reducing income poverty and improving access to food, it may not be as effective in reducing food insecurity across the other dimensions. In the sections below, I briefly review the literature that links NTX production and smallholder food security across the four dimensions of food security: availability, access, utilization, and stability. It is important to note that this is not a comprehensive literature review, but rather an attempt to reconcile past findings with a more recent framework for food security research. This topic will be revisited in greater depth in Chapter 2.

The food security implications of shifts from subsistence to commercialized crop production have been reviewed in depth by von Braun and Kennedy (1986), and in a series of case studies undertaken in Africa, the Philippines, and Guatemala (Kennedy and Cogill 1987; Kennedy 1989; von Braun et al. 1989a; von Braun et al. 1989b; Bouis and Haddad 1990). The broad findings of these studies indicate that cash cropping is often associated with significant increases in household income, but tends to have a neutral effect on total household food availability, and neutral or slightly positive effects on nutrition. Results are often mixed, indicating considerable heterogeneity among social-ecological and macro-level policy contexts (von Braun and Kennedy 1986). Many existing studies of cash cropping do not limit the discussion to NTX production (excepting the study by von Braun et al. 1989a), nor do they directly categorize effects of cash cropping across all four dimensions of food security. In fact, there is only minimal literature that tries to quantitatively link household food security and non-traditional export agriculture.

Across a selection of studies that address NTX production and food security, no clear pattern emerges for how NTX production influences all four dimensions of food security (Table 1.5). While there is a consistent body of evidence indicating that NTX production can increase income and thus positively influence food access, the implications for the other three dimensions are less clear. Some studies show that NTX production has a positive effect on a given dimension, whereas others show a neutral or negative effect. This reflects the heterogeneity of social-ecological contexts of these studies, and, in great part, the diversity of indicators employed. In the sections below, I describe in more detail the implications of NTX production across the four dimensions of food security.

Table 1.5. Examples of studies concerning the food security implications of NTX production across the four dimensions of food security: availability, access, utilization, and stability. The effects of NTX adoption on each of the four dimensions are classified as positive, neutral, or negative, and the indicator(s) used to capture each dimension are italicized.

Study	**Country**	**Crop**	***Effects on***			
			Availability	**Access**	**Utilization**	**Stability**
von Braun et al. (1989a)	Guatemala	Snow pea	Positive *(Staple production;caloric intake)*	Positive *(Income; total expenditures)*	Neutral to slightly positive *(Anthropometry)*	n.a.
Immink and Alarcon (1991)	Guatemala	Broccoli, cauliflower, cabbage	Neutral *(Dietary energy intake)*	Positive *(Income)*	Neutral *(Micronutrient intake)*	n.a.
Immink and Alarcon (1993)	Guatemala	Broccoli, cauliflower, cabbage	Negative *(Staple production)* Neutral *(Dietary energy and protein intake)*	Positive *(Income)*	n.a.	n.a.
Katz (1994)	Guatemala	Snow peas; Broccoli	Neutral *(Staple Production)*	Positive (Income)	n.a.	n.a.
Govereh and Jayne (2003)	Zimbabwe	Cotton	Neutral *(Staple production)*	Positive *(Income)*	n.a	n.a.
Hamilton and Fischer (2003)	Guatemala	Snow peas, broccoli	n.a.	Positive *(Income)*	Positive *(Perception of nutritional improvement by mothers)*	n.a
Carletto et al. (2011)	Guatemala	Snow peas	n.a.	Positive *(Food expenditures)*	n.a.	Negative *(Crop yield over 20 years)*

Availability

Indicators of food availability typically relate to both agricultural production and yields or to daily dietary energy and protein intake (Pangaribowo et al. 2013). From a production standpoint, a common question within the NTX debate is whether NTX adoption increases or decreases the availability of staple food crops from a household's own production (e.g., corn and bean in Latin America). This is an important question because staple crops make up the lion's share of the dietary intake of many smallholders and their families. On the one hand, it is often assumed that the food availability of smallholder NTX adopters is negatively affected by crop commercialization because cash crops may displace the production of staple food crops by a household (von Braun and Kennedy 1986). On the other hand, other studies have found that the household production of staple food crops can actually increase following NTX adoption (von Braun et al. 1989a; Immink and Alarcon 1993; Govereh and Jayne 2003; Hamilton and Fischer 2003). Interestingly, Immink and Alarcon (1993) argue that that the yields of staple crops may benefit from fertilizers left in the soil after harvesting a given NTX crop. Overall, however, the impact of NTX adoption on staple food production may be positive or negative, and no clear trend emerges in the literature.

In terms of dietary intake, von Braun et al. (1989a) found that NTX farming had a modest yet positive effect on caloric availability, both in terms of calories from staple crops and calories from non-staples. On average, non-adopters (traditional subsistence households) acquired approximately 7 percent fewer calories per capita than NTX adopters. However, Immink and Alarcon (1993) found that daily energy intake, when measured more comprehensively, did not differ among households that farmed NTX vegetables relative to traditional corn and bean farmers. Interestingly, even though NTX households earned more income, the income-dietary energy intake relationship was generally weak for both farmer groups. Overall, despite a fair amount of research, our understanding about the effects of NTX production on food availability – whether in terms of crop production or dietary intake - remains unclear.

Access

The most commonly used proxy for food access is income. As previously mentioned, NTXs are often touted as a strategy to increase household income, and several studies in locations around the world have shown that smallholder households that diversify out of traditional crops in order to grow NTXs are able to increase income levels (Gambia: von Braun et al. 1989b; Kenya: Kennedy and Cogill 1987; the Philippines: Bouis and Haddad 1990; India: Birthal et al. 2005). NTX adoption is also linked to rising incomes in Guatemala (von Braun et al. 1989a; Katz 1995). Although these findings support the hypothesis that NTX adoption can increase household food access through income gains, Pinstrup-Anderson (1983) describes a number of scenarios in which export crop production could negatively affect household income, such as if world market prices fall, input prices increase dramatically, or long-term productivity of export crops declines. Moreover, the use of income as a key indicator for measuring the food access dimension remains contentious (Coates et al. 2003), and some authors argue that other, more direct indicators, such as the Household Food Insecurity Access Scale are preferable. However, I am aware of no studies addressing NTXs that have used the HFIAS as an indicator to date.

Utilization

It is sometimes assumed that the nutrition of household members improves following NTX adoption due to increased income and therefore increased access to food. However, there is a fair amount of controversy about the strength of the relationship between increases in household income and greater access to and intake of nutritious foods (Fleuret and Fleuret 1980; Katz 1994; Schuftan 1998). The literature shows that NTX crop production may either 1) improve nutritional status (Hamilton and Fischer 2003), 2) have a neutral effect on nutrition (von Braun et al. 1989a; Immink and Alarcon 1991; Immink et al. 1995), or 3) adversely affect nutritional status (Dewey 1979; Fleuret and Fleuret 1980; Dewey

1981). There is no apparent trend for the relationship, and as von Braun and Kennedy (1986) note, there may even be heterogeneous impacts across studies for the same crop type or within the same country. The inconsistency of these findings can be attributed, in part, to differences in the indicators used to evaluate outcomes (e.g., nutrient intake, anthropometry, opinions), thus highlighting how methodological choices influence conclusions. Given these disparate findings, it is not surprising that the merit of NTX agriculture for improving the food security of rural smallholders remains a confusing subject for policymakers.

An important study by von Braun et al. (1989a), based in the Central Highlands of Guatemala, provides a more complete picture of the effects that NTX adoption may have on the food availability, access, and utilization of smallholders. Following a boom in non-traditional exports in the region in the early 1980s, von Braun et al. (1989a) found that although NTX adoption did not reduce the staple food production of adopters, and although it led to significantly increased income for adopters, there were no visible positive effects on nutrition. These results are consistent with studies demonstrating that gains in income from NTX agriculture do not necessarily lead to improved dietary energy and protein intake (Immink and Alarcon 1993) or improved nutritional outcomes in Guatemala (Immink et al., 1995). Moreover, this disconnect is not a phenomenon restricted to Guatemala (Dewey 1981; Longhurst 1988; Bouis and Haddad 1990; Sharpe 1990; DeWalt and Barking 1991).

Stability

What are the consequences of NTX adoption for food system stability? I am interested in the links between ecological resilience and food security, and focus here on the relationship between NTX adoption and ecological indicators. I do not address other factors that may influence food system stability (e.g., food price volatility, political upheaval). Importantly, most of the studies that address the ecological implications of farming NTX crops do not directly discuss food security. Instead, I am making an assumption that ecological conditions influence food security, and thus that we can draw on this literature base to discuss food security. More specifically, I assume that cumulative agro-ecological degradation may someday limit food security. This assumption is based on evidence that degrading agro-ecological conditions (e.g., long-term depletion of soil fertility, increased water resource scarcity, pest populations) may constrain agricultural production (Nellemann et al. 2009; Raudsepp-Hearne et al. 2010). However, despite this assumption, cumulative environmental degradation may not inevitably limit food security in the future, as adaptive strategies to cope with environmental change may emerge (Maxwell and Smith 1992).

Many authors have expressed reservations about the ecological implications of NTX production in Guatemala (Arbona 1998; Carletto et al. 1999; Morales and Perfecto 2000), Central America (Murray and Hoppin 1990; Rosset 1991; Conroy et al. 1996) and in developing countries around the world (Morvaridi 1995; Opondo 2000; Storey and Murray 2001). Numerous agroecological risks to the sustainability of smallholder NTX production have been identified, including: (i) dramatic increases in pest problems and pesticide resistance (Carletto et al. 1999; Morales and Perfecto 2000); (ii) declines in soil quality (Thrupp et al. 1995; Carletto et al. 1999; Carletto et al. 2011); (iii) biodiversity loss (Murray and Hoppin 1990), and (iv) the toxicological contamination of crops (Hallam et al. 2004). These issues raise the question of whether NTX production may be detrimental to smallholders' food security in the long run. Interestingly, a longitudinal study by Carletto et al. (2011) found that cumulative agronomic challenges (e.g., soil degradation, pest resistance) associated with the farming of snowpeas (an NTX crop) in one region of Guatemala were associated with a 30% decline in snow pea productivity between 1985 and 2005. Recognizing that most studies of NTX production are cross-sectional and for only one point in time, the study by Carletto et al. (2011) provides an important contribution to our understanding of the long-term implications of farming NTXs.

CONCLUSION

It is clear that critical factors at play in determining food security are affected by the farming of NTX crops, although the magnitude and direction of that effect are far from apparent. The effects of NTX adoption on food security may be positive or negative, and may vary across the four dimensions. This is not a surprising conclusion, given the variety of NTX crops and social-ecological contexts, and the different methodological approaches used in the studies (Raynolds et al. 1993). There is a distinct need for more place-based research that can inform policy development to help the rural poor and food insecure (ibid).

The research I present in Chapter 2 stems from my thinking about these mixed results and from the fact that no studies to date have systematically explored the relationship between NTX adoption and all four dimensions of food security. Recognizing that most research linking food security and NTX production was conducted in the 1980s and 1990s – prior to the conceptual framework for food security grounded in four dimensions - there may be important trade-offs among the dimensions of food security and these trade-offs have received only limited attention to date. As a result, there is a clear need to update this field of research by taking advantage of recent advancements in food security theory and assessment methods.

PREFACE TO CHAPTER 2

As shown in Chapter 1 (Part 1), the predominant conceptual framework for food security has evolved to include four dimensions– availability, access, utilization, and stability. However, although the concept of food security has come of age, food security assessments typically fail to capture this multidimensionality. In Chapter 1 (Part 2), I argued that comprehensive food security assessment should consider all four dimensions of food security and I discussed some of the advantages and disadvantages associated with common indicators of household food security. In the final part of the chapter, and to set the stage for Chapter 2, I presented a literature review of the relationship between non-traditional export agriculture and rural smallholder food security. I found that previous research concerning this relationship is typically framed in narrow terms, either focusing on the importance of income generation for food security or measuring some but not all of the four dimensions. Overall, the literature shows that NTX farming can have mixed effects and ungeneralizable effects on the different dimensions of household food security.

Chapter 2 moves beyond theory and into the field, recognizing that, for the purposes of improving the lives of the food insecure, it is crucial that research is attuned to specific social-ecological contexts in a way that can be locally meaningful (MA 2005). I explore the implications of farming broccoli, a non-traditional export crop, in relation to the four dimensions of household food security, and present a case study based in the rural Guatemalan community of Chilascó. Specifically, I compare whether or not smallholder households that farm broccoli for export are more food secure relative to households that farm traditional subsistence crops and identify patterns between NTX production, income levels, and multidimensional food security. I also explore potential links between agricultural ecosystem services and local food security, thus helping to explore the dimension of food system stability at the local level.

CHAPTER 2. FOOD SECURITY AND NON-TRADITIONAL EXPORT AGRICULTURE: A CASE STUDY IN RURAL GUATEMALA

ABSTRACT

Food security includes four important dimensions: food availability, food access, food utilization and food system stability. However, strategies to ensure food security in the developing world often focus narrowly on agricultural production (i.e., availability) and markets (i.e., access) while neglecting the other dimensions. Here, I explore the multiple dimensions of household food security through an examination of the food security implications of farming broccoli for export in Guatemala, recognizing that broccoli production is widely promoted in this region as a means to increase smallholder incomes and food security.

Using a case study approach, I explore and compare each of the four dimensions of the household food security of broccoli farmers (*adopters)* and corn farmers (*non-adopters*) in the community of Chilascó, in Central Guatemala. I employ a mix of quantitative and qualitative methods, including household surveys, semi-structured interviews, focus groups, and soil sampling. Household surveys (N= 52) are the principal tool used to compare the food security status of adopters and non-adopters and to assess food security across the four dimensions.

Survey results show that adopters earned significantly more income (40%) than non-adopters. However, income gains did not translate into improvements in food access for adopters according to outcome indicators. Food availability and food utilization did not differ between groups. In terms of food system stability, adopters applied twice as much organic fertilizer per hectare, three times more inorganic fertilizer, and had a higher environmental impact associated with pesticide use. A nuanced conclusion from this work is that increased income *can* lead to positive food security outcomes, but does not *guarantee* them. An income-oriented approach to food security can mask important differences among the four dimensions of food security, signalling the need for more systematic approaches to food security assessment.

INTRODUCTION

In Guatemala, the face of food insecurity is young, rural, and agricultural. Guatemala has the fourth highest rate of chronic undernutrition in the world and the highest in Latin America (WFP 2011). In 2011, a staggering 49.8% of Guatemalan children under 5 were chronically undernourished (Kothari and Abderrahim 2010). Over half (52%) of Guatemalans live in rural areas, of whom 71% live in poverty (INE 2011) and 70% engage in farming (de Janvry and Sadoulet 2010). Despite being food producers, farming families in Guatemala often struggle to meet their basic food, nutritional, and livelihood needs.

Beginning in the 1980s, multiple government and development agencies in Guatemala began to encourage smallholders to farm non-traditional export crops (NTXs) as a means to reduce widespread poverty and improve food security (Barham et al. 1992). These groups believed that by increasing the income of poor farmers, they would improve access to food, and so decrease food insecurity while bringing farmers out of poverty (von Braun et al. 1989a). In Guatemala, NTXs are crops such as broccoli, snowpeas, and baby carrots that were not traditionally exported from Guatemala before the last quarter of the twentieth century. They do not include traditional exports such as sugar, coffee, or banana (Goldín 2001).

Multiple interventions catalyzed the rapid adoption and expansion of smallholder NTX production across Guatemala. These included making NTX production a central component of U.S. economic assistance policy in the 1980s, the establishment of favourable trade rules (e.g. duty-free export of NTXs) as mandated through structural adjustment policies enforced by the International Monetary Fund and the World Bank, and the targeted flow of foreign development aid to export-related agencies (Barham et al. 1992). Guatemala more than doubled the volume of its NTX exports between 1992 and 2001, and the upward trend in production continued as exports of fresh vegetables to the United States increased fivefold between 2001 and 2009 (Carletto et al. 2011).

NTXs have been heralded as a way for smallholder agriculturalists to work their own lands, integrate into international markets, and increase household income through the sale of specialty export crops (Barham et al. 1992). Importantly, advocates of the NTX model have also argued that NTX production may improve the food security of smallholder farmers. This argument rests on two assumptions: (1) that NTX adoption will improve household income, and (2) that household income gains will lead to improved overall household food security (Fleuret and Fleuret 1980; von Braun et al. 1989a; Carletto et al. 2009).

While the widespread diffusion of NTXs in Guatemala initially fueled optimism, recent research contests the positive impacts of NTXs, calling into question the assumed relationship between NTX adoption and food security (Carletto et al. 2011). While NTX adoption has helped alleviate rural poverty in some areas, the benefits have been both inconsistent and unevenly distributed (Barham et al. 1992; Carletto et al. 2009), and have led to a deepening of gender inequalities (Katz 1995) and environmental degradation in some areas (Arbona 1998; Carletto et al. 1999). Previous research also indicates that NTX farming may have only mixed effects on key indicators of food security, including indicators of dietary quantity (von Braun et al. 1989a; Immink and Alarcon 1993) and quality (Dewey 1981; von Braun et al. 1989a). Taken together, these findings point to considerable uncertainty about the relationship between NTX farming and smallholder food security.

This uncertainty is compounded by the fact that we now recognize food security to include four dimensions: food *availability*, food *access*, food *utilization*, and food system *stability* (FAO 2008). Achieving food security requires that that the *availability* of food is sufficient, that there is adequate economic and social *access* to food supplies through the market or through other means, and that the *utilization* of food supplies is sufficient to meet the specific dietary and nutritional needs of individuals (*ibid*). Moreover, each of these factors must be *stable through time* in order to support food security in the long-term (Stamoulis and Zezza 2003; Ingram 2011). To date, no research has systematically explored the impacts of NTX production on the food security of smallholders across all four dimensions. Instead, food security is still commonly measured through income and consumption indicators that fail to fully capture the breadth of the concept (Coates et al. 2006). The need to consider food system *stability,* in particular, is often an afterthought in policy and evaluation processes (Maxwell and Smith 1992; Ingram 2011).

In this chapter, I ask: does the adoption of NTX crops by smallholder households in central Guatemala positively influence each of the four dimensions of household food security? Using a case study approach, I compare levels of household food security in households in Chilascó, central Guatemala, that have adopted NTX broccoli (*Brassica oleracea*) production as a livelihood strategy (adopters) relative to households who do not farm broccoli, and instead farm traditional corn, bean, or other secondary crops (non-adopters). My primary objective is to assess the impact of NTX adoption on the four dimensions of household food security while exploring the broader implications for the use of NTX agriculture as an instrument of rural development. I examine the impact of NTX adoption on a set of indicators presumed to have a direct or indirect link with food *availability, access, utilization,* and food system *stability*, and compare whether or not adopters are more food secure than non-adopters across these dimensions. See Table 2.1 for an expansion of the research questions, definitions, study hypotheses, and literature related to each of the four dimensions of food security.

Through this research, I address two important gaps in the literature. First and foremost, to my knowledge this study is the first of its kind to systematically analyze the impacts of NTX farming on the four dimensions of food security. More holistic approaches to food security assessment may help to better identify potential food security trade-offs and improve the targeting of interventions. The second gap in the literature is the under-representation of food system stability in assessments. I contribute to narrowing this gap by employing indicators of ecosystem services – defined as the benefits that humans receive from nature (MA

2005) – in order to explore how agroecosystems and their specific services can contribute to food security in the long-term. It has been shown that the ecosystem services generated by agroecosystems, such as biological pest control and nutrient cycling, are a key part of how agroecosystems can enable long-term food security (stability) and also fundamentally underscore the resilience and desirability of a given food system (Bennett 2005; MA 2005; Nellemann et al. 2009). The ecosystem services framework is thus an interesting entry-point to better address food system stability in assessments. As the commercialization of smallholder agriculture expands across Guatemala – particularly within broccoli producing regions of central Guatemala – understanding the impacts of NTX farming on food access, availability, utilization, and food system stability is of fundamental importance for improving the livelihoods of the rural food insecure.

Table 2.1. The four guiding research questions for this study, as related to the four dimensions of food security. The table provides definitions for each dimension and my hypotheses for how NTX farming in Chilascó may affect each.

QUESTION	DEFINITION	HYPOTHESIS	RATIONALE
AVAILABILITY: How does the adoption of NTXs influence the food *availability* of local households?	Availability refers to the "supply side" of food security, specifically the availability of sufficient quantities of food, as supplied by domestic production, imports, or food aid (FAO 2006).	The availability of staple crops (corn and bean) from household production will be lower in adopter households than in non-adopter households.	Cash crops are commonly criticized for displacing food crops (von Braun and Kennedy 1986).
ACCESS How does the adoption of NTXs influence the food *access* of local households?	Access refers to individual's resources (e.g., income, products for barter) to acquire appropriate foods for a nutritious diet (FAO 2006).	Household food access will be higher for adopter households than for non-adopter households.	NTX production may increase food access because of higher incomes (Immink and Alarcon 1993).
UTILIZATION: How does the adoption of NTXs influence the food *utilization* of local households?	Utilization refers to the fulfillment of physiological needs through nutrition, as influenced by adequate diet, clean water, sanitation and health care (FAO 2006).	The nutritional status of household members will be higher for adopter households compared to non-adopter households.	It is typically assumed that nutrition improves following NTX adoption due to better economic access (von Braun and Kennedy1986).
STABILITY: How does the adoption of NTXs influence the stability of the local food system of Chilascó, as mediated by impacts to agroecosystems?	Stability refers to the need for food availability, access, and utilization to be consistent through time despite seasonal cycles or unexpected shocks (e.g., drought) (FAO 2006).	NTX farming will be associated with higher impacts to regulating services (e.g., biological pest control) posing a risk to food system stability through slow declines in ecological resilience.	Intensive agriculture is recognized as a key driver behind declines in regulating services (MA 2005), and NTX production is generally more intensive than the production of corn and bean.

METHODS

STUDY LOCATION

This research is based in the highland community of Chilascó, a hotspot for broccoli production located in the central Guatemalan province of Baja Verapaz (15º 07' 20'' N and 90º 06' 50'' W). Baja Verapaz is characterized by: (i) the central role, both agriculturally and culturally, of corn and beans; (ii) levels of chronic malnutrition in children above the national average (53.3% of children were chronically malnourished in 2008) (INE 2009); (iii) the small size of land holdings – typically under two hectares; and, (iv) the growing importance of smallholder NTX agriculture, particularly broccoli production.

Chilascó is a town of approximately 7,000 people, predominantly ladino, with local livelihoods structured around corn, bean, and broccoli farming. Corn and bean have traditionally made up a majority of the dietary intake of Guatemalans, and remain important crops for the community (INCAP 2004). Secondary crops grown locally include several varieties of squash, French bean, and to a lesser extent, potato. Smallholder farmers in the community have been farming broccoli for international export since the late 1980s. To farm broccoli, farmers enter into contracts with regional representatives of one of two agro-export companies. Each season, agro-export companies provide farmers with agricultural inputs (e.g., broccoli seedlings, fertilizers, pesticides), and farmers are then expected to repay these input costs upon selling the harvest back to the agro-export company.

Chilascó sits within the western buffer zone of the Sierra de las Minas Biosphere Reserve in Guatemala, one of the largest and most ecologically important areas in the country, and lies in a transition zone between mixed conifer and broadleaf cloud forests. At an elevation of 1840 m, Chilascó occupies the highlands of the San Jeronimo watershed and is cool and rainy most of the year. In many ways, the agricultural lands of Chilascó are a farmer's dream: local soils are deep and historically fertile (rich organic andisols with a sandy loam texture) (Dix 1997), ample annual rainfall enables a yearlong growing season, and a communal land tenure system helps to ensure that most households have access to small plots of land. However, both chronic and seasonal food insecurity are pervasive and longstanding local problems, and have led regional agricultural and food security experts to characterize Chilascó as a "puzzle". How is it that a community surrounded by productive agricultural lands is unable to provide sufficient, safe, and nutritious food to community members? Moreover, what influence does the production of broccoli for export have on the food security status of local households?

METHODOLOGICAL OVERVIEW

To explore the relationship between NTX adoption and household food security in Chilascó, I employed a case study research design (Yin 2009) that integrates quantitative and qualitative methods. Case studies have been shown to be critical for understanding real world problems like food insecurity (Flyvbjerg 2006), in part because they permit researchers to study complex phenomena within a local context using a variety of data sources. Case study designs are particularly useful when the boundaries between the phenomenon of interest – in this case household food security – and local context are unclear (Yin 2009).

I employed mixed methods – defined as the integration of quantitative and qualitative approaches in a single study (Tashakkori and Creswell 2007) – because this approach is known to be able to produce results that are "more than the sum of the individual quantitative and qualitative parts" (Bryman 2007). Mixed methods may minimize the limitations and biases inherent within each type of research (Creswell 2003), although it is important that the primary method is rigorous enough to be able to sustain the study (Morse 1991). Household surveys were the primary method used in this study, while biophysical measurements in agricultural fields, focus groups, and interviews were also used.

I explored the relationship between NTX adoption and food security by comparing indicators of all four dimensions of food security for two types of smallholder households: '*adopters*' (households that farm broccoli in addition to corn and bean) and '*non-adopters'* (households that farm corn and bean). Smallholder households in my study were those who possess less than 2 hectares of agricultural land. While a non-adopter household does not farm any broccoli whatsoever, an *adopter* household may also farm corn and beans during the broccoli off-season.

Broccoli can be planted and harvested within 90 days, meaning that some farmers are able to harvest broccoli four times in a single year. However, most adopter households typically plant broccoli two or three times per year, with principal harvests in early August, early November, and late January. Adopters also typically plant a non-traditional variety of corn (four month growing period), and bean once per year. Non-adopter households favour planting polycultures of corn, bean and squash, and will plant either the four-month or the more traditional corn variety, which takes nine months to come to maturity.

The sampling "universe" for my study was adopter and non-adopter smallholder households in Chilascó (Table 2.2.). Every household in Chilascó was classified as either adopter or non-adopter using a list of households from the year 2010 obtained from the local medical clinic and confirmed by local farmers. A total of 779 households were identified. Of these, 52 households were sampled, including 25 adopter households and 27 non-adopter households. These were selected using a stratified random sampling technique and using 'adopter' and 'non-adopter' as the stratifying variable. I used this approach because stratified random sampling can economize on the costs of gathering information while increasing the likelihood that it will be both accurate and available in a timely fashion (Carletto 1999).

Table 2.2. The major elements of the quantitative research design

Sampling unit	Households who possess less than 2 hectares of agricultural land
Universe	Adopter and non-adopter smallholder households in Chilascó, Baja Verapaz (total of 779 households)
Sample frame	List of all households (census) updated in 2010
Sampling design	Stratified random sampling of households in Chilascó
Stratifying variable	Smallholder household type: *adopter* or *non-adopter*

Fieldwork was carried out from May to September 2011. Two structured surveys were administered to each household. The first survey was targeted at the female head of household (the person in charge of cooking food) and was designed to collect information on food availability, access, and utilization within the home (see 'Food Security Survey' in Appendix A). The second survey was conducted with the member of the household most familiar with agricultural activities (typically the male head of household). This survey collected information about agricultural production, on-farm income, farming practices, and opinions about livelihoods (see 'Agriculture Survey' in Appendix B). Both surveys were pre-tested in the community to enhance reliability and reduce bias.

An important way of learning about local conditions is to ask people what they know, not just through direct questions, but also through informal dialogue that helps to establish rapport and build trust (Beebe 1995). To this end, two focus groups were conducted in order to better understand local perceptions about the links between food security, the state of the environment, and NTX production in Chilascó. Semi-structured interviews were also conducted with key informants (e.g., local health and education workers, community leaders, an export company representative) in order to develop a qualitative context within which to frame survey results (Miles and Huberman 1994).

Issues of validity in this research were addressed primarily through data triangulation, specifically using different methods and data sources to explore the same questions (Thurmond 2004). Triangulation may increase the validity, strength, and interpretative potential of a study (ibid). Whittemore and Chase et al. (2001) outline several other validity considerations in qualitative research and these were considered throughout the research process. Techniques employed to reduce threats to validity include pre-testing the surveys with participants, ensuring that marginalized voices were heard – particularly those of women, and comparing findings to verify consistency with existing reports and literature (e.g., statistical data, food security trends and drivers in Guatemala). I also used correlation analysis to check for convergent validity among indicators of food access and food utilization (Adcock and Collier 2001).

Limitations: There are some limitations related to this choice of study design. A common concern about case study research is that it provides little basis for generalization (Yin 2009). In this study, the relatively small sample size (N=52) makes the generalization of findings to reflect the subgroups in the population difficult (Flyvbjerg 2006). Great care must therefore be taken when drawing conclusions. Nevertheless, the results of case studies are often useful for generalizing to theoretical propositions rather than populations (Yin 2009), and results may provide constructive insights into both the phenomena and the surrounding context.

Another limitation relates to the choice of the 'household' (undifferentiated) as the unit of study, as this ignores intrahousehold issues and questions of gender, age, and power. There is therefore a possibility that households were classified as food secure, when individual members were not, or vice versa (Coates et al. 2010). Recall bias is also a significant issue when participants are asked to remember activities over extended periods of time (Delang 2006). Finally, the cross-sectional design of this study – which classifies the population of Chilascó into a dichotomy of adopters and non-adopters – ignores how the timing and duration of NTX adoption may influence household welfare levels (Carletto et al. 2011). Nevertheless, while there are drawbacks to any approach, a carefully planned mixed methods study may produce findings that are mutually illuminating, robust, and trustworthy.

CALCULATING FOOD SECURITY INDICATORS

Separate indicators and data collection methods are needed to independently assess each dimension of food security (Webb et al. 2006). In this section, I describe the indicators I used to to assess each dimension of food security (see Table 2.3 for a summary). The two surveys administered to each household were used to collect the data necessary for indicator construction.

Table 2.3. Indicators of food availability, food access, food utilization, and food system stability. The Food Security Survey can be found in Appendix A and the Agriculture Survey in Appendix B.

INDICATOR	DEFINITION	SURVEY	***Section***, Question
AVAILABILITY			
Annual corn and bean production (kg yr^{-1})	Total annual household production of corn and bean (kg yr^{-1}).	Agriculture	***(II)***, 5-8
Annual corn and bean consumption per capita (kg yr^{-1} per capita)	The amount of corn and bean cooked (kg) in the household for a 'good' week and a 'bad' week (kg), taken as an average, multiplied by 52, and then divided by the number of household members. Calculated as $[((kg_{bad} + kg_{good})/2)*52]$ / (Number of household members).	Food Security	***(I)****, 2;* ***(III)****,* 6-8, 12-14,
Wild food collection (# of products yr^{-1})	The number (out of 14) of distinct wild edible forest products (including medicinal herbs) collected by the household over the previous 12 months.	Food Security	***(III)***, 43b,c,d,f,j, l,m,n,o,p,q,r,s,v
ACCESS			
Annual net household income (USD yr^{-1})	The sum of annual agricultural sales, the imputed value of staple crop consumption, off-farm wage income and miscellaneous income sources (e.g. sale of wild edible plants, small livestock) minus agricultural input costs (pesticides, fertilizers, hired labour, seeds, and technology). See Appendices E and F for more information.	Food Security	***(II)***, 6, 9a-j **(III),** 42-45
		Agriculture	***(I)***, 44 ***(II)***, 11,12 ***(III)***, 2, 9-14, 16,17,21,22, 27, 29-32,
Household Food Insecurity Access Scale (HFIAS)	Used to classify households as either food secure or mildly, moderately, or extremely food insecure (Dietchler et al. 2010). It is based on a respondent's subjective experience of household food insecurity	Food Security	***(III)***, 16-24b

INDICATOR	DEFINITION	SURVEY	***Section***, Question
	over the previous 30 days. Results may also be displayed as a continuous score (range: 0 (food secure) to 27 (extreme food insecurity)).		
Household Hunger Scale (HHS)	Used to classify households as experiencing three levels of hunger (little to no, moderate, or severe) (Dietchler et al. 2011). It is based on a respondent's subjective experience of hunger over the previous 30 days.	Food Security	***(III),*** 22-24b
Months of Adequate Home Food Provisioning (MAHFP)	The number of months in a given year that a household self-reports adequate access to food for consumption (either through household production, purchase, or aid) (Bilinsky and Swindale 2007).	Food Security	***(III)***, 25a-b
Household dietary diversity score (HDDS)	The number of distinct food groups (up to 12) that were eaten within the household the previous day (Swindale and Bilinsky 2006).	Food Security	***(III)***, 46-47
Coping strategies index (# strategies yr^{-1})	A score reflecting the number of extreme coping strategies used by a household when confronted by shortfalls in income or food (for a 12-month period).	Food Security	***(III)***, 32c,d,i,j,l,o
UTILIZATION			
Food Consumption Score	A composite score based on the dietary diversity, food frequency, and weighted nutritional importance of different food groups (WFP 2008). The FCS was calculated for one-child (randomly selected) between the ages of 1 and 8 years old per household.	Food Security	***(III)***, 48-49
STABILITY			
Environmental Impact Quotient	Employed here as a proxy for the ecosystem service of biological pest control, the EIQ is a continuous	Agriculture	***(I),*** 16; ***(III)**,* 21

INDICATOR	DEFINITION	SURVEY	***Section***, Question
(EIQ) for pesticide use (EIQ ha^{-1})	measure of the environmental impact of pesticide use per hectare based on the type, toxicity, and application rate of pesticides in a year (Kromann et al. 2011).		
Inorganic and organic fertilizer use (kg ha^{-1} yr^{-1})	Employed here as a proxy for the ecosystem service of nutrient cycling, and defined as the quantity per hectare (kg ha^{-1} yr^{-1}) of chicken manure and inorganic fertilizers (15-15-15, 46-0-0, 20-20-0) applied by households over the previous 12 months.	Agriculture	***(III)***, 9-14; 17-18
Nitrogen application (kg N ha^{-1} yr^{-1}) Phosphorus application (kg P ha^{-1} yr^{-1})	Employed here as a proxy for the ecosystem service of nutrient cycling, and defined as the kilograms of nitrogen (N) and phosphorus (P) applied per hectare over a 12 month period. The kilograms of N and P were calculated using the known Nitrogen: Phophorus: Potassium (N:P:K) ratios for each fertilizer type.	Agriculture	***(III)***, 9-14; 17-18
Soil parameters	Biophysical measurements of soil parameters (K, P, Ca, Mg, Cu, Zn, Fe, Mn, and organic matter) are employed here as proxies for the ecosystem service of soil fertility.	n.a. (These measurements were taken biophysically in fields.)	n.a.
Farming practices	A binary indicator to show whether or not a farmer had used a specific farming practice in the previous 12 months (“yes”/ “no”). The indicator was constructed for 10 different farming practices that could either help or hinder soil conservation, and is employed here to investigate the ecosystem service of erosion regulation.	Agriculture	***(IV)***, 1

INDICATORS OF FOOD AVAILABILITY

I employed three indicators to measure food availability: 1) total annual household production of corn and bean (kg yr^{-1}); 2) total annual corn and bean consumption per capita (kg yr^{-1} per capita); and 3) the number of wild food types collected annually by the household (number of products yr^{-1}). See Table 2.3 for short definitions of these indicators and a listing of the specific survey questions used to construct each indicator. See Appendices A and B for entire surveys and specific survey questions.

A common indicator of food availability is a household's production of basic staple crops (Maire and Delpeuch 2005; Pangaribowo et al. 2013). Although it is also important to consider the availability of other foods (e.g., fruits, vegetables, protein sources), I chose to focus on the availability (through production) of two Guatemalan staple crops – corn and bean – because these crops account for upwards of 60% of the caloric intake of Guatemalans (INCAP 2004). The annual production of both corn and bean (kg yr^{-1}) by each household was calculated by asking farmers about harvest quantities over the previous 12 months (see Table 2.3 for questions). Farmers were also asked about the harvested quantities of other crops (e.g., broccoli, potato), however, because farmers typically sell these crops for monetary gain, I consider their contribution to food security within the section on food access through income. As another production-based indicator, I also calculated the average crop yields of corn, bean, and broccoli per household (kg ha^{-1}) by averaging all harvest yields over a 12-month period.

Staple food production is only one aspect of food availability, and so additional measures are needed to understand the food actually available to any given household (Pangaribowo et al. 2013). Foods, including but not limited to staples, may be acquired from multiple sources (e.g., from production, purchase, or aid). To improve estimates of food availability, it is common to use indicators of dietary intake in addition to indicators of food production. To do this, I estimated the annual corn and bean consumption per capita in each household (kg yr^{-1} per capita) using a proxy based on survey questions about consumption (von Braun et al. 1989a). I first asked participants to provide estimates of the amount of corn and bean cooked within the household for a ‘good’ week and a ‘bad’ week. These values were then averaged to find the amount cooked during an ‘average’ week, multiplied by the number of weeks in a year (52), and finally divided by the number of household members (see Table 2.3 for equation). Overall, this approach provides a rough indication of the corn and bean cooked within each home and available to each individual annually, regardless of the food source. I also modified this indicator by dividing total household consumption by the number of adult equivalents per household. The use of adult equivalent scales is common in household consumption analysis because they are more meaningful than assuming indiscriminate per capita consumption (Demoussis and Mihalopoulos 2001). Household size was adjusted to ‘adult-equivalents’ by comparing recommended daily energy requirements (kcal day^{-1}) for household members according to age and gender in Guatemala (INCAP 2006; see Appendix C for detailed methodology).

Wild edible plants that are gathered are an important addition to the food availability of households, particularly as a means to supplement diets with protein and vitamins and to improve the palatability of staple foods (Burlingame, 2000). Working from a list of 14 local wild edible plants (Appendix D), I asked households whether they had gathered those plants in the previous 12 months in order to see if there was a difference in household dependencies on wild foods. It is generally the poorest households that are most dependent on wild foods, particularly as sources of micronutrients during seasonal food shortages or crises (Bharucha and Pretty 2000). While I was able to ask about the types of wild foods collected over the previous year, my experience, and the experience of other researchers, has been that it is difficult to estimate the economic value or quantities of wild foods collected through household surveys (Bharucha and Pretty 2000). It follows that this indicator is quite exploratory.

INDICATORS OF FOOD ACCESS

I employed six indicators of food access: 1) annual net household income; 2) the Household Food Insecurity Access Scale (HFIAS); 3) the Household Hunger Scale (HHS); 4) the Months of Adequate Home Food Provisioning (MAHFP); 5) the Household Dietary Diversity Score (HDDS); and, 6) a coping strategies index. All six indicators were calculated on the basis of survey questions (see Table 2.3 for a listing of specific survey questions).

Income is the proxy most commonly used to measure food access. I defined annual net household income as the sum of agricultural and non-agricultural wages, annual agricultural sales, the imputed value of staple crop consumption, and miscellaneous income sources (e.g., sale of wild edible plants, foreign remittances) minus agricultural input costs (pesticides, fertilizers, labour, seeds, technology, land) (McKay 2000). Appendix E lists the agricultural prices used to calculate different components of household income. Prices were either determined directly – by visiting local markets and vendors, or indirectly – by consulting with a focus group about local market trends. The monetary value of crop consumption was imputed using average sale prices in the region (ILRI 1995; see Appendix E for details). I also calculated net on-farm income as total annual agricultural production multiplied by the average price of products, minus the cost of inputs (pesticides, fertilizers, seed, and technology) and the cost of labour. This calculation excludes imputed labour. See Appendix F for a more detailed description of the income components assessed, their specific data inputs, and a listing of the survey questions used to calculate each component.

Income is a food security determinant; it is not a food security outcome. A robust analysis of the food access dimension also requires indicators of food security outcomes. For this reason, I also calculated the Household Food Insecurity Access Scale (HFIAS), based on a set of nine questions (Table 2.4) designed to provide a single measure of a household's ability to access food (Coates et al. 2007). In the HFIAS questionnaire, each item is administered initially as a yes/no question. If a respondent answers yes to a question, then a follow up question is asked to determine how often the situation occurred in the previous 30 days (*rarely* -– once or twice; *sometimes* – three to ten times; *often* – more than ten times) (Coates et al. 2007). Following the methodology of Coates et al. (2007), I calculated the HFIAS score for each household based on survey responses, with scores ranging from a minimum of zero (food secure) to a maximum of 27 (extremely food insecure). I also classified households into four categories of food insecurity based on their scores: food secure, and mildly, moderately, and severely food insecure (ibid). Because the HFIAS is based on a respondent's self-reported experiences of food insecurity, it is considered to be a direct indicator of food insecurity (Deitchler et al. 2010).

Table 2.4. The questions comprising the HFIAS (Q1-9) and the Household Hunger Scale (HHS) (Q7-9) (Coates et al. 2007; Deitchler et al. 2011).

Question
1. In the past four weeks, did you worry that your household would not have enough food?
2. In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?
3. In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?
4. In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other foods?
5. In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?
6. In the past four weeks, did you or any other household member have to eat fewer meals in a day because there was not enough food?
7. In the past four weeks, was there ever no food to eat of any kind in your household because of a lack of resources to get food?
8. In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?
9. In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?

In addition, I assessed food access using an indicator called the Household Hunger Scale (HHS). The HHS is a derivative of the HFIAS used to assess only hunger (itself only one expression of food insecurity). To calculate the HHS, I used a participant's responses to three questions (Table 2.4) about how often a given situation occurred in the previous 30 days (Deitchler et al. 2011). I then calculated a score for each household (ranging from 0 to 6) by summing responses to the three questions (never = 0, rarely or sometimes =1, and often = 2). I used these scores to classify households as experiencing "little to no hunger" (0-1), "moderate hunger" (2-3), or "severe hunger" (4-6) (Deitchler et al. 2011).

I also assessed the desired outcome of improved food access – improved household food consumption –using two indicators called the Months of Adequate Home Food Provisioning (MAHFP) and the Household Dietary Diversity Score (HDDS), respectively. The MAHFP is measured as the number of months over the previous 12 months that a household self-reports having had adequate access to food for consumption (through household production, purchase, or aid) (Bilinsky and Swindale 2007). To calculate the MAHFP, I tallied the number of months a household reported having access to adequate food over the previous year. The HDDS is an indicator of household-level dietary diversity that has been validated as a meaningful measure of household food access: households consuming a more diverse diet (as assessed by the HDDS) were shown to have greater access to food, as indicated by food consumption and expenditure data (Hoddinott and Yohannes 2002). To calculate the HDDS, I asked the female head of household whether or not a specific list of foods had been prepared and eaten in the household the previous day. I then tallied the number of distinct food groups (up to 12) that had been eaten within the household the previous day (Swindale and Bilinsky 2006).

The strategies that people use for dealing with insufficiency of food at the household level (henceforth 'coping strategies') may also be employed as indicators of food access (Maxwell 1996a). To understand the coping strategies used by adopter and non-adopter households, I employed a modified version of the Coping Strategies Index (CSI) (Maxwell and Caldwell 2008). The CSI is based on a series of questions about how households manage to cope with shortfalls in either income or food and results in a simple numeric score. Food insecurity increases as the CSI value increases. To construct the CSI, I first held a focus group with community members to identify common coping strategies and we ranked them according to their severity. I selected the six most 'severe' types of coping strategies, and I later asked households in the survey sample whether or not they had employed these six strategies in the previous 12 months (see Table 2.5 for specific questions). To calculate the CSI score, I assigned a score of 1 to every ‘yes’ answer and tallied the answers into a six-point score. It is important to note that I asked about coping strategies used over a 12 month period, whereas Maxwell and Caldwell (2008) suggest using either a one week or 30 day reference period in order to improve recall accuracy.

Table 2.5. The survey questions used to construct a modified Coping Strategies Index. Questions are based on severe coping strategies identified in a focus group.

In the last 12 months, have you had to take one of the following actions to obtain food or satisfy other necessities?	
• Migrate elsewhere	• Reduce portion sizes for children
• Sell household possessions (e.g., television)	• Take children out of school so they can work
• Reduce portion sizes for adults	• Ask for aid from non-governmental organizations or other groups

INDICATORS OF FOOD UTILIZATION

Adequate household access to food does not necessarily correspond to adequate food utilization and nutritional outcomes at the individual level. To measure the *utilization* dimension, I used a single proxy of the dietary quality of children called the Food Consumption Score (FCS) (WFP 2008). The FCS is a composite score based on dietary diversity, food frequency, and the weighted nutritional importance of different food groups (WFP 2008), and is calculated on the basis of standardized survey questions (see Table 2.3 for more information). Data on dietary diversity and food frequency have proven to be reliable proxy indicators of diet quality across a range of settings (Ruel 2002; Wiesmann et al. 2009).

I calculated the FCS for one child (randomly selected) between the ages of 1 and 8 years old per household. I was unable to calculate an FCS score for households with no children in the age cohort. To calculate the FCS, mothers were first asked how often a child had eaten a certain food item (later aggregated to food groups) over the last week. The number of times each food group was eaten was multiplied by a weight (values above 7 days were truncated to 7), developed according to the nutritional density of the food group (WFP 2008). Food group scores were then summed to determine the overall FCS, and FCS scores were compared to international benchmarks (ibid).

INDICATORS OF FOOD SYSTEM STABILITY

I consider a stable food system to be one that can deliver consistent food security *outcomes* over the long term (i.e. food availability, food access, and food utilization that are stable through time), where consistent means varying only within a range of acceptable values (Ingram 2011). For example, agricultural production is stable even if there is some variation (cf. Conway 1987) so long as the variation is within an acceptable range and any *temporary* loss in food availability stemming from declines in production are compensated for by other sources (e.g. food aid or trade). We might call such a food system a *resilient* food system - i.e., it tends to maintain its integrity when subject to disturbance, adapting to stresses but without fundamental change outside of pre-determined boundaries (Holling 1973; Misselhorn et al. 2012).

As an entry-point to assessing food system stability, I employed indicators of ecological resilience, recognizing that the best indicators of ecological resilience are often slowly changing ecological variables such as regulating ecosystem services (Bennett et al. 2005; MA 2005). Specifically, I assessed four slowly changing regulating ecosystem services –biological pest control, soil nutrient regulation, soil fertility, and soil erosion regulation using proxies.

Biological control of pests: As a regulating ecosystem service, the biological control of pest insects and weeds provided by natural pest enemies (predators, parasites, pathogens) can help prevent outbreaks of pests and stabilize agroecosystems (Naylor and Ehrlich 1997; Sandhu et al. 2010). However, this ecosystem service is threatened by the increasing use of agrochemicals because although pesticides often successfully address pest problems, pesticides also kill natural pest enemies. This can sometimes lead to worse pest outbreaks in the future (MA 2005). The intensification of agriculture involving heavy pesticide use can thus lead to a reduction in natural biological pest control (Sandhu et al. 2010).

To investigate the status of biological pest control in the parcels of adopter and non-adopter households, I employed an indicator called the Environmental Impact Quotient (EIQ) of pesticide use (Kovach et al. 1992). The EIQ is a widely used measure that is useful for estimating environmental hazards associated with agricultural pesticide use in diverse environments (Kromann et al. 2011). It is a continuous measure of the environmental impact of pesticide use per hectare and is a composite hazard indicator that includes dimensions of ecological, farmworker, and consumer exposure risk to pesticides used in crop production (Kovach et al. 1992; Levitan et al. 1995). The higher the EIQ score per hectare, the higher the hazard posed to the social-ecological system. I hypothesize that higher EIQ scores indicate lower provision of the service of biological pest control, as natural pest enemies are often eliminated through increasing pesticide use (Sandhu et al. 2010).

I calculated the average EIQ score per hectare for each household in the sample, based on survey questions detailing seasonal pesticide use. The EIQ score per ha was calculated in three steps (Kovach et al. 1992). I first assigned a reference EIQ value to the active ingredient of each pesticide known to be used in Chilascó. Reference EIQ values were obtained from a database managed by Cornell University (http://nysipm.cornell.edu/publications/eiq/). Second, the environmental impact of each active ingredient per hectare (EIQ ha^{-1}) was calculated for each household's agricultural land using the formula:

$$\textbf{EIQ per ha for a single active ingredient} = [\text{reference EIQ for active ingredient}] * [\text{dosage ha}^{-1}\ \text{yr}^{-1}] * [\%\ \text{active ingredient}]$$

where dosage ha^{-1} yr^{-1} is the amount of formulation in kilograms or liters per ha. Finally, a household's overall EIQ score per hectare (which includes all active ingredients) was calculated by summing the EIQ per hectare for each active ingredient over the previous 12 months.

Recognizing that there are methodological uncertainties relating to the use of hazard pest indices such as the EIQ (Kromann et al. 2011), I also asked farmers survey questions to determine whether they perceived differences in pest levels among broccoli, corn, and bean parcels or if they noticed changes in pest levels over time. Specifically, I asked male household heads whether or not they agreed with the following two statements:

- Pests cause more damage to broccoli fields than to corn and bean fields (Agriculture Survey, Section *IV*, Question 5); and
- There are more pests now compared to five years ago (Agriculture Survey, Section *IV*, Question 6).

I also asked farmers if any of their agricultural parcels were affected by clubroot disease (Agriculture Survey, Section *IV*, Question 4) because some farmers noted it was a local concern.

Nutrient cycling: In agroecosystems, nutrient cycling is a service provided by soils that helps make nutrients available for plant growth, maintains inherent soil fertility, and may help limit nutrient losses to aquatic systems (MA 2005). In turn, nutrient cycling and soil fertility increase the capacity of agroecosystems to buffer environmental, climatic, and economic risks and contribute to the long-term maintenance and stability of the system (MA 2005). When inherent soil fertility is naturally low or has been degraded, farmers often use fertilizers to provide additional fertility. This fertilizer use can have a profound effect on soil nutrient content, and also on a soil's ability to regulate nutrients like phosphorus and nitrogen (MA 2005).

As a proxy for the ecosystem service of soil nutrient regulation, farmers were asked about the types and quantities (kg) of inorganic and organic fertilizers applied to their fields over the previous 12 months (see Table 2.3 for listing of questions). This indicator is only an entry point to understanding soil nutrient regulation, as fertilizer use may indicate as much or more about farmer responses to perceived soil nutrient levels than it does about soil nutrients or nutrient regulation itself. In Chilascó, farmers primarily apply organic fertilizers in the form ofchicken manure; however, inorganic fertilizers such as Triple Quince (15-15-15), urea (46-0-0), and 20-20-0 are also common. I asked farmers about the types and quantities of fertilizers they applied to their farmlands in the previous 12 months and used responses to calculate the total nitrogen (N) (kg yr^{-1}) applied to a household's agricultural land by multiplying the quantity of a given fertilizer by its nitrogen content based on N:P:K ratios. The N:P:K ratios quoted on fertilizers provide the weight percent of the fertilizer in nitrogen (N), phosphate (P_2O_5) and potash (K_2O equivalent). I calculated the total phosphorus (kg yr^{-1}) applied using the same method as above, however I then multiplied everything by 0.44 to convert P_2O_5 to P based on the ratio of their molecular weights (Mikkelsen 2011). An N:P:K of 2.5-1.25-0 was used as an estimate for chicken manure and was based on advice given from the soil laboratory at the Universidad de San Carlos de Guatemala (personal communication –Anibal Sacbajá). Overall, total annual nitrogen and phosphorus applied (kg yr^{-1}) were calculated as:

$$Total\ N\ application\ = \sum \left((kg_{fertilizer}) \times\ (\%_N) \right)$$

$$Total\ P\ application\ = \sum \left((kg_{fertilizer}) \times\ (\%_P) \times\ 0.44 \right)$$

Soil fertility is the potential of soil to supply nutrients in the quantity, form, and proportion necessary to support optimum plant growth (MA 2005). While the ecosystem services of nutrient cycling and soil fertility are fundamentally linked (as nutrient cycling helps maintain soil fertility), soil fertility is influenced by a broader set of processes (e.g., macro-invertebrates improving soil structure) (Zhang et al. 2007), and thus provides more information about the soil itself. To investigate the ecosystem service of soil fertility, I took soil samples in selected agricultural parcels belonging to adopter households (that had contained broccoli in the previous 12 months) and compared these to soil samples taken from parcels belonging to non-adopter households (that had not contained broccoli in the previous ten years). I selected paired parcels (one adopter, one non-adopter) with similar soil types within 250 m of one another (see Appendix G for geographic coordinates). Altogether, only a subset of parcels belonging to adopter (N= 8) and non-adopter households (N=7) were sampled. This is because some non-adopter households periodically rented out their lands to adopter households for broccoli production, which made it difficult to find parcels that had never contained broccoli. In each parcel, eight soil samples taken to a depth of 30 cm were drawn and mixed to form a single composite sample. Samples were then sent to the soil laboratory at the Universidad de San Carlos de Guatemala for the analysis of soil parameters (K, P, Ca, Mg, Cu, Zn, Fe, Mn, organic matter, texture). Phosphorus was measured as plant available P using the Mehlich I extraction method.

Soil erosion regulation: The vulnerability of agroecosystems to erosion can also affect the potential for long-term food production, particularly in regions with poor vegetative cover and high rainfall (Powlson et al. 2011). Erosion is a huge challenge to food system stability because, even on a timescale of several generations, soils are non-renewable (Powlson et al. 2011). Farming practices can either promote or help prevent erosion, for example, vegetative cover within and along the edges of agricultural parcels can help prevent erosion (*ibid*). To investigate the ecosystem service of erosion regulation, farmers were asked whether or not they employed specific farming practices in the previous 12 months (see Table 2.3 for listing of questions). I then classified practices as either ‘beneficial’ for soil conservation (e.g. planting hedgerows, using terraces) or ‘erosion inducing’ (e.g. no fallow periods, slash and burn agriculture), and I tested to see if the adopters and non-adopters differed in the use (defined as yes or no) of ‘beneficial’ or ‘erosion inducing’ farming practices.

INDICATORS BASED ON PERCEPTIONS

Many academic studies that focus on quantifying the social, economic, or environmental impacts of NTX production conclude by framing NTX production in a negative light. However, there is a tension between these academic assessments and the frequently positive perceptions of farmers regarding local economic conditions, social relations, and NTX production (Hamilton and Fischer

2003). To better understand the implications of NTX production in Chilascó, I asked male household heads about their general perceptions of the local economy and NTX production, and in particular, their perceptions about the fairness of the market chain and principal beneficiaries. Market prices and the NTX market structure may be factors that influence food system stability, given linkages with volatile international markets (Carletto et al. 2011).

STATISTICAL ANALYSES

To determine whether or not there are significant differences in the food security status of adopters and non-adopters for each of the four dimensions, I tested for significant differences between these two groups for each of the different indicators of each dimension. I conducted all statistical comparisons using SPSS Statistics Version 17.0 (SPSS Inc., Chicago, IL) and present the level of significance at both $p < 0.05$ and $p < 0.1$. Data are reported as mean ± SEM (the standard error of the mean) unless otherwise stated. I compared continuous data using Student's *t*-tests and two-way analysis of variance for normally distributed data, and used the non-parametric Mann-Whitney U test for non-normally distributed data. In the case of multiple comparisons with a significant test result, I conducted post-hoc Tukey tests. I used chi-squared tests to compare nominal or ordinal level data. I used Phi to measure the strength of association for cross-tabulations of nominal variables with only two categories, whereas I used Cramer's V for *nominal* by *nominal* or *ordinal* by *nominal* cross-tabulations with more than three categories per variable. In cases where two or more indicators were chosen to represent one concept (i.e., the HDDS and the HFIAS both represent the concept of 'food access'), I tested the empirical association between indicators using Pearson's (parametric) or the Spearman Rank (non-parametric) correlation coefficients as a measure of convergent validation. More detailed information about these tests is provided in Chapter 1. Table 2.6 provides a summary of the key statistical tests used to compare indicators across groups. Some additional tests were conducted as part of data analysis and their use is noted directly in the text. Additional information – including all test statistics - is provided in Appendix H.

Table 2.6. General listing of the statistical tests employed to compare indicators across groups. See Appendix H (Table H.2) for specific test results.

INDICATOR	TEST TYPE
AVAILABILITY	
Annual corn and bean production (kg yr^{-1})	Mann-Whitney U
Annual corn and bean consumption per capita (kg yr^{-1} per capita)	*t*- test; Mann-Whitney U
Wild food collection (# of products yr^{-1})	*t*- test
ACCESS	
Annual net household income (USD yr^{-1})	*t*- test
Household Food Insecurity Access Scale (HFIAS)	*t*- test
Household Hunger Scale (HHS)	chi-squared test
Months of Adequate Home Food Provisioning (MAHFP)	*t*- test
Household dietary diversity score (HDDS)	*t*- test
Coping strategies index (# strategies yr^{-1})	Mann-Whitney U
UTILIZATION	
Food Consumption Score	*t*- test
FOOD SYSTEM STABILITY	
Environmental Impact Quotient (EIQ ha^{-1})	Mann-Whitney U
Inorganic and organic fertilizer use (kg ha^{-1} yr^{-1})	*t*- test
Nitrogen application (kg N ha^{-1} yr^{-1}) Phosphorus application (kg P ha^{-1} yr^{-1})	*t*- test
Soil parameters	*t*- test; Mann-Whitney U
Farming practices	chi-squared test

RESULTS

The survey results are described in the coming sections, and are followed by a summary of the qualitative results from interviews and focus groups.

GENERAL CHARACTERISTICS OF HOUSEHOLDS

There was no significant difference in the amount of agricultural land farmed by non-adopter and adopter households (Independent samples t-test; t (50) = -1.66, p = 0.103; Table 2.7).The general demographic characteristics of households – including household size, the average number of children per household, and the ages and literacy levels of female and male heads of household – were not significantly different between groups (Table 2.7). Access to education in Chilascó is limited, as 69% of female heads of household, and 42% of male heads of household, were illiterate. The primary occupation of male household heads in adopter households was household agriculture, whereas significantly more non-adopters relied on local agricultural wage labour as the primary occupation of male adults (Chi-square, X^2 (3, N=52) = 7.23, p = 0.065, V = 0.380).

Table 2.7. The general household characteristics of non-adopter (N=27) and adopter (N=25) households. See Appendix H for details on statistical tests.

	Non-adopter		Adopter	
	Mean	**SEM**	**Mean**	**SEM**
Agricultural land (ha)	0.75	0.14	1.06	0.13
Household size	5.89	0.43	6.72	0.45
Household size (adjusted)	4.05	0.23	4.18	0.26
No. of children	2.67	0.33	3.24	0.35
Male household head				
• Age	45.4	2.7	41.4	2.7
• Primary occupation is household agriculture (%)	56		88*	
• Primary occupation is hired agricultural labour (%)	36		8*	
• Illiteracy (%)	52		32	
Female household head				
• Age	41.4	2.3	39.1	2.5
• Primary occupation is domestic work (%)	85		88	
• Works in household agricultural fields (%)	81.5		76	
• Illiteracy (%)	74		64	

Statistically significant: * P <0.1, ** P <0.05, *** P <0.001

IMPACT OF NTX ADOPTION ON FOOD AVAILABILITY

Summary: There were no statistically significant differences between adopter and non-adopter groups for any of the three indicators of food availability employed in this study, whether for staple food production, staple food consumption, or wild foods collection.

There were no statistically significant differences in the amounts of corn (p >0.05) or bean (p > 0.05) grown by adopter and non-adopter households (Table 2.8;

Figure 2.1). Similarly, there were no statistically significant differences in the corn yields (p>0.05) or bean yields (p>0.05) obtained by both groups (Table 2.8; Figure 2.2). Adopter households produced, on average, about 10,917 ± 2073 kg of broccoli per year. The average broccoli yield obtained by adopter households (9666 ± 1321 kg ha^{-1}) was consistent with the national average (Figure 2.3).

There was no statistically significant difference in annual corn consumption between groups, whether on a per capita basis (p>0.05) or in terms of adult equivalents (p>0.05) (Table 2.8; Figure 2.4a). Annual bean consumption also did not differ significantly between groups, whether on a per capita basis (p>0.05) or in terms of adult equivalents (p>0.05) (Table 2.8; Figure 2.4b).

The mean number of wild edible forest products (out of 14) collected by households over a 12-month period did not differ significantly between groups (p >0.05; Table 2.8). Although the survey was designed to collect information about the quantity of each product collected per year, respondents were generally unable to give meaningful estimates of quantities.

Table 2.8. Results for indicators of food availability for non-adopter and adopter households in Chilascó. See Appendix H for details on statistical tests.

	Non-adopter			**Adopter**		
	Mean	**SEM**	**N**	**Mean**	**SEM**	**N**
Total production (kg yr^{-1})						
• Corn	734	257	27	824	148	25
• Bean	180	58	27	195	42	25
• Broccoli				10917	2073	25
Yield (kg ha^{-1})						
• Corn	911	110	26	1156	162	25
• Bean	266	40	22	287	44	23
• Broccoli				9666	1321	25
Annual consumption of staples						
• Corn (kg yr^{-1} per capita)	153	18	27	144	14	25
• Bean (kg yr^{-1} per capita)	32	6	27	23	3	25
• Corn (kg yr^{-1} per adult equivalent)	219	25	27	231	22	25
• Bean (kg yr^{-1} per adult equivalent)	46	9	27	36	4	25
Collection of wild edible forest products						
• Number of products per year	4.8	0.7	27	5.4	0.8	25

Statistically significant at: * P <0.1, ** P <0.05, *** P <0.001.

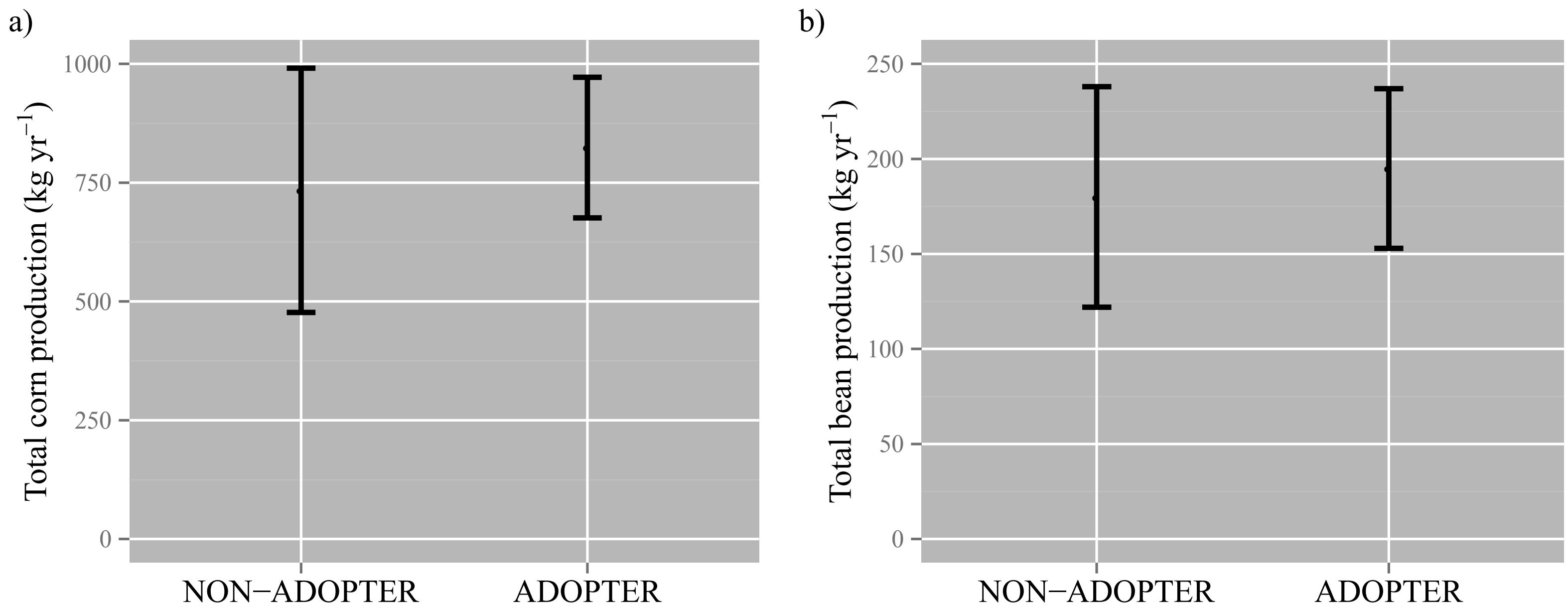

Figure 2.1. a) Average corn production (kg yr^{-1}) of non-adopter (N= 27) and adopter (N=25) households in Chilascó. Average corn production was calculated as the total production of all corn harvests over a 12-month period for each household. **b)** The average bean production (kg yr^{-1}) of non-adopter (N= 27) and adopter (N= 25) households in Chilascó. Average bean production was calculated as the total production of all bean harvests per household over a 12-month period. Error bars show ± 1 SE.

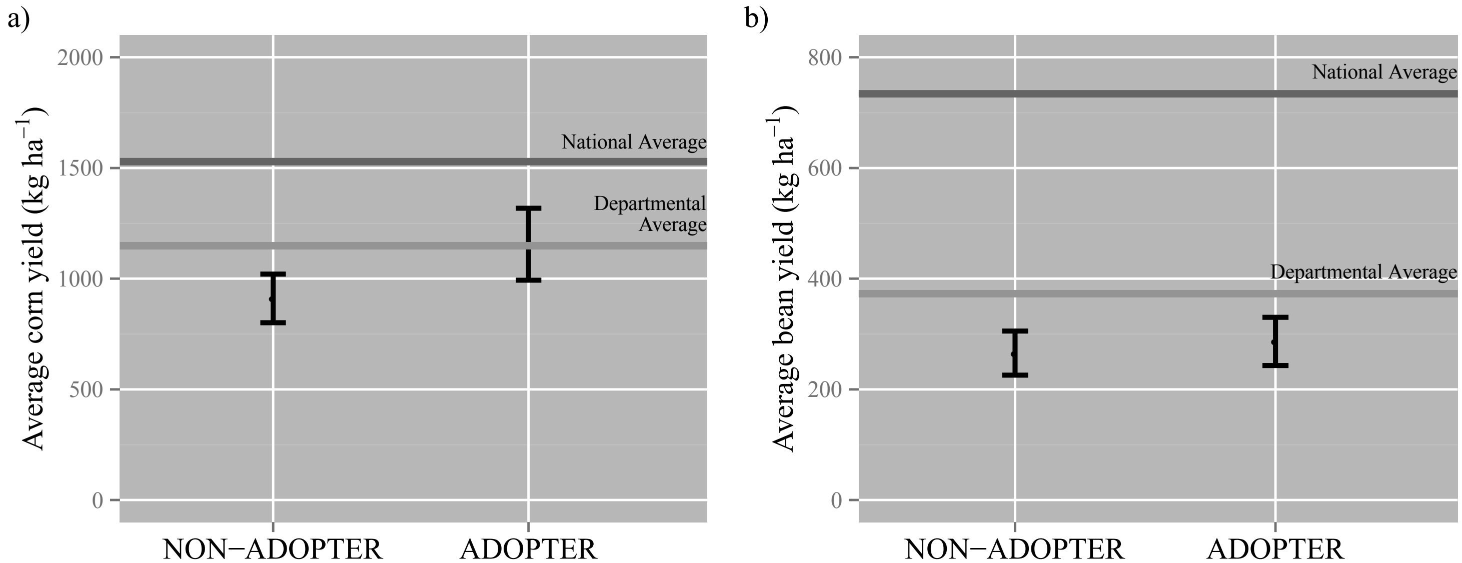

Figure 1.2. a) Average corn yields (kg ha^{-1}) of non-adopter (N= 27) and adopter (N=25) households in Chilascó. Average corn yield was calculated as the average of all corn harvests over a 12-month period for each household. The average corn yield in Guatemala was 1,529 kg ha^{-1} in 2004 and the average yield in the department of Baja Verapaz was 1,149 kg ha^{-1} (INE 2004). **b)** The average bean yield (kg ha^{-1}) of non-adopter (N= 27) and adopter (N= 25) households in Chilascó. Average bean yield was calculated as the average of all bean harvests per household over a 12-month period. The average yield of bean in Guatemala was 734 kg ha^{-1} in 2004 and was 373 kg ha^{-1} in Baja Verapaz that same year (INE 2004). Error bars show ± 1 SE.

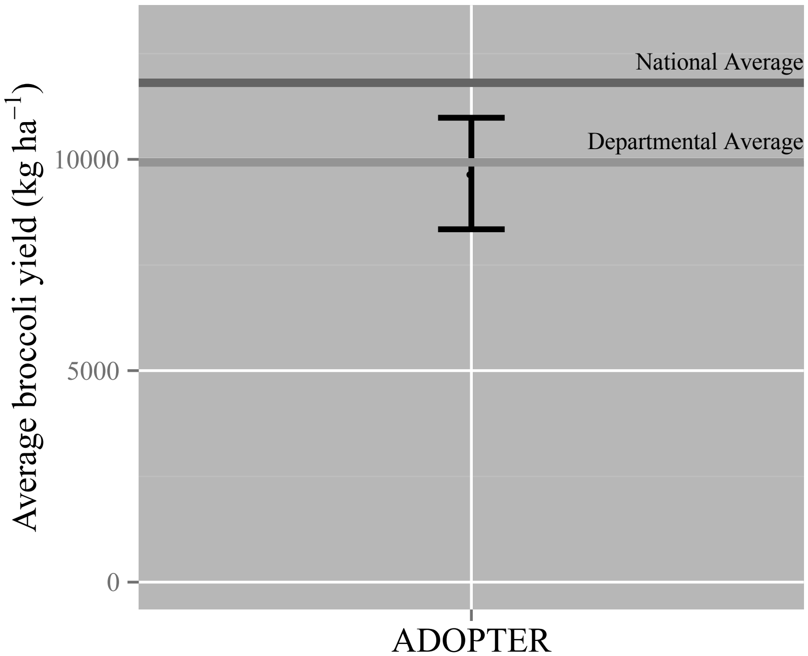

Figure 2.3. The average broccoli yield of adopter households in Chilascó (N = 25). Average annual yield was calculated as the average of all broccoli harvests over a 12-month period for each household. The average broccoli yield in Guatemala was 11,811 kg ha^{-1} in 2004 and in Baja Verapaz it was 9,928 kg ha^{-1} (INE 2004). Error bars show ± 1 SE.

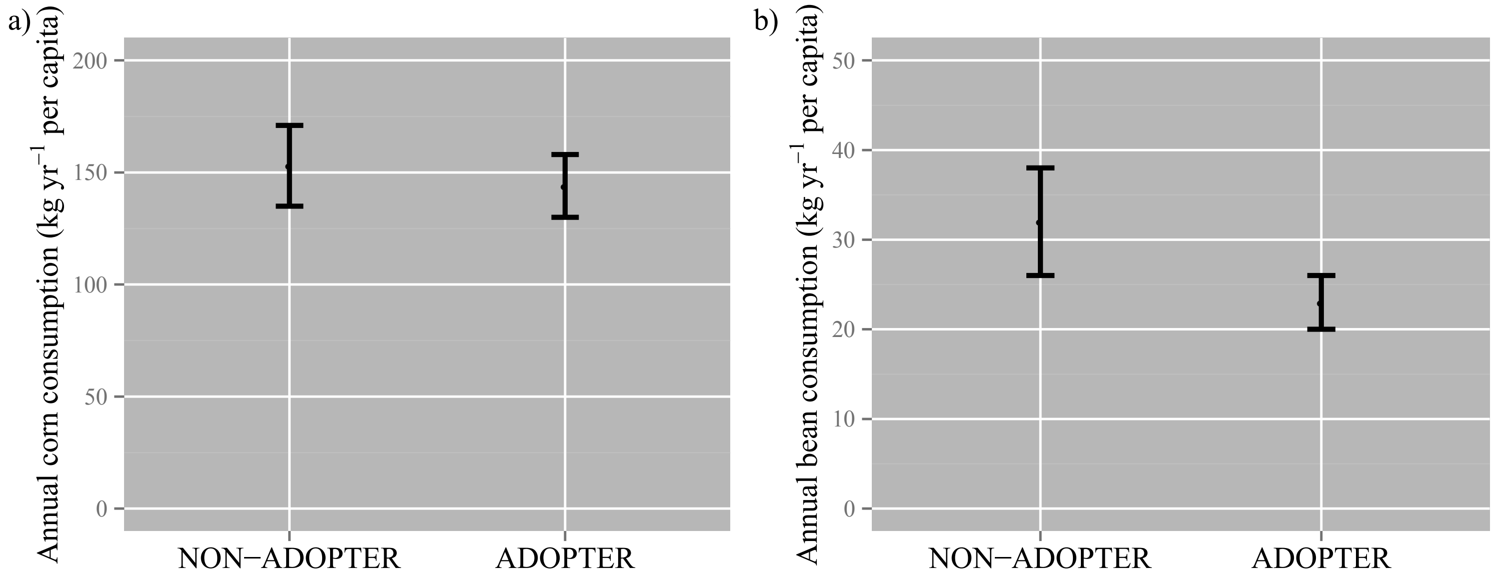

Figure 2.4. Average annual per capita **(a)** corn consumption (kg yr^{-1} per capita) and **(b)** bean consumption (kg yr^{-1} per capita) of non-adopter (N= 27) and adopter (N=25) households in Chilascó. Consumption figures are based on estimates of the amount of corn and bean cooked in a household for a 'good' week and a 'bad' week. These estimates were subsequently averaged, multiplied by the number of weeks in a year (52), and then divided by the number of household members. Error bars show ± 1 SE.

IMPACT OF NTX ADOPTION ON FOOD ACCESS

Summary: Only one of the six indicators of food access– net annual household income – differed significantly between groups, as adopter households had significantly higher net annual incomes. There were no significant differences between groups for any of the outcome indicators of food access (HFIAS, HHS, MAHFP, HDDS, or coping strategies).

Adopter households had significantly higher net annual incomes than non-adopter households (Independent Samples t-test; $t(50) = -1.91$, $p = 0.062$) (Table 2.9). On average, there was a 40% difference in net annual income between groups. While off-farm income did not differ significantly between groups ($p>0.05$), adopter households had significantly higher net annual on-farm incomes compared to non-adopters (Mann-Whitney $U = 199.00$; $z = 2.54$; $p=0.011$). The average daily per capita income of non-adopter households was slightly above the international extreme poverty line ($1.25 day^{-1} per capita, 2005 Purchasing Power Parity - PPP), yet fell below the international general poverty line ($2.00 day^{-1} per capita, 2005 PPP) and the general and extreme poverty lines developed for Guatemala (Figure 2.5). The average daily per capita income of adopter households exceeded both the international and Guatemalan extreme poverty lines, yet fell below the international and Guatemalan general poverty lines (Figure 2.5). See Appendix I for more information on the calculation of poverty lines.

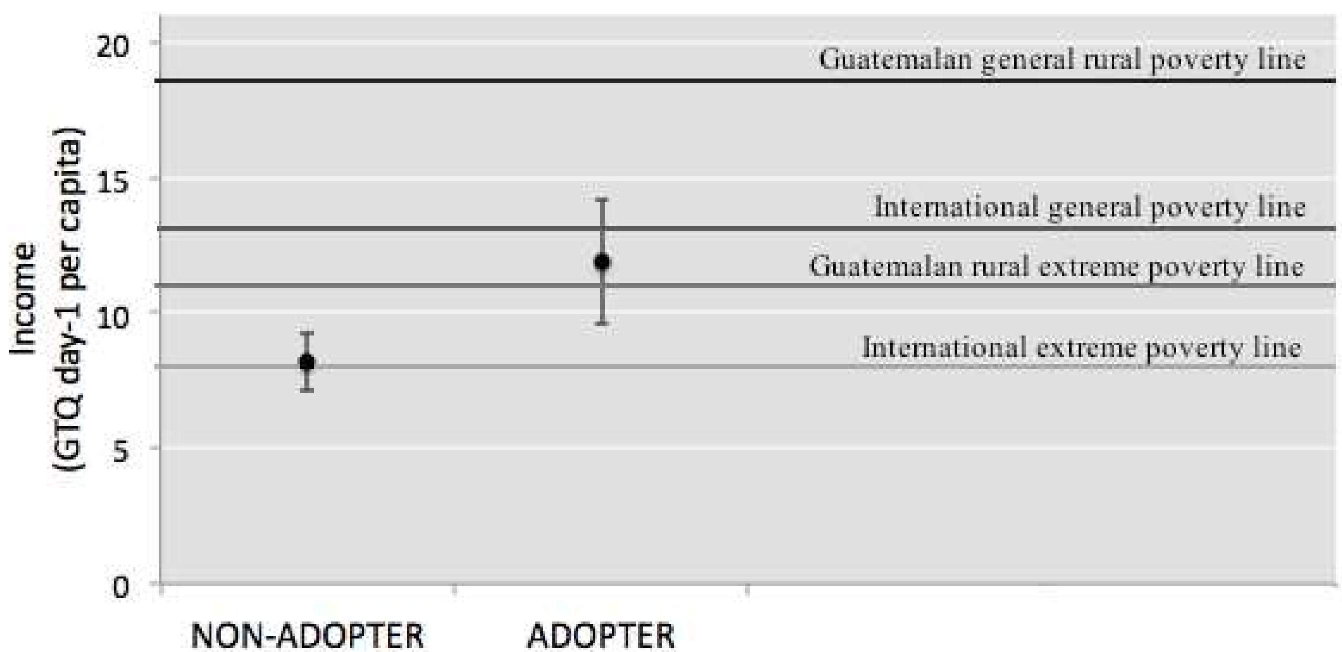

Figure 2.5. Daily income per capita (Guatemalan quetzales (GTQ) day^{-1} per capita) compared against four absolute poverty lines: 1) the international general poverty line - $2.00 day^{-1} per capita (2005 Purchasing Power Parity - PPP) - which converts to GTQ 13.01 day^{-1} per capita, 2) the international extreme poverty line - $1.25 day^{-1} per capita (2005 PPP) – which converts to GTQ 8.13 day^{-1} per capita, 3) the Guatemalan general rural poverty line of GTQ 18.78 day^{-1} per capita for the year 2011, and 4) the Guatemalan extreme rural poverty line of GTQ 10.68 day^{-1} per capita for the year 2011. Error bars show ± 1 SE. To convert USD to GTQ (quetzals), I used an exchange rate of 1 USD = 7.8285 GTQ (as of 2011-09-09, accessed from www.xe.com). See Appendix I for more information on the calculation of poverty lines.

Table 2.9. The income profiles of non-adopter (N=27) and adopter households (N=25).

	Non-adopter (N=27)		Adopter (N=25)	
	Mean	SEM	Mean	SEM
• Net annual household income (USD yr^{-1})	2100	257	3133*	489
o Net on-farm income (USD yr^{-1})	382	137	1572**	423
o Off-farm income (USD yr^{-1})	1717	198	1560	273

Statistically significant at: * P <0.1, ** P <0.05, *** P <0.001.

Interestingly, there were no significant differences for any of the access outcome indicators between adopter and non-adopter households. The HFIAS shows that the experience of household food insecurity (at the perception level) does not differ significantly between groups, when treated as either a continuous (p>0.05) or as a categorical variable (p>0.05). According to this indicator, over 70% of both non-adopter and adopter households were moderately or severely food insecure (Figure 2.6). Looking across the nine questions comprising the HFIAS (Table 2.10), there was only one significant difference in the responses for a question between groups. Non-adopter households had a significantly higher rate of responding "yes" to the question of whether or not they had to eat food they did not want to out of necessity (Chi-square, X^2 (1, N=52) = 7.63, p= 0.01, V= 0.39). Interestingly, in both groups, anxiety about food (Question 1) is the most common expression of food insecurity, followed by insufficient dietary quality (at least one yes answer for questions 2,3 and 4). The experience of insufficient food intake is least common (at least one of questions 5 – 9) (Figure 2.7a). This trend is consistent across income terciles (Figure 2.7b).

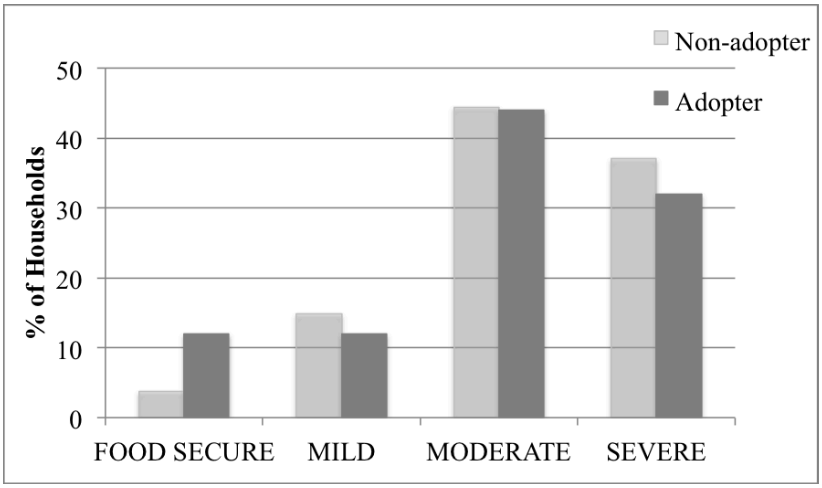

Figure 2.6. The percentage of non-adopter (N=27) and adopter (N=25) households classified as mildly, moderately, or severely food insecure – or food secure – according to the Household Food Insecurity Access Scale (HFIAS).

Table 2.10. Itemized responses to the Household Food Insecurity Access Scale (HFIAS), for non-adopter (N=27) and adopter (N=25) households in Chilascó. The percentage of households that responded "yes" to each specific occurrence question from the scale are listed, as related to three domains of food insecurity: 1) anxiety and uncertainty, 2) insufficient diet quality, and 3) insufficient food intake.

	Question	Domain	Non-adopters (%)	Adopters (%)
1.	Worry about food quantity	Anxiety about food supply	89	88
2.	Unable to eat preferred foods	Insufficient quality	78	80
3.	Eat just a few kinds of food	Insufficient quality	81	68
4.	Eat foods that you do not want to eat	Insufficient quality	74	36**
5.	Eat less than necessary during meals	Insufficient food intake	67	64
6.	Eat fewer meals per day	Insufficient food intake	41	44
7.	No food to eat in home	Insufficient food intake	26	16
8.	Go to sleep hungry	Insufficient food intake	30	20
9.	Full day without food	Insufficient food intake	15	8

Statistically significant at: * P <0.1, ** P <0.05, *** P <0.001.

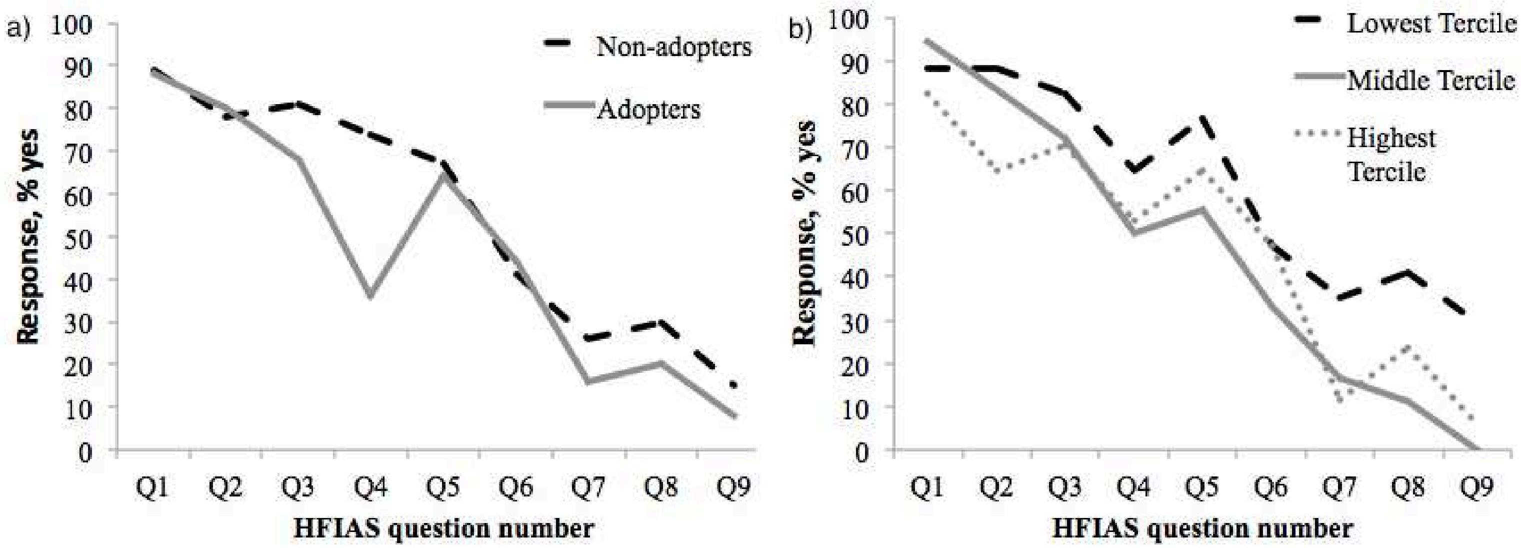

Figure 2.7. a) Response curves showing the percentage of non-adopter (N=27) and adopter (N=25) households experiencing the three domains of food security: 1) anxiety and uncertainty (Q1); 2) insufficient food quality (Q2 - Q4); and, 3) insufficient food intake and its physical consequences (Q5-Q9). **b)** HFIAS item response curves across household income terciles among 52 non-adopter and adopter households. Note that the nine questions represent a generally increasing level of severity of food insecurity from a food access perspective (Coates et al. 2007).

There was no statistically significant difference in the experience of hunger across groups according to the Household Hunger Scale (p>0.05; Table 2.11). Most households experienced little to no hunger over the previous 30 days, although both moderate and severe levels of household hunger were found in some adopter and non-adopter households.

According to another indicator of food access, the Months of Adequate Home Food Provisioning, both adopter and non-adopter households reported that they had inadequate food (both produced and purchased) over a least four months of the previous year. There was no significant difference in the reported number of months of adequate home food provisioning between groups (p>0.05; Table 2.11). June and July are the 'hunger months' in Chilascó, and even adopter households with higher annual incomes struggled to feed household members adequately.

There was no significant difference in the total number of severe coping strategies used by non-adopter and adopter households (p>0.05; see Appendix J for additional information). The most common coping strategies employed by both groups included: adults eating smaller portions, children eating smaller portions, and adults migrating to work outside of the community part-time. However, over a 12-month period, significantly more adopter households reduced the portion sizes given to children as a coping strategy (Chi-square, X^2 (1, N=52) = 4.19, p= 0.041, V= 0.284). Approximately 40% of adopter households reported having had to use this coping strategy, compared to 15% of non-adopter households.

There was no significant difference in the mean household dietary diversity scores for non-adopter and adopter households (p>0.05; Table 2.11; Figure 2.8). Dietary diversity in Chilascó is based on the consumption of staple cereals, legumes, sugar and honey, and coffee. Overall, households in the lowest dietary diversity tercile ate a restricted diet of cereals, legumes, and sugar/honey (Table 2.12). The food items that make up the additional diversity of higher scoring diets include oils, vegetables, fruits, and eggs. Households with the highest dietary diversity also ate meats and roots or tubers (typically potatoes). According to a two-way analysis of variance, there was a significant main effect of income on the household dietary diversity score ($F_{2,46}$= 5.71, p=0.006), with households in the top income tercile having significantly higher dietary diversity compared to households in the bottom tercile (Tukey HSD, p=0.009). There was no significant main effect of household type (adopter versus non-adopter, $F_{1, 46}$= 1.41, p=0.41) and no interaction effect ($F_{2, 46}$= 0.09, p=0.920).

Table 2.11. Results for indicators of food access for non-adopter (N=27) and adopter (N=25) households in Chilascó.

	Non-adopter		**Adopter**	
	Mean	**SEM**	**Mean**	**SEM**
HFIAS scale - *continuous*	9.48	1.10	8.64	1.16
HFIAS – *categorical* (mode)	Moderate food insecurity		Moderate food insecurity	
HHS – *categorical* (mode)	Little hunger		Little hunger	
Months of adequate home food provisioning	7.48	0.56	7.72	0.68
Household dietary diversity score	7.59	0.37	7.40	0.41

Statistically significant at: * P <0.1, ** P <0.05, *** P <0.001.

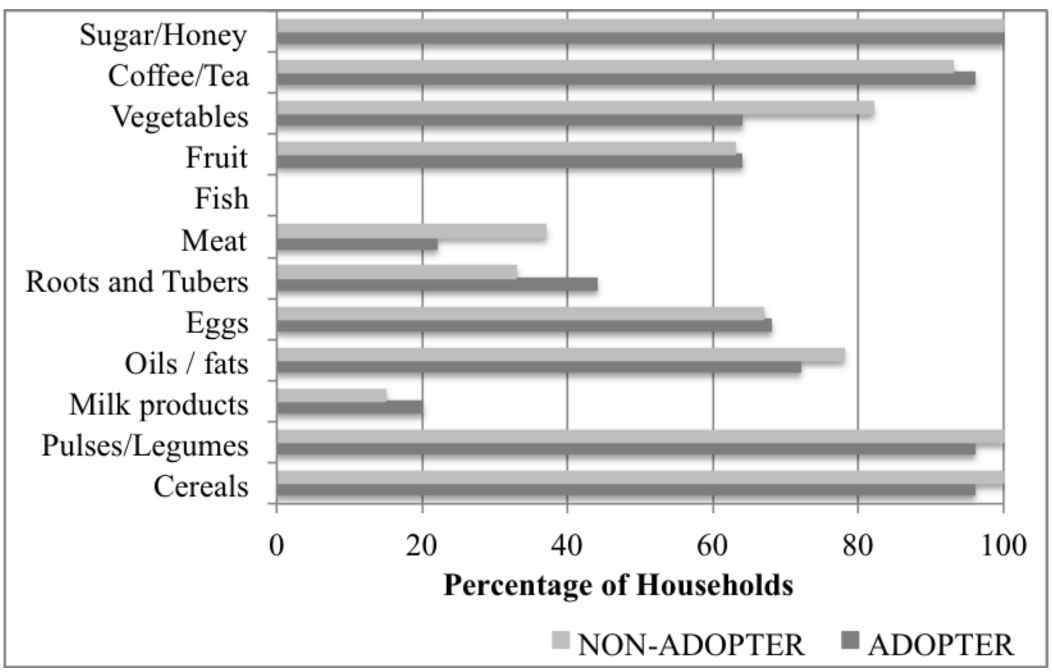

Figure 2.8. The percentage of non-adopter (N=27) and adopter (N=25) households who had consumed a given food group the previous day, within the home, according to the Household Dietary Diversity Scale.

Table 2.12. The food groups consumed by greater than 50% of the households in each dietary diversity tercile. Dietary diversity terciles were calculated based on the total number of food groups eaten the previous day within each household. No distinction is made between non-adopter and adopter households.

Lowest dietary diversity	Medium dietary diversity	High dietary diversity
Cereals	Cereals	Cereals
Pulses/Legumes/Nuts	Pulses/Legumes/Nuts	Pulses/Legumes/Nuts
Sugar/Honey	Sugar/Honey	Sugar/Honey
	Oils/Fats	Oils/Fats
	Eggs	Eggs
	Fruits	Fruits
	Vegetables	Vegetables
		Roots/Tubers/Plantains
		Meats

IMPACT OF NTX ADOPTION ON FOOD UTILIZATION

Summary: The food consumption scores of children living in non-adopter (62.8 ± 4.1) and adopter households (65.6 ± 4.4) were not significantly different ($p>0.05$).

According to international benchmarks (WFP 2009; Wiesmann et al. 2009), the majority of children in the sample had ‘acceptable’ food consumption scores (scores over 42) although some ‘borderline unacceptable’ (scores of 28 -42) and ‘poor’ (scores of 0-28) food consumption scores were reported in each group. There was a significant main effect of total annual income on the food consumption score of children ($F_{2,33}= 3.18$, $p = 0.055$). Children living in households in the highest income tercile had significantly higher food consumption scores compared to children living in lower income households (Tukey HSD, $p=0.042$). However, there was no significant main effect of household type (adopter; non-adopter) ($F_{1,33}= 0.01$, $p = 0.918$) and no interaction between these two factors ($F_{2,33}= 0.07$, $p = 0.933$).

The correlations used to test for convergent validation among indicators of food access and food utilization are also included in Appendix H. The correlations were consistent with the expected relationships among indicators.

IMPACT OF NTX ADOPTION ON FOOD SYSTEM STABILITY

Summary: Adopters used significantly higher quantities of pesticides and fertilizers compared to non-adopters (p<0.05). Soil measurements indicate that adopter parcels had marginally higher soil potassium compared with non-adopter parcels (p<0.05) but there were no other significant differences in soil parameters related to the ecosystem service of soil fertility. Finally, the farming practices employed by both groups were similar, suggesting that the ecosystem service of erosion regulation is not disproportionately affected by NTX farming compared to corn and bean farming.

***Biological control of pests*:** All adopters (N=25) applied pesticides in the previous 12 months; only 56% (N=15) of non-adopters used pesticides. On a per hectare basis, adopters had a significantly higher environmental impact quotient (EIQ) associated with pesticide use compared to non-adopters (Mann-Whitney U = 146.000; z =-3.097, p=0.002). The median EIQ per hectare for non-adopters was 4 whereas for adopters it was nearly 52 (Table 2.13). It is more informative to report median values here because a few non-adopter households used high quantities of toxic pesticides while the majority used none whatsoever, and the mean EIQ per ha for non-adopters was sensitive to high values.

Table 2.13. The environmental impact quotient per hectare (EIQ ha^{-1}) associated with pesticide use by adopter (N=25) and non-adopter (N=27) households.

	Non-adopter (N=26)			**Adopter (N=25)**		
	Median	**Mean**	**SEM**	**Median**	**Mean**	**SEM**
Non-adopter	4.23	104.7	52.4	51.6	128.6	44.4

Statistically significant at: * P <0.1, ** P <0.05, *** P <0.001.

Farmers were overwhelmingly of the opinion that there were more pests in Chilascó in 2011 than 5 years before; broccoli farmers were more in agreement with this statement than non-adopters (Chi-square, X^2 (1, N=52) = 5.069, p= 0.079, V= 0.315; Table 2.14). Farmers tended to attribute this to, in order of decreasing frequency: 1) increasing intensity and expansion of broccoli production (n= 9); 2) increasing pesticide resistance by pests (n= 8); 3) leftover crop residue from broccoli and cabbage production (n= 5), and 3) poor soil fertility in general (n= 3). This question was not posed to every farmer, which accounts for response levels below the sample size. Local farmers identified clubroot, a disease affecting Brassica crops and caused by the parasite *Plasmodiophora brassicae* Woronin, as being their chief agricultural concern during a focus group. The presence of clubroot was reported by approximately 60% of adopter households and by 22% of the non-adopter households who rent out their lands for broccoli farming.

Table 2.14. The opinions of non-adopter (N=27) and adopter farmers (N=25) regarding agricultural pest levels and damages.

% Agreement with the statement	**Non-adopter (N=27)**	**Adopter (N=25)**
	% of households	*% of households*
There are more pests now than 5 years ago	81	96*
Pests cause more damage to broccoli fields than to corn and bean parcels	85	76

Statistically significant at: * P <0.1, ** P <0.05, *** P <0.001.

***Nutrient cycling*:** On a per-hectare basis, adopters applied significantly more chicken manure compared to non-adopters (Independent samples t-test, t (50)=-2.554, p=0.014; Table 2.15). Adopters also applied close to three times more inorganic fertilizer than non-adopters, which is a statistically significant difference (Independent samples t-test, t (50) = -2.577, p=0.013). Overall, adopters applied significantly more nitrogen per hectare than non-adopters (Independent samples t-test, t (49)= -2.45, p=0.018; Figure 2.9). The phosphorus application rate was also significantly higher – approximately double - for adopters compared to non-adopters (Independent samples t-test, t (49) = -2.725, p=0.009).

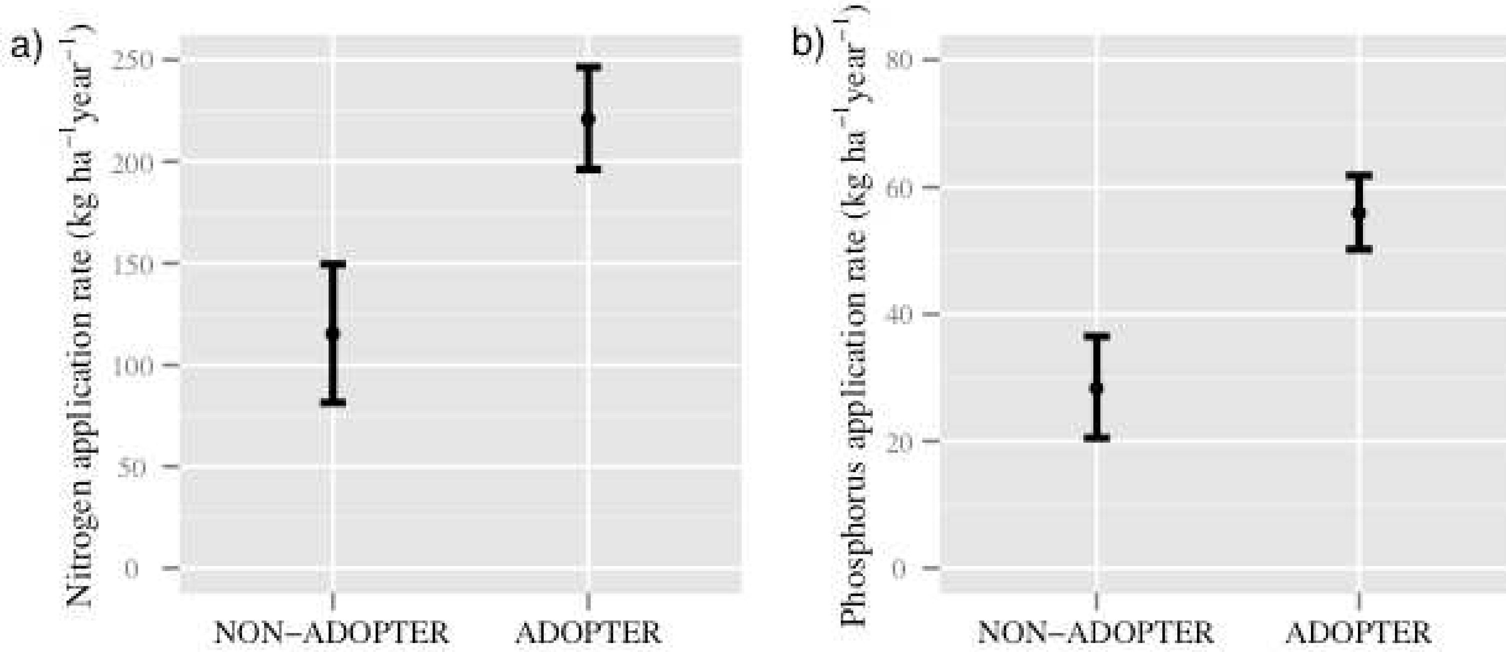

Figure 2.9. a) The annual rate of nitrogen application (kg N ha^{-1} yr^{-1}) from fertilizer use for non-adopter households (N=27) and adopter households (N=25). **b)** The annual rate of phosphorus application (kg P ha^{-1} yr^{-1}) from fertilizer use. Error bars show ± 1 SE.

Table 2.15. Annual manure and inorganic fertilizer use by non-adopter (N=27) and adopter (N=25) households and the nitrogen and phosphorus loads associated with fertilizer use.

	Non-adopter		**Adopter**	
	Mean	**SEM**	**Mean**	**SEM**
Manure (kg ha^{-1} yr^{-1})	2673	585	4892**	644
Inorganic fertilizer (kg ha^{-1} yr^{-1})	235	108	655**	123
N application (kg ha^{-1} yr^{-1})	116	34	221**	25
P application (kg ha^{-1} yr^{-1})	28	8	56**	6

Statistically significant at: * P <0.1, ** P <0.05, *** P <0.001.

Soil fertility: The only soil parameter that differed significantly between groups was soil potassium (K), with adopter parcels having higher soil K (146.47 ± 19.63 ppm) compared to non-adopter parcels (102.43 ± 6.91 ppm) (Independent samples t-test, t (13) = -2.01, p = 0.066). Mehlich I P levels for non-adopter (3.16±0.4 ppm) and adopter (3.93±0.71 ppm) parcels were both lower than the adequate range (12-16 ppm) generally specified for agricultural production in this region. The mean pH of soils (5.3) was favourable for broccoli production. Soils were also characterized by high organic matter content for both non-adopter (18.4± 2.8 %) and adopter (22.6± 2.1 %) parcels. Appendix J lists the results for all soil sample testing.

Soil erosion regulation: There were no significant differences between the farming practices employed by non-adopters and adopters (Table 2.16; see Appendix H for detailed test results). Many simple soil conservation practices are not employed on the steep slopes surrounding Chilascó. Many parcels were without, or had very limited, tree cover, and did not have terraces, hedgerows, or active barriers. However, the herbicide Gramoxone was commonly applied to avoid tilling the soil (by 73% and 88% of non-adopter and adopter households, respectively), which helps to minimize soil erosion but may reduce soil biodiversity. Finally, while almost 40% of households had let their lands rest in the previous 12 months, this was often only in one small parcel and it is unclear whether fallow lands were left covered so as to prevent erosion.

Table 2.16. Farming practices employed by non-adopter (N=27) and adopter (N=25) households and their frequency of use (%) by group. Practices were classified as 'beneficial for soil conservation' or 'erosion inducing' based on the literature.

Variable	Classification	Non-Adopters	Adopters
		% households employing practice	
Mix/mulch greens in soil	Beneficial	96	100
Vegetation along borders	Beneficial	65	68
Active barriers	Beneficial	23	32
Terraces	Beneficial	8	8
Reforest	Beneficial	15	28
Allow land to rest	Beneficial if covered	39	40
Plant trees inside parcel	Beneficial	20	42
Plant fruit trees	Beneficial	44	44
Use Gramoxone to prepare soil	Beneficial	73	88
Slash and burn	Erosion inducing	19	32

Statistically significant at: * P <0.1, ** P <0.05, *** P <0.001.

PERCEPTIONS OF THE LOCAL ECONOMY

The perceptions of male household heads vis-à-vis the local economy reveal an interesting dynamic: although 89% of respondents had a positive perception of community-level socioeconomic change following the introduction of broccoli, this contrasted with the overwhelming perception that broccoli companies take advantage of farmers, are the primary beneficiaries of production, and fail to offer fair prices to farmers (Table 2.17). There were no significant differences in the opinions of respondents between groups for any of these questions. These survey results are supported by discussions held in a focus group exploring the links between community development, food security, and agriculture. During the focus group, local farmers expressed concern that broccoli export companies are the primary beneficiaries of broccoli production, especially since broccoli prices continue to drop and the financial risk of production is borne entirely by the producer. If broccoli harvests are damaged by pests (even cosmetically), the farmer is at risk of finishing a planting season without profit and without food for the family (because a staple crop was not planted). There are cases of export companies refusing to pay for broccoli due to cosmetic pest damage, cases where companies delay payment for delivered harvest, and cases where the farmer is forced to plant more broccoli to pay back a prior debt with the company.

Table 2.17. The opinions of non-adopter (N=27) and adopter (N=25) farmers regarding social development and market trends related to NTX cultivation in Chilascó.

	Non-adopter	**Adopter**
Agreement with the statement	**%**	**%**
• Broccoli companies take advantage of farmers	93	96
• Broccoli companies never lose	78	80
• Broccoli companies offer fair prices	15	20
• Broccoli farming helps families	93	88
*Who benefits the most from broccoli production? **		
• Broccoli companies	74	75
• Farming households	7	8
• Everyone benefits equally	19	17

*Percentages may not sum due to rounding.

CONTEXTUAL FACTORS INFLUENCING HOUSEHOLD FOOD SECURITY

In the sections below, I provide illustrative quotes from community members who participated in interviews or focus groups in order to better contextualize food insecurity in Chilascó. These qualitative results are presented as a complement to the quantitative survey results already discussed. When asked why malnutrition and hunger persist in Chilascó despite the apparent productivity of local farmlands, community members provided several explanations. A nurse who has worked at the local health clinic for over a decade highlighted three key drivers of food insecurity in Chilascó (in this order): i) the production of vegetables for export rather than for household consumption; ii) parental neglect of children and poor hygiene; and, iii) a lack of education, especially for mothers. She spoke passionately about the influence of export markets:

- Nurse #1: " The first cause [of food insecurity] is the poor nutrition of all children. In Chilascó, we are blessed to have many types of vegetables but many times our people do not consume them. They prefer to give them to the market. Many of our children do not consume the vegetables that our community produces. Our community produces many vegetables and exports the broccoli, the potato, to the United States."

A local woman working to promote tourism had a similar point of view:

- Tourism worker #2: "The vegetables, they take them to the capital to sell where they can be sold for more. So here, you cannot get them, well, you can but only one or two times, nothing more, because they take them to be sold for more."

In agreement with the nurse, other participants pointed to the parental neglect of children as a reason for the disconnect between local productivity and food security:

- A local leader (#1) explained: "Maybe it isn't a shortage of food; in this case, we should be more focused and look at the food system surrounding each person. The problem is that, sometimes, the mother of a family, or those in charge of a family in a household, do not pay much attention to the nutrition of children ages zero to five."

In turn, some argued that parental neglect might stem from high agricultural labour loads.

- A local schoolteacher (#1) explained: "The land – the people here exploit it. Whether a person is planting broccoli or planting corn, still they neglect their homes. Everyday they wake up at five in the morning, and sometimes it is seven at night before they return home, but they neglect their homes. A case emerged here where a girl of seven years took care of a girl of one year because her mother was always working. Basically, a young girl took care of an even younger girl. People are more worried about their harvest and neglect their families. That is where I believe malnutrition comes from."
- Another schoolteacher (#2) agreed: "The father goes and the mother goes, and they leave their children alone, sometimes they leave them without food, and they don't return until three or four in the afternoon".

Another important driver of food insecurity, one that is also linked to parental neglect, is a lack of education. Several participants pointed to the general lack of education in the population as a problem, whereas others were concerned specifically with a lack of knowledge relating to the food system and nutrition. For example:

- Local farmer #1: "I think that malnutrition, like my friend said, comes from a lack of knowledge by the mother and the family. Here we are aware that it is not only single mothers [who have malnourished children], there are malnourished children who have fathers. But many times, the mom, the dad, take little responsibility."

- Nurse #1: “Many mothers are not informed about how they can prepare foods that are produced in our community.”

Participants also pointed to several other factors influencing food security in Chilascó, including, among others, access to land, family size, child labour, weather patterns and food prices. Interestingly, participants tended to speak of household food insecurity generally, finding it difficult to distinguish differences between factors influencing adopters and non-adopters.

Returning once more to the four dimensions of food security, qualitative findings from interviews and focus groups indicate that food availability – specifically a lack of calories - is generally not the core issue underlying food insecurity in Chilascó, although some families do struggle to produce enough staple crops for their large families and although some harvests fail due to environmental factors. Instead, food access is a major concern locally and may be limited by both market forces and cultural preferences. As mentioned, the export of vegetables limits access to a diverse food basket within the community, especially since locals “plant broccoli and can then earn money, but they do not necessarily buy good food with the profit” (Nurse #1). From a cultural perspective, while many farmers have diversified their agricultural production and this could theoretically improve access to diverse foods within the home, corn and bean continue to play a central role in the diet of locals. Local leader # 1 explains:

- “The truth is that we live on tortillas and beans. Occasionally we will eat a salad of broccoli, cabbage or cauliflower, but our favourite dishes as Guatemalans are tortillas and beans.”

Importantly, factors affecting food utilization, including dietary diversity, human health, and sanitation, are also major concerns in Chilascó. Nurse # 1 described how food insecurity is linked to “the poor handling of everything” and how, poor hygiene and sanitation is then linked to diarrhea (the most common sickness treated in the clinic) and malnutrition. These concerns extend to the local environment, where farmers are concerned about issues ranging from soil degradation and erosion to climate change. Many farmers are quick to admit that the indiscriminate use of agrochemicals is causing environmental harm, although they emphasize that a lack of agroecological knowledge is the root cause of improper use. Taken together, in Chilascó, issues of food access, food utilization, and food system stability seem to be more grievious than issues of food availability, although this may vary by year and by household.

DISCUSSION

This study was motivated by the desire to better understand the relationship between NTX farming and household food security in a poor, rural part of Guatemala. It is the first of its kind to systematically analyze the impacts of NTX farming on the four dimensions of food security. Overall, my analysis reveals that the relationship between NTX farming and food security is nuanced by considerations of food availability, food access, food utilization, and food system stability. I found that broccoli farming in this community is neither wholly beneficial nor utterly harmful to the four dimensions of food security. By and large, adopters were no more, and no less, food secure than non-adopters.

Within the scope of this case study, I found that NTX adoption has heterogeneous impacts across the different dimensions of food security, whereby some indicators show improvements for adopters (e.g., income), others remain unchanged (e.g., the HFIAS and staple crop production), and others degrade (e.g., the ecosystem service of biological pest control as proxied by the EIQ) (Table 2.18). More specifically, the key findings of this study were that:

- Adopter households earned significantly more income than non-adopter households. However, other indicators of food access and food utilization were *not* significantly different between adopter and non-adopter households.
- Income gains *can* improve smallholder food security yet do not *guarantee* it. Income gains did not translate to improvements in all food security outcome indicators, particularly at the perception-level.
- Intensive non-traditional export agriculture may erode local ecological resilience over time. Adopters used significantly higher amounts of

agrochemicals compared to non-adopters, and this may be associated with declines in agricultural ecosystem services.

Perhaps the most striking finding of this study is that – despite widespread assumptions in the agricultural development community that higher incomes tend to improve food security –I found that higher incomes achieved by adopter households did not equate with improved food access and food utilization. Moreover, I found that multiple factors contribute to food insecurity in Chilascó, including, *inter alia*, cultural preferences for corn and bean, poor hygiene, parental neglect of children, and child labour. This signals that blanket statements about the benefits of NTX production for rural food security may be blind to differences among the four dimensions and contextual factors influencing food security.

Table 2.18. The food security status of adopters relative to non-adopters according to indicators of food availability, access, utilization, and stability.

AVAILABILITY		**UTILIZATION**	
Staple production	***Neutral***	Food Consumption Score	***Neutral***
Staple consumption	***Neutral***		
Wild foods collection	***Neutral***		
FOOD SYSTEM STABILITY		**ACCESS**	
EIQ	***Higher***	Income	***Higher***
N and P Loads	***Higher***	HFIAS	***Neutral***
Soil Parameters	***Higher** (K)* ***Neutral*** *(others)*	Household Hunger Scale	***Neutral***
		HDDS	***Neutral***
		Coping Strategies Index	***Neutral***
Erosion	***Neutral***	MAHFP	***Neutral***

EXPLORING IMPACTS ACROSS DIMENSIONS

Fischer and Benson (2006) argue "there is no absolute ground from which to make ethical pronouncements about whether the global broccoli trade is a "good thing" or a "bad thing"" (Fischer and Benson 2006, p. 8). Similarly, the results of this case study suggest that broccoli farming for international export by smallholders is neither "good" nor "bad" for household food security. NTX adoption did deliver on the promise of increase household income for adopter households; the average net annual income of adopters was 40% higher than that of non-adopters in my study. This reflects previous evidence that NTX adoption can increase household income in areas around the world (*Guatemala*: von Braun et al. 1989a; Katz 1995; Immink and Alarcon 1993; *Gambia*: von Braun et al. 1989b; *Kenya*: Kennedy and Cogill 1987; the *Philippines*: Bouis and Haddad 1990; *India*: Birthal et al. 2005). However, this increase in income did not translate to increased food security, as discussed in more detail later on.

Broccoli farming did not reduce the staple food production of adopter households. Although it is often assumed that cash crops displace food crops, I found no evidence that broccoli production crowds out staple production in Chilascó. Given that there was no significant difference in the average size of land holdings between groups, staple production by adopters is likely maintained by multiple factors, including: (i) a shift by adopters towards planting corn that can be harvested within four months (instead of a traditional nine-month variety), allowing them to grow both broccoli and corn on the same land in any given year; (ii) the preference of non-adopters to continue farming nine-month corn in order to maintain low farm input costs and because of taste; and, (iii) a possible spillover effect of broccoli fertilization on the yields of staple crops (Immink and Alarcon 1993). Indeed, a local leader (#1) suggested that corn yields have increased "little by little" since broccoli was introduced to the community.

Food insecurity in Chilascó may not be first and foremost an issue of food availability. The estimated annual corn consumption per capita in both non-adopter and adopter households exceeds the Guatemalan average of 110 kg per person per year (Fuentes López et al. 2005). This suggests that corn requirements per capita – where corn and bean can account for upwards of 60% of dietary intake in Guatemala (INCAP, 2004) – are, on average, satisfied throughout the year. Although this does not account for seasonal variation, these results are consistent with the finding that most adopter and non-adopter households experienced '*little to no hunger'* over the previous month according to the Household Hunger Scale. From this stance, basic corn and bean availability may preempt chronic hunger associated with a lack of calories, barring occasions when corn and bean harvests are reduced or fail due to environmental reasons. However, it is important to remember that hunger is an extreme manifestation of food insecurity, and other indicators suggest that food insecurity in Chilascó stems primarily from a breakdown in the other dimensions.

The disconnect between income and food security

As previously noted, outcome indicators of food access suggest that adopters and non-adopters have similar access to food despite the fact that adopters earn more income. The majority of adopters and non-adopters alike were categorized as moderately to extremely food insecure according to the HFIAS. Households also reported using the same coping strategies when confronted by shortfalls in either money or food, and these shortfalls seemed to limit food access for about four months of the year for both groups. This is an interesting finding, with important policy-making implications, because higher income – a food security determinant commonly recognized as an indicator of food access – is not associated with improvements in outcome indicators of food access.

Similarly, the results for *food utilization* – as measured by the food consumption scores of children - suggest that the dietary quality of children was mostly adequate across groups, regardless of adoption status. Looked at one way, we might conclude that although adopters were not better off than non-adopters, it is a positive sign that children's food consumption was considered adequate in both groups. However, our understanding of nutritional outcomes using this indicator is limited because current benchmarks for the FCS may significantly underreport cases of inadequate food consumption in Guatemala (WFP 2008). Importantly, qualitative findings based on interviews I conducted in Chilascó suggest that food utilization is not adequate in some non-adopter and adopter households. In speaking with health workers in Chilascó, I was told that children and young mothers in both groups were vulnerable to acute and chronic malnutrition. Indeed, while I was in the field, eleven local children (four of whom lived in adopter households) were identified as acutely undernourished by local health officials, based on measurements of each child's middle-upper arm circumference.

Overall, these results are consistent with studies demonstrating that gains in income from NTX agriculture do not necessarily lead to improved dietary energy and protein intake (Immink and Alarcon 1993) or improved nutritional outcomes in Guatemala (von Braun et al. 1989a; Immink et al. 1995). Moreover, this disconnect is not a phenomenon restricted to Guatemala (Dewey 1981; Longhurst 1988; Bouis and Haddad 1990; DeWalt and Barking 1991; Sharpe 1990). At the same time, it is also not possible to state unequivocally that income gains from NTX farming do not lead to improvements in food security, given mixed results documented in multiple studies (von Braun and Kennedy 1986; Schuftan 1998). Schuftan (1998) argues that although multiple studies suggest that household income alone cannot lead to improved food security and nutritional status, income actually does have an important role to play in improving food security, however typically for the lowest income decile households or for the already extremely malnourished.

I found that household dietary diversity and the food consumption score of children were significantly higher for households in the top income tercile compared to the bottom tercile, and that this effect was independent of adopter status. On the one hand, these two indicators suggest that income gains *are* associated with improved food security outcomes, whereas, on the other hand, income gains do not translate to improved food security at the perception-level. It is remarkable that, according to the HFIAS, 44% of adopter households were moderately food insecure and 32% were extremely food insecure, and this did not vary with income. Since the HFIAS is an indicator reflecting the subjective experience of food insecurity within a household, these values capture the fact that households across all income levels felt anxious about the food supply and also coped with food of insufficient quality, quantity, and the physical consequences of these deficits. Despite the high prevalence of food insecurity according to the HFIAS, valuation frameworks grounded in monetary reductionism typically ignore this psychological dimension (Kumar and Kumar 2008). A nuanced conclusion from this work is therefore that income *can* lead to positive food security outcomes, but does not *guarantee* them.

Reasons for the 'income-food security' disconnect

The potential reasons for the 'income-food security' disconnect are manifold. A useful starting point is to recognize that households have objectives beyond achieving and maintaining food security (Swift and Hamilton 2001), so income may be used for purposes other than purchasing food, such as buying agricultural inputs, paying debts, or acquiring more land. The suggestion by the local nurse (#1) that profits from broccoli production are not necessarily used to purchase nutritious foods support this idea. Moreover, asymmetrical intrahousehold resource distribution plays a key role in determining the nutritional status of individuals within households (Katz 1995). Katz (1995) argues that male-biased NTX market structures threaten to deepen gender inequalities within producing households, meaning that even if income gains are achieved, male household heads may not allocate additional (or sufficient) resources to the food budget. Health professionals and women in Chilascó expressed concern that male household heads frequently misspent household income, choosing to purchase non-essential items, particularly alcohol. In the words of one local woman, "I don't have the money…it costs…the food and the vices…it all costs" (Focus group participant, 2011).

The high labour requirements of broccoli production, particularly for women and children, can also negatively affect food security outcomes (*ibid*). In Chilascó, women spend substantially more time farming now then they did prior to growing broccoli and it is common for children to skip school in order to work in the fields. Local schoolteachers lament the lack of care given to children by their working parents, the prioritization of agricultural work over education in many cases, and the perceived intensification of these issues despite interventions by schools and NGOs. This is a trend associated with NTX production throughout Guatemala, and Katz (1995) argues that as female household members work longer hours in agricultural fields, they reduce the time spent caring for children, endangering child nutrition and health.

Breaking out of the vicious cycle of poverty and food insecurity requires, in addition to food availability and access, elements that contribute to a state of nutritional well-being, including clean water, sanitation, and health care (Renzaho and Mellor 2010). In Chilascó, the fecal contamination of food and water sources with chicken manure and a lack of adequate hygiene practices pose significant challenges to ensuring appropriate food utilization. Local health workers and families report that the chicken manure being used to enable broccoli production contaminates local food (via improper handling of food and large housefly, *Musca spp*., populations) and leads to diarrhea in children and malnutrition. Locals – especially women – claim that before broccoli production and the subsequent excessive use of raw chicken manure, flies were not a problem. Instead, the use of chicken manure as a substitute for the natural fertility of local soils (which have been degraded through poor and intensive farming practices) is indirectly associated with malnutrition stemming, not from a lack of calorie and protein intake, but from abnormal nutrient loss through diarrhea or chronic illness (secondary malnutrition). In other words, the food security outcomes that one might expect from farming broccoli for export (i.e., gains in income and consequent gains in food security) are constrained by the degradation of a regulating service (soil fertility) and the imperfect substitution of this service with chicken manure. Similarly, the increasing use of pesticides in NTX production, coupled with poor pesticide management practices stemming from poor education, are also tied to pesticide exposure and consequent problems for health and nutrition (Arbona 1998).

The forgotten dimension: Food system stability

There are currently multiple variables influencing food security outcomes in Chilascó, including, among others, poor health, low education levels, agricultural labour loads, and environmental exposure to the wind and rain due to poor housing. However, expanding the frame of reference to include those variables that may influence food security outcomes in the longer-term, we necessarily begin to consider food security in Chilascó as part of an interconnected social-ecological system (Berkes and Folke 1998) grounded in the stocks and flows of natural goods and services. Using the concept of ecosystem services as an entry-point to explore the stability of food systems, I found evidence that broccoli production may be undermining the ability of agricultural systems to naturally control pests, regulate nutrients, and conserve soil in the long-term.

In Chilascó, escalating pesticide use and mounting pest problems indicate that the service of biological pest control is being threatened by agricultural intensification. The higher environmental impact quotient (EIQ) of pesticide use associated with adopters suggests that the NTX model is driving these changes. Pesticides are known to kill natural pest enemies and beneficial insects (Arbona 1998; Thrupp 2000) and this may limit the ability of agroecosystems to control pest outbreaks in the absence of pesticides. Of the adopters surveyed in Chilascó, 96% reported higher pest levels between 2006 and 2011, and this trend evokes an image of the "pesticide treadmill" facing other NTX producers in Guatemala (Morales and Perfecto 2000) and Central America (Murray and Hoppin 1992).

Steep slopes, abundant rainfall, year-round cultivation, and a general lack of soil conservation practices are a recipe for soil erosion in non-adopter and adopter parcels alike. Apart from limiting the ability of agroecosystems to provide the service of sediment retention, these factors may also hinder the provision of services such as flood control and the maintenance of soil nutrients for plant uptake (Power 2010). Although locals frequently expressed a desire to be better land stewards, they felt they lacked the time, knowledge, and resources necessary to implement better practices, especially given pressures to meet immediate needs. This pressure also extends toward the forest margin, where highly multifunctional cloud forests are being converted to broccoli monocultures. Holder (2006) shows that local stream discharge has already changed as a result of cutting down the local cloud forest.

Broccoli farming in Chilascó is also facing a new challenge: clubroot disease. Clubroot, caused by the parasite *Plasmodiophora brassicae* Woronin, can lead to declines in yield, crop quality, palatability, and land capital value (Dixon 2009a).

Clubroot is a “disease of cultivation” because the severity of infestation increases with the intensity of production (*ibid*). In Chilascó, continuous cropping, short crop rotations, broccoli monocultures, and ideal host soils (Dixon 2009b) are fostering the conditions necessary for clubroot expansion, and some farmers in Chilascó have been forced to abandon broccoli production in contaminated fields. Overall, clubroot threatens to undermine livelihoods tailored to intensive broccoli production. Communities in other areas of Guatemala report broccoli crop losses from clubroot ranging from 70-100% (Fernández-Rivera 2007; Nájera Juárez 2010). Although the integrated control of clubroot is possible (Donald and Porter 2009), the costs of control measures may further squeeze producers between rising agricultural input prices and declining crop prices. A key question is thus to what extent clubroot may impact the long-term viability of broccoli production in Chilascó and local food security.

The agronomic problems confronting Chilascó are similar to those in other areas with intensive NTX production throughout Guatemala, and include dramatic increases in pest problems and pesticide resistance (Carletto et al. 1999; Morales and Perfecto 2000), declines in soil quality (Carletto et al. 1999), and the toxicological contamination of crops (Hallam et al. 2004). The degradation of agricultural ecosystem services that this implies is not without consequence for food security, because undermining natural assets can limit the capacity of households to generate future-income and avoid social vulnerability (Watts and Bohle 1993). Working in a region of Guatemala where farmers grow snowpeas (an NTX crop), Carletto et al. (2011) found that the prolonged and excessive use of fertilizers and pesticides contributed to soil degradation and, ultimately, a 30% decline in snow pea productivity between 1985 and 2005. The combined effects of soil degradation and pest resistance, coupled with rising production costs and a reduction in NTX profitability over time (Carletto et al. 1999), have forced some smallholders to abandon NTX cultivation. In light of these concerns, Carletto et al. (1999, 2010) argue that NTX farming may not favour smallholder well-being in the medium and long terms.

None of this is to say that the farming of corn, bean and other secondary crops by non-adopter households is without ecological impact. Many of the same concerns apply, but I am interested here in the relative impact of non-adopter and adopter households on local agroecosystems. Moreover, although NTX production may not lead to improvements in food access and food utilization as indicated in this study, this does not, by default, suggest that NTX production should be abandoned in favour of farming corn, bean and squash polycultures as part of a subsistence agricultural system. Guatemala's subsistence farmers have long faced challenges of food insecurity, so it is important not to romanticize subsistence agriculture as inherently "better" than NTX farming. Instead, more research is needed to help unpack the assumptions of the NTX model relating to food security, in the hopes of better targeting interventions in the future.

Local perceptions of NTX agriculture

Smallholder perceptions of the NTX model, from an economic perspective, highlight a central tension underlying export-oriented models of rural development. On the one hand, smallholders expressed mostly positive perceptions of community-level economic change following the introduction of broccoli in Chilascó. On the other hand, farmers were overwhelmingly of the opinion that broccoli companies take advantage of farmers, are the primary beneficiaries of production, and fail to offer fair prices to farmers.

In Chilascó, exploitation may coexist with income-oriented 'development', and the perception as to which of these predominates is blurry even to those most directly involved and impacted. Indeed, income poverty remains a serious issue in Chilascó, for non-adopter and adopter households alike. The average daily per capita incomes of non-adopters and adopters in Chilascó were below the absolute general poverty lines established for Guatemala and internationally (i.e., $2.00/day per capita (2005 PPP)). At these levels, economic access to even the basic food basket is constrained for households and their members. In this sense, broccoli farmers are still poor and the profitability of broccoli farming remains limited (Fischer and Benson 2006). Moreover, NTX production in Chilascó is a gamble predicated on asymmetries of power and knowledge, whereby international agro-export companies largely define when, how much, and for what price, broccoli is planted and sold. At the start of every 3-month harvest cycle, farmers enter into contracts with one of two export companies and are given agricultural inputs (seedlings, fertilizers, pesticides), the costs of which they repay by selling the harvest back to the export company at a pre-determined price. The profitability of this cycle is low. In the words of a local export company representative, broccoli production in Chilascó is “not profit, it is recovery…it is for survival” (Original Interview, 2011). In this sense, the relationship between smallholders and NTX agriculture is defined by both opportunities and risks, and neither can be adequately measured using a single dimension standard such as income (Fischer and Benson 2006).

One lingering question relates to the interaction between people and their natural environment and the bearing this may have upon psychological wellbeing (Kumar and Kumar 2008) and, possibly, food security. While the psychological elements of food insecurity are only beginning to be understood, it is important to note that environmental degradation has been linked to emotional distress (Albrecth et al. 2007; Sartore et al. 2008) and this distress may impact an individual’s sense of wellbeing and sense of control (Albrecth et al. 2007). In Chilascó, locals expressed concern over mounting population pressures, the expansion of clubroot, changing weather patterns, and whether or not these factors –among others - would ultimately influence their relative abilities to feed their families. Environmentally induced distress has been called *solastalgia* and is a new avenue for psychological research (*ibid*). Although it is unclear if – or to what extent – environmental degradation is linked to the psychological domain of food insecurity, it would be worthwhile to explore whether or not environmental distress can alter the perceptions of individuals vis-à-vis their own food security in both the short and long-terms.

LIMITATIONS

When faced with multidimensional issues that span ecological, economic, and social considerations, a researcher will inevitably encounter some methodological challenges. As previously described (see *Methods*), some basic limitations to my study's design relate to: (i) the small sample size (N= 52); (ii) the potential to overlook food insecurity at the individual level by focusing on the household; and, (iii) the classification of groups into a dichotomy of non-adopters and adopters. The cross-sectional design based on two groups (non-adopters and adopters) may also ignore linkages between groups, recognizing that there is some interdependence between broccoli farming by adopters and the wage income of non-adopters. For example, it is possible that NTX farming in the community has helped to improve food security for both groups overall (e.g., by providing jobs to non-adopters to help in fields).

The indicators used in this study also impose a few limitations. Some of the indicators used correspond to different time periods (e.g., the previous day, the previous week, seasons). Not only can memory recall bias lead to measurement error over longer reference periods (Pérez-Escamilla and Segall-Correa 2008), but also the food security status of households was discussed generically across time periods. While it would have been desirable to repeatedly visit the community to understand seasonal trends, this was not possible given the time frame of the study. In the sections below, I describe specific limitations relating to indicators across the four dimensions.

Indicators of food availability: The quantitative analysis of food availability presented here is somewhat limited by the lack of comprehensive data on dietary intake. While other researchers have used proxies for caloric intake akin to the estimates of corn and bean intake used here (von Braun et al. 1989a), dietary intake data would have provided a clearer picture of protein and energy availability within households. However, I chose not to collect this data because it would have required too much time in the context of a multi-objective survey. Moreover, while it is important to consider the role wild foods play in local diets, the simple count of wild food types used here does not provide information about the frequency of wild foods collection.

Indicators of food access: In terms of food access, one limitation relates to the use of income as a key indicator instead of household expenditures (McKay 2000). Economists typically prefer consumption expenditure to income as expenditures may fluctuate less across seasons (Falkingham and Namazie 2002). However, I chose to measure income because: (i) increasing income is commonly used as an argument in favour of NTX development; (ii) collecting data on expenditures was impractical for this study; and (iii), income is still commonly measured in food security surveys (McKay 2000). Another limitation relates to the use of "perception measures" based on a respondent's self-reported experience (e.g., the HFIAS and the HHS), because there is a risk that respondents may exaggerate their answers with the expectation that they will be eligible for aid (Deitchler et al. 2010). However, as of 2010, studies aimed at validating these measures have found no evidence of this "exaggeration effect" and the measures are commonly viewed as useful indicators of the behavioural and psychological responses to food insecurity, from an access perspective (*ibid*). Finally, the modified Coping Strategies Index provides only a rough and relative indication of food access across households, especially because the 12-month recall period used to calculate the CSI may have introduced unacceptably high recall error.

Indicators of food utilization: Although nutritional outcomes as measured by the food consumption score were not significantly different between groups, our understanding of the food utilization dimension is limited because the FCS gives only a snapshot of food consumption over the previous week for one individual and because there are currently no appropriate benchmarks for the FCS. While nutritional outcomes were mostly considered adequate, the cutoff points used by the World Food Programme (WFP) to define poor, borderline and adequate food consumption may be too low (Wiesmann et al. 2009) and have been shown to underreport cases of inadequate food consumption in Guatemala (WFP 2008). Wiesmann et al. (2009) thus recommend adjusting current FCS benchmarks upwards, although no benchmarks have been established specifically for Guatemala. The quantitative analysis of food utilization presented here is also limited because, ideally, it would include considerations of nutritional adequacy, access to water, housing, sanitation, and health care (Renzaho et al. 2010).

Indicators of food system stability: The proxies for ecosystem services presented here are mere entry-points into a line of inquiry linking ecosystem services with food security. One limitation relates to the environmental impact quotient (EIQ) used as a proxy for biological pest control. As calculated, the EIQ may slightly overestimate the environmental impact because the application of a highly toxic pesticide may inflate the EIQ value. However, this is a minor limitation tied to how the indicator is constructed (Kromann et al. 2011). Direct field-level measurements of pest populations would be a more appropriate approach for future studies, although this may prove challenging in this part of Guatemala where it can take one to two hours to walk to a farmer's field from their household. Another limitation relates to the use of farming practices as indicators of erosion, as it is difficult to predict how management impacts soil-related ecosystem services, owing to complex interactions between biotic and abiotic factors (Powlson et al. 2011). It follows that additional survey questions or direct field measurements would refine the analysis aimed at understanding the ecosystem service of erosion regulation. Another important limitation is that, while food system stability comprises social, ecological, and economic elements, the indicators of ecosystem services do not capture this full scope. However, it is important to note again that indicators of food system stability are still quite nascent and can still provide important information about the role of the environment in long-term food security (Pangaribowo et al. 2013), while also stimulating new questions for future research.

Taken together, the limitations described do not invalidate the conclusions of the study but rather call for more diversified information in the future. Many of the limitations were imposed by time and resource constraints, in particular because multi-objective surveys take time to administer and compromises must be made to ensure that participants are not burdened by requests for information.

CONCLUSION

As it stands, sweeping arguments are often made either for or against the potential for non-traditional export agriculture to improve the food security of smallholder farmers in developing countries. However, this case study of the relationship between NTX agriculture and the four dimensions of food security in a poor rural Guatemalan community suggests that these arguments may be lacking in necessary nuance. My results show that structural changes in social, economic, and ecological systems induced by NTX production do not have a single effect on the food security of smallholder farmers. Instead, it is important to consider the differential impacts that NTX production may have on the four dimensions of food security: availability, access, utilization, and food system stability. Context also matters. As described by community members in Chilascó, food security is linked to issues of education, health, long-term ecological resilience and nutritional diversity.

The most striking finding of this study is that the higher incomes achieved by adopter households in Chilascó did not necessarily translate to improvements in household food access and food utilization. These results are consistent with those of several other studies, yet are unique in that they are presented side-by-side as part of a systematic assessment of the four dimensions of food security. Importantly, I also found that adopters used significantly more agrochemicals than non-adopters, and that locals are concerned about perceived declines in environmental quality associated with intensive agriculture. Whether or not cumulative ecological degradation in and around Chilascó may threaten food security in the future remains to be seen.

Overall, the multidimensionality of food security poses a formidable challenge to the assumption that NTX adoption can increase food security through income gains. Income gains may not be enough to bring about true gains across all four dimensions of food security. Food availability, food access, food utilization and food system stability are *all* important elements of ensuring food security in the long term. Investigating the impact of NTX adoption on each of these dimensions moves beyond a dualistic understanding of food security outcomes (better/worse) toward an analytical framework that considers food security outcomes within a matrix of interactions and potential trade-offs. As the commercialization of smallholder agriculture expands across Guatemala – particularly within the broccoli producing regions of Baja Verapaz – understanding these interactions has important implications for the food security and wellbeing of the rural poor.

RECOMMENDATIONS FOR FUTURE RESEARCH

i. Selecting appropriate (and adequate) indicators for the dimensions of food security remains a stubborn challenge. For practical reasons, the design of this study excluded some indicators that would likely have strengthened the study had time and money been available to measure them. In particular, I would suggest that follow-up research also include indicators of total dietary and protein intake (to measure food availability), household food expenditures (to measure food access), and anthropometry (to measure food utilization). Given that my results show that the choice of indicators can influence how food security is understood, there is value in making multiple measurements of each dimension in addition to measuring multiple dimensions.

ii. The results of this study suggest that the impact of NTX farming on household food security is more nuanced than simple assertions of "better" or "worse" and that there may not be simple, straightforward relationships among the different dimensions of food security. It is important to consider the potentially heterogeneous impacts of development across all four dimensions. This has received limited analytical attention to date. I therefore recommend future studies to better analyse food security using multidimensional techniques. A key question is how to model interactions among indicators and among dimensions (Alkire 2007).

iii. The question of how to measure food system stability stood out as an important problem area. While indicators of ecosystem services are one entry-point to addressing this gap in the literature, there is also a need to: (i) deepen this line of inquiry by measuring multiple ecosystem services at the field scale (see Sandhu et al. 2008); and (ii) explore economic and social variables influencing food system stability (Pangaribowo et al. 2013). This could be linked to research into food system vulnerabilities (Watts and Bohle 1993; Dilley and Boudreau 2001) and cross-scale relationships among indicators (e.g., at local, regional, and global scales). More specifically, there is a major need for more longitudinal studies that explore social-ecological change over extended periods of time.

iv. It is unclear to what extent changing the type, quantity, and relative mix of ecosystem services provided by agroecosystems will impact the food security of the rural poor over time. This is because, while ecosystem services are important, they can sometimes be replaced by technology (i.e., fertilizer use to improve the productivity of a region), at least for some period of time. The extent to which the services themselves are needed for long-term stability remains unclear (Raudsepp-Hearne et al. 2010). To fill this gap, it will be crucial to investigate how an ecosystem and its specific services can contribute to food security in the long-term, while also bolstering ecological resilience. This is a novel area of research and would benefit from more long-term studies of food security across all four dimensions.

CHAPTER 3. CONCLUSIONS

The specific objectives of this thesis were:

1. To review the concepts and indicators used to assess food security at the household level, specifically with respect to the four dimensions of food security; and,
2. To analyze the implications of farming non-traditional export crops for the multidimensional food security of rural households using a small community in Guatemala as a case study.

I was motivated to undertake the first part of this work to provide a better understanding of how household food security can be measured in a way that adequately captures all four dimensions of food security: availability, access, utilization, and food system stability. To do so, I reviewed common indicators of food security and stressed the need for food security assessments to systematically include indicators of the four dimensions (see Chapter 1, *Parts 1 and 2*). Recognizing that food system stability is often overlooked in food security assessments, I also argued that ecosystem services might be used as indicators of food system stability, owing to their importance as building blocks of ecological resilience.

I was motivated to undertake the second part of this work because of the pressing need to develop evidence-based solutions to issues of household food insecurity, particularly in developing countries. This is particularly true in Guatemala, where food insecurity is a major concern and where NTX agriculture is often considered to be a strategy to improve the food security of rural smallholders. However, there is significant controversy surrounding the potential for NTX agriculture to alleviate smallholder food insecurity.

In order to better understand the relationship between non-traditional export agriculture and the four dimensions of household food security, I first presented a literature review summarizing previous studies that linked the two issues (see

Chapter 1, *Part 3*). I found that the food security implications of shifts from subsistence to commercial crop production, in general, and NTX production, specifically, are shaped by time and place (Immink and Alarcon 1993) and may vary across the four dimensions of food security. I also found that the different methodological approaches used to assess food security have contributed to mixed results across studies.

Building off of this literature review, I then presented a case study exploring the implications of farming broccoli, a non-traditional export crop, with respect to the multidimensional food security of smallholder households in the rural Guatemalan community of Chilascó, Baja Verapaz (see Chapter 2). Smallholders in Chilascó have been farming broccoli and exporting it internationally since the 1980s. Over this same period, the community has faced pervasive challenges relating to both chronic and seasonal food insecurity. In order to explore this social-ecological puzzle – one where food insecure individuals farm productive agricultural lands – I employed a multidimensional approach to food security analysis and systematically considered indicators of food availability, food access, food utilization, and food system stability. Through the use of household surveys, semi-structured interviews, focus groups, and biophysical measurements in fields, I explored the relationships between NTX farming and the four dimensions of food security within the social-ecological context of the community.

I found that food insecurity in Chilascó is largely linked to issues of food access, food utilization, and food system stability. Interestingly, while NTX production is often touted as an opportunity to increase income and food access, the export of vegetables outside of the community seemed to limit access to locally produced vegetables (e.g., broccoli, cauliflower) for adopters and non-adopters alike. Food utilization in the community was negatively affected by poor hygiene, environmental contamination, and intrahousehold factors such as parental neglect. In turn, food system stability was potentially compromised by declines in agricultural ecosystem services such as biological pest control and by degrading soil quality.

More specifically, in comparing the food security status of smallholder households that farm broccoli for export (adopters) with households that farm traditional subsistence crops (non-adopters) using household surveys, I found that adopters earned significantly more income over the previous year compared to non-adopters, a finding in alignment with the rationale being used to expand NTX development across Guatemala and other developing countries. Importantly, however, these income gains did not translate into improvements across the board for food security outcomes for adopter households. The overall evaluation was nuanced by evidence that some food security indicators were improved, others did not differ, and others were even degraded, when evaluated against non-adopter households. Specifically, the production and consumption of corn and bean did not differ between groups (i.e., household food availability) nor did the level of household food insecurity as measured by the Household Food Insecurity Access Scale. In fact, the majority of adopter and non-adopter households alike were categorized as moderately to extremely food insecure according to this perception-level indicator. There were no significant differences in the dietary diversity (i.e., food access) and food consumption scores (i.e., food utilization) between groups. Moreover, adopters applied twice as much manure per hectare, three times more inorganic fertilizer per hectare, and had a higher environmental impact associated with pesticide use. A related question that deserves more attention is whether or not high agrochemical use, cloud forest felling, and the expansion of clubroot across local soils threatens food system stability and long-term food security in Chilascó.

As it stands, sweeping arguments are often made either for or against NTX oriented development. However, my research suggests that these arguments are lacking in necessary nuance. As shown in this thesis, structural changes in social, economic, and ecological systems induced by NTX production do not have a single effect on the well-being and food security of smallholder farmers. While NTX production improved household income in Chilascó, I found no evidence that NTX production led to significant improvements in the food security status of adopters across all four dimensions. Importantly, I also found that intensive NTX production has contributed to local ecological degradation. On the basis of these findings, a word of caution is warranted regarding the potential of NTXs to deliver food security to smallholders over the long-term. My research suggests that the relationship between smallholders, NTX agriculture, and food security is defined by both opportunities and risks, whereby neither can be adequately measured using only a few indicators. Recognizing that food security is not a monolithic condition, but instead is shaped by issues of food availability, access, utilization, and stability, an important avenue of research is therefore to find better ways of assessing these dimensions and potential differences among them.

REFERENCES CITED

Adcock, R., and D. Collier. 2001. Measurement validity: A shared standard for qualitative and quantitative research. The American Political Science Review **95**:529–546.

Alaimo, K., R.R. Briefel, E.A. Frongillo, Jr, and C.M. Olson. 1998. Food insufficiency exists in the United States: results from the third National Health and Nutrition Examination Survey (NHANES III). American Journal of Public Health **88**:419–426.

Albrecht, G., G.M. Sartore, L. Connor, N. Higginbotham, S. Freeman, B. Kelly, H. Stain, A. Tonna, and G. Pollard. 2007. Solastalgia: the distress caused by environmental change. Australasian Psychiatry **15**:S95–S98.

Alcock, R. 2009. Speaking food: A discourse analytic study of food security. Working Paper No. 07-09. School of Sociology, Politics, and International Studies. University of Bristol.

Arbona, S. I. 1998. Commercial agriculture and agrochemicals in Almolongo, Guatemala. Geographical Review **88**:47–63

Bailey, R. 2011. Growing a better future: food justice in a resource-constrained world. Oxfam International, Great Britain.

Barham, B., M. Clark, E. Katz, and R. Schurman. 1992. Nontraditional agricultural exports in Latin America. Latin American Research Review **27**:43–82.

Barham, B., M.R. Carter, and W. Sigelko. 1995. Agro-export production and peasant land access: Examining the dynamic between adoption and accumulation. Journal of Development Economics **46**:85-107.

Barrett, C. B. 2002. Food security and food assistance programs. Handbook of Agricultural Economics **2**:2103–2190.

Barrett, C. 2008. Smallholder market participation: Concepts and evidence from eastern and southern Africa. Food Policy **33**:299–317.

Barrett, C.B. 2010. Measuring food insecurity. Science 327(5967): 825-828.

Beebe, J. 1995. Basic concepts and techniques of rapid appraisal. Human Organization **54**:42-51.

Becquey, E., Y. Martin-Prevel, P. Traissac, B. Dembele, A. Bambara, and F. Delpeuch. 2010. The Household Food Insecurity Access Scale and an Index-Member Dietary Diversity Score Contribute Valid and Complementary Information on Household Food Insecurity in an Urban West-African Setting. Journal of Nutrition **140**:2233–2240.

Bennett, E. M., G.S. Cumming, and G.D. Peterson. 2005. A systems model approach to determining resilience surrogates for case studies. Ecosystems **8**:945–957.

Berkes, F., and C. Folke. 1998. Linking social and ecological systems: Management practices and social mechanism for building resilience. Cambridge University Press.

Bharucha, Z., and J. Pretty. 2010. The roles and values of wild foods in agricultural systems. Philosophical Transactions of the Royal Society B: Biological Sciences **365**:2913–2926.

Bickel, G, M. Norde, et al. 2000. Guide to measuring household food security, US Department of Agriculture, Food and Nutrition Service, Office of Analysis, Nutrition, and Evaluation.

Biggs, R., M. Schlüter, D. Biggs, E. L. Bohensky, S. BurnSilver, G. Cundill, V. Dakos, T. M. Daw, L. S. Evans, K. Kotschy, A. M. Leitch, C. Meek, A. Quinlan, C. Raudsepp-Hearne, M. D. Robards, M. L. Schoon, L. Schultz, and P. C. West. 2012. Toward Principles for Enhancing the Resilience of Ecosystem Services. Annual Review of Environment and Resources **37**:421–448.

Bilinsky, P., and A. Swindale. 2007. Months of adequate household food provisioning (MAHFP) for measurement of household food access: Indicator Guide. Food and Nutrition Technical Assistance Project (FANTA).Washington, D.C., USA.

Birthal, P. S., P. K. Joshi, and A. Gulati. 2005. Vertical coordination in high-value food commodities: Implications for smallholders. IFPRI MTID Discussion Paper No. 85. International Food Policy Research Institute. Washington, D.C., USA.

Bouis, H. E., and L. J. Haddad. 1990. Effects of agricultural commercialization on land tenure, household resource allocation, and nutrition in the Philippines. Research Report no. 79. International Food Policy Research Institute, Washington, D.C.

Bryman, A. 2007. Barriers to Integrating Quantitative and Qualitative Research. Journal of Mixed Methods Research **1**: 8-22.

Burlingame, B. 2000. Wild Nutrition. Journal of Food Composition and Analysis **13**:99-100.

Campbell, C. C. 1991. Food insecurity: A nutritional outcome or a predictor variable? The Journal of Nutrition **121**:408.

Carletto, C., A. de Janvry, and E. Sadoulet. 1999. Sustainability in the diffusion of innovations: Smallholder nontraditional agro- exports in Guatemala. Economic Development and Cultural Change **47**:345–369.

Carletto, C., and T. Kilic. 2009. Non-Traditional Export Crops in Guatemala: Short-Term Tool or Long-Term Strategy for Poverty Alleviation? 111th Seminar.

Carletto, C., A. Kirk, and P. Winters. 2010. Globalization and smallholders: The adoption, diffusion, and welfare impact of non-traditional export crops in Guatemala. World Development **38**:814-827.

Carletto, C., T. Kilic, and A. Kirk. 2011.Nontraditional crops, traditional constraints: The long-term welfare impacts of export crop adoption among Guatemalan smallholders. Agricultural Economics **42**:61–76.

Carlson, S.J., M.S. Andrews, et al. 1999. Measuring food insecurity and hunger in the United States: Development of a national benchmark measure and prevalence estimates. The Journal of Nutrition **129**:510S.

Carpenter, Steve, B. Walker, J. M. Anderies, and N. Abel. 2001. From metaphor to measurement: Resilience of what to what? Ecosystems **4**:765–781.

Carter, M., and B. Barham. 1996. Agricultural export booms and the rural poor in Chile, Guatemala, and Paraguay. Latin American Research Review **31**:33-65.

Covarrubias, K., A.P. de la O Campos, and A. Zezza. 2009. Accounting for the diversity of rural income sources in developing countries: The experience of the rural income generating activities project. Food and Agriculture Organization, Rome, Italy.

Cassman, K., A. Dobermann, and D. T. Walters. 2002. Agroecosystems, nitrogen-use efficiency, and nitrogen management. AMBIO: A Journal of the Human Environment **31**:132-140.

Chee, Y. E. 2004. An ecological perspective on the valuation of ecosystem services. Biological conservation **120**:549–565.

Chung, K., L. Haddad, J. Ramakrishna, and F. Riely. 1997. Alternative approaches to locating the food insecure: Qualitative and quantitative evidence from South India. International Food Policy Research Institute-FCND.

Coates, J., P.Webb and R. Houser. 2003. Measuring Food Insecurity: Going Beyond Indicators of Income and Anthropometry. Washington, D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development.

Coates, J., E. A. Frongillo, B. L. Rogers, P. Webb, P. E. Wilde, and R. Houser. 2006. Commonalities in the experience of household food insecurity across cultures: what are measures missing? Journal of Nutrition **136**:1438S – 1448S.

Coates, J. A., A. Swindale, and P. Bilinsky. 2007. Household Food Insecurity Access

Scale (HFIAS) for measurement of food access: Indicator guide version 3. Food and Nutrition Technical Assistance Project (FANTA). Washington, D.C., USA.
Coates, J. C., P. Webb, R. F. Houser, B. L. Rogers, and P. Wilde. 2010. "He said, she said": who should speak for households about experiences of food insecurity in Bangladesh? Food Security **2**:81–95.
Collier, P. 2002. The future of perennial crops. African Development Review **14**:237-250.
Conroy, M., D.L. Murray and P.M. 1996 A cautionary tale. Failed U.S. development policy in Central America. Boulder: Lynne Reinner Publisher.
Conway, G. R. 1987. The properties of agroecosystems. Agricultural systems **24**:95–117.
Coolican, H. 1994. Research methods and statistics in psychology. 2nd Edition. Hodder & Stoughton, London.
Corbett, J. 1988. Famine and household coping strategies. World Development **16**:1099-1112.
de Haen, H., S. Klasen, and M. Qaim. 2011. What do we really know? Metrics for food insecurity and undernutrition. Food Policy **36**, 760–769.
Dawson, T., M. Rounsevell, T. Kluvánková-Oravská, V. Chobotová, and A. Stirling. 2010. Dynamic properties of complex adaptive ecosystems: implications for the sustainability of service provision. Biodiversity and Conservation **19**:2843-2853.
de Janvry, A., and E. Sadoulet. 2010. The global food crisis and Guatemala: What crisis and for whom? World Development **38**:1328-1339.
de Pineres, A. Gutierrez, and M. Ferrantino. 1997. Export diversification and structural dynamics in the growth process: the case of Chile. Journal of Development Economics **52**:375-391.
Deitchler, M., T. Ballard, A. Swindale, and J. Coates. 2010. Validation of a measure of household hunger for cross-cultural use. Food and Nutrition Technical Assistance II Project (FANTA-II). Washington, D.C., USA.
Deitchler, M., T. Ballard, A. Swindale, and J. Coates. 2011. Introducing a Simple Measure of Household Hunger for Cross-Cultural Use. Technical Note #12:1–16. Food and Nutrition Technical Assistance II Project (FANTA-II). Washington, D.C., USA.
Delang, C.O. 2006. Not just minor forest products: The economic rationale for the consumption of wild food plants by subsistence farmers. Ecological Economics **59**:64-73.
DeWalt, B., and D. Barking. 1991. Mexico's two green revolutions: Feed for food. Pages 12-39 in D.E. McMillan, editor. Anthropology and Food Policy: Human dimensions of food policy in Africa and Latin America. The University of Georgia Press for the Southern Anthropological Society, London.
Demoussis, M., and V. Mihalopoulos. 2001. Adult equivalent scales revisited. Journal of Agricultural and Applied Economics **33**:135–146.
Dewey, K. 1979. Agricultural development, diet, and nutrition. Ecology of Food and Nutrition **8**:265-273.
Dewey, K. G. 1981. Nutritional consequences of the transformation from subsistence to commercial agriculture in Tabasco, Mexico. Human Ecology **9**:151-187.
Dilley, M., and T.E. Boudreau. 2001. Coming to terms with vulnerability: a critique of the food security definition. Food Policy **26**: 229-247.
Dix, A. M. 1997. The biology and ecology of broccoli white grubs (Coleoptera scarabaeidae) in the community of Chilascó, Baja Verapaz, Guatemala: An integrated approach to pest management. Unpublished doctoral dissertation, University of Georgia, Athens.
Dixon, G. R. 2009a. The occurrence and economic impact of Plasmodiophora brassicae

and clubroot disease. Journal of Plant Growth Regulation **28**:194–202.

Dixon, G. R. 2009b. Plasmodiophora brassicae in its environment. Journal of Plant Growth Regulation **28**:212–228.

Donald, C., and I. Porter. 2009. Integrated control of clubroot. Journal of Plant Growth Regulation **28**:289–303.

Ericksen, P. 2008. Conceptualizing food systems for global environmental change research. Global Environmental Change **18**:234-245.

Falkingham, J., and C. Namazie. 2002. Measuring health and poverty: a review of approaches to identifying the poor. DFID Health Systems Resource Center.

FAO (Food and Agriculture Organization of the United Nations). 1996. Rome Declaration on World Food Security and World Food Summit Plan of Action. Rome.

FAO (Food and Agriculture Organization of the United Nations). 2002. Measurement and assessment of food deprivation and undernutrition. Summary of Proceedings. International Scientific Symposium "Measurement and assessment of food deprivation and undernutrition", Rome.

FAO (Food and Agriculture Organization of the United Nations). 2005. State of Food Insecurity in The World – Eradicating World Hunger – Key to Achieving the Millennium Development Goals, Rome.

FAO (Food and Agriculture Organization of the United Nations). 2006. Policy Brief: Food Security. Issue 2. Available at: ftp://ftp.fao.org/es/esa/policybriefs/pb_02.pdf. Last accessed: August 10, 2012.

FAO (Food and Agriculture Organization of the United Nations). 2008. An introduction to the basic concepts of food security. Food Security Information for Action - Practical Guides. Available at: http://www.fao.org/docrep/013/al936e/al936e00.pdf. Last accessed: April 27, 2013.

FAO (Food and Agriculture Organization of the United Nations. 2009. Resilience of rural communities to climatic accidents – a need to scale up socio-environmental safety nets (Madagascar, Haiti): Policy Brief EASYPol: Food and Agriculture Organization (online). www.fao.org/easypol.

FAO, WFP and IFAD. 2012. The State of Food Insecurity in the World 2012. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome, FAO.

Fernández-Rivera, R. d. J. 2007. Manejo del cultivo de broccoli (Brassica oleracea Var. Italica) en la empresa Alimentos Congelados, S.A. (ALCOSA) en el departamento Jalapa, Guatemala de agosto de 2004 a mayo de 2005. Graduate dissertation, Universidad de San Carlos de Guatemala, Facultad de Agronomía.

Fischer, E. F., and P. Benson. 2006. Broccoli and desire: Global connections and Maya struggles in postwar Guatemala. Stanford University Press, Stanford, California, USA.

Fleuret, P., and A. Fleuret. 1980. Nutrition, consumption and agricultural change. Human Organization **39**:250-260.

Flyvbjerg, B. 2006. Five misunderstandings about case-study research. Qualitative inquiry **12**:219-245.

Foley, J. A., N. Ramankutty, K. A. Brauman, E. S. Cassidy, J. S. Gerber, M. Johnston, N. D. Mueller, et al. 2011. Solutions for a cultivated planet. Nature **478**:337–342.

Frankfort-Nachmias, C., and D. Nachmias. 2007. Research Methods in the Social Sciences, 7th edition. Worth Publishers.

Fuentes López, M., J. van Etten, A. Ortega Aparicio, and J. Vivero Pol. 2005. Maíz para Guatemala: Propuesta para la reactivación de la cadena agroalimentaria del maíz blanco y Amarillo. Food and Agriculture Organization of the United Nations. Guatemala, Guatemala.

Gentilini, U., and P. Webb. 2008. How are we doing on poverty and hunger reduction? A new measure of country performance. Food Policy **33**:521–532.
Gerster-Bentaya, M. 2009a. Instruments for the assessment and analysis of the food and nutrition security situation at macro level, in K. Klennert (ed.), Achieving Food and Nutrition Security: actions to meet the global challenge – A training course reader (3rd Edition), Inwent, Bonn.
Gerster-Bentaya, M. 2009b. Instruments for the assessment and analysis of the food and nutrition security situation at micro and meso level, in K. Klennert (ed.), Achieving Food and Nutrition Security: actions to meet the global challenge – A training course reader (3rd Edition), Inwent, Bonn.
Gittelsohn, J., S. Mookherji and G. Pelto, 1998. Operationalising Household Food Security in Rural Nepal. WIDER, Mimeo.
Goldin, L. 1996. Economic mobility strategies among Guatemalan peasants: prospects and limits of nontraditional vegetable cash crops. Human Organization **55**:99-107.
Goldín, L. R., and L. Asturias de Barrios. 2001. Perceptions of the economy in the context of non-traditional agricultural exports in the Central Highlands of Guatemala. Culture & Agriculture **23**:19-31.
Govereh, J., and T. Jayne. 2003. Cash cropping and food crop productivity: synergies or trade-offs? Agricultural Economics **28**:39–50.
Haddad, L., J. Sullivan, and E. Kennedy. 1992. Identification and evaluation of alternative indicators of food and nutrition security: some conceptual issues and an analysis of extant data. Food and Nutrition Monitoring Project. International Food Policy Research Institute, Washington, DC.
Hallam, D., P. Liu, G. Lavers, P. Pilkauskas, G. Rapsomanikis, and J. Claro. 2004. The market for non-traditional agricultural exports. Commodities and Trade Technical Paper. Food and Agriculture Organization of the United Nations.
Hamilton, S., and E. Fisher. 2003. Non-traditional agricultural exports in highland Guatemala: Understandings of risk and perceptions of change. Latin American Research Review **38**:82-110.
Hoddinott, J. 2002. Measuring dietary diversity: A guide. Food and Technical Assistance Project (FANTA), Washington, DC.
Hoddinott, J., and Y. Yohannes. 2002. Dietary diversity as a household food security indicator. Food and Nutrition Technical Assistance Project (FANTA). Washington D.C., USA.
Holder, C. D. 2006. The hydrological significance of cloud forests in the Sierra de las Minas Biosphere Reserve, Guatemala. Geoforum **37**:82-93.
Holling, C. S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics **4**:1–23.
Immink, M., and J. Alarcon. 1991. Household food security, nutrition and crop diversification among smallholder farmers in the highlands of Guatemala. Ecology of Food and Nutrition **25**:287-305.
Immink, M., and J. Alarcon. 1993. Household income, food availability, and commercial crop production by smallholder farmers in the western highlands of Guatemala. Economic Development and Cultural Change **41**:319–342.
Immink, M., E. Kennedy, and R. Sibrian, R. 1995. Export vegetable crops and poverty alleviation for smallholder farm households: A case study from Guatemala. A Paper presented at the Workshop on Poverty alleviation through international trade. UNCTAD, Santiago, Chile, 10– 13 January.
IFAD (International Fund for Agricultural Development). 2011. Viewpoint: Smallholders can feed the world. Rome, Italy.
ILRI (International Livestock Research Institute). 1995. *Livestock Policy Analysis.* ILRI

Training Manual 2. Module 3.5.1. Computation equations for consumption, net income and cash income. ILRI, Nairobi, Kenya. pp. 264. Available at http://www.fao.org/wairdocs/ilri/x5547e/x5547e0q.htm#3.5.1 computation equations for consumption, net income and cash income. Last accessed: June 13, 2013.

INCAP (Instituto de Nutrición de Centro América y Panamá). 2006. La canasta básica de alimentos en Centroamérica. Revisión de la metodología. Publicación INCAP ME/105.

INE (Instituto Nacional de Estadística). 2009. National Maternal and Child Health Survey (ENSMI). Guatemala City, Guatemala.

INE (Instituto Nacional de Estadística). 2011. Encuesta Nacional de Condiciones de Vida 2011 (ENCOVI 2011). Guatemala City, Guatemala.

Ingram, J. 2011. A food systems approach to researching food security and its interactions with global environmental change. Food Security **3**:417–431.

Johnson, R.K. 2002. Dietary Intake – How do we measure what people are really eating. Obesity **10**:63S-68S.

Katz, E.G. 1994. The impact of non-traditional agriculture on food expenditures and consumption in the Guatemalan Central Highlands: An intra-household per- spective. Food and Nutrition Bulletin **15**, No. 4.

Katz, E.G. 1995. Gender and trade within the household: observations from rural Guatemala. World Development **23**:327-342.

Kennedy, E. T., and B. Cogill. 1987. Income and nutritional effects of the commercialization of agriculture in Southwestern Kenya. Research Report no. 63. International Food Policy Research Institute. Washington, D.C.

Kennedy, G., A. Berardo, C. Papavero, P. Horjus, T. Ballard, M. Dop, J. Delbaere, J., et al. 2010. Proxy measures of household food consumption for food security assessment and surveillance: Comparison of the household dietary diversity and food consumption scores. Public Health Nutrition **13**:2010–2018.

Kothari, M., and N. Abderrahim. 2010. Nutrition Update 2010. United States Agency for International Development (USAID): ICF Macro. Calverton, Maryland, USA.

Kovach, J., C. Petzoldt, J. Degni, and J. Tette. 1992. A method to measure the environmental impact of pesticides. New York Agricultural Experiment Station, Geneva, New York's Food and Life Sciences Bulletin 139. Cornell University, Ithaca, NY.

Kromann, P., W. Pradel, D. Cole, A. Taipe, and G. A. Forbes. 2011. Use of the Environmental Impact Quotient to estimate health and environmental impacts of pesticide usage in Peruvian and Ecuadorian potato production. Journal of Environmental Protection **2**:581–591.

Kumar, M., and P. Kumar. 2008. Valuation of the ecosystem services: A psycho-cultural perspective. Ecological Economics **64**:808–819.

Levitan, L., I. Merwin, and J. Kovach. 1995. Assessing the relative environmental impacts of agricultural pesticides: the quest for a holistic method. Agriculture, Ecosystems & Environment **55**:153–168.

Little, P.D. 1994. Contract farming and the development question. In: Living Under Contract. Eds: Peter D. Little and Michael J. Watts. Madison, University of Wisconsin Press.

Longhurst, Richard. 1988. Cash crops, household food security and nutrition. IDS Bulletin **19**:28-36.

Maire, B., and F. Delpeuch. 2005. Nutrition indicators for development. Food and Nutrition Division. Food and Agriculture Organization of the United Nations.

Mannon, S. E. 2005. Risk takers, risk makers: Small farmers and non-traditional agro-exports in Kenya and Costa Rica. Human Organization **64**:16–27.

Martínez-Alier, J., G. Munda, and J. O'Neill. 1998. Weak comparability of values as a foundation for ecological economics. Ecological Economics **26**:277–286.
Max-Neef, M. 1992. Development and human needs. Pages 197-214 in P. Ekins and M. Max-Neef, editors. Real-life economics: Understanding wealth creation. Routledge, London.
Maxwell, S., and T. Frankenberger. 1992. Household food security: Concepts, indicators, measurements. Edited by S. Maxwell and T. Frankenberger. Rome and New York: IFAD and UNICEF.
Maxwell, D.G. 1996a. Measuring food insecurity: the frequency and severity of “coping strategies." Food Policy **21**: 291-303.
Maxwell, S. 1996b. Food security: a post-modern perspective. Food Policy **21**:155-170.
Maxwell, S., and M. Smith. 1992. Part 1 Household food security: A conceptual review. Pages 1-72 in Household food security: Concepts, indicators, and measurements. A Technical Review. UNICEF/IFAD.
Maxwell, D., and R. Caldwell. 2008. The Coping Strategies Index: A tool for rapid measurement of household food security and the impact of food aid programs in humanitarian emergencies. Field Methods Manual, 2nd edition.
McKay, A. 2000. Should the Survey Measure Total Household Income? in: Designing Household Survey Questionnaires for Developing Countries: Lessons from Fifteen Years of Living Standard Measurement Study, Grosh, M., & Glewwe, P. (Eds.), The World Bank, 83- 104.
Migotto, M., B. David, G. Carletto, and K. Beegle. 2005. Measuring Food Security Using Respondents' Perception of Food Consumption Adequacy. ESA Working Paper No. 05-10, 1–40.
Mikkelsen, R. 2011. Math anxiety: Fertilizer calculations. International Plant Nutrition Institute. Reference 10143.
Miles, M.B., and A.M. Huberman. 1994. An Expanded sourcebook: qualitative data analysis. Second Edition. Sage Publications. Thousand Oaks, USA.
Millennium Ecosystem Assessment (MA). 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.
Misselhorn, A., P. Aggarwal, P. Ericksen, P. Gregory, L. Horn-Phathanothai, J. Ingram, and K. Wiebe. 2012. A vision for attaining food security. Current Opinion in Environmental Sustainability **4**:7–17.
Morales, H., and I. Perfecto. 2000. Traditional knowledge and pest management in the Guatemalan highlands. Agriculture and Human Values **17**:49-63.
Morse, J. 1991. Qualitative nursing research: A free for all? In J. Morse (Ed.), *Qualitative nursing research: A contemporary dialogue* (2nd ed., pp. 14-22). Newbury Park, CA: Sage.
Mortimore, M. 1989. Adapting to drought: famines, farmers and desertification in west Africa. Cambridge: Cambridge University Press.
Morvaridi, B. 1995. Contract farming and environmental risk: The case of Cyprus. Journal of Peasant Studies **23**:30–45.
Munda, G. 1993. Multiple criteria decision aid: some epistemological considerations. Journal of Multi-Criteria Decision Analysis **2**:41-55.
Munda, G., P. Nijkamp, and P. Rietveld. 1994. Qualitative multicriteria evaluation for environmental management. Ecological Economics **10**:97–112.
Murray, D., and P. Hoppin. 1990. Pesticides and nontraditional agriculture: A coming crisis for U.S. development policy in Latin America? Austin: Institute of Latin American Studies, University of Texas, Austin.
Murray, D. L., and P. Hoppin. 1992. Recurring contradictions in agrarian development: Pesticide problems in Caribbean Basin nontraditional agriculture. World

Development **20**:597–608.
Nájera Juárez, H.A. 2010. Plasmodiophora brassicae: Enfermedad denominada hernia o nudo de la raíz de las crucíferas. Graduate dissertation, Universidad Rafael Landívar, Facultad de Agronomia.
Naylor, R., and P. Ehrlich. 1997. The value of natural pest control services in agriculture. Pages 151-174 in G. Daily, editor. Nature's services: societal dependence on natural ecosystems. Island Press, Washington, D.C.
Nellemann, C., M. MacDevette, T. Manders, B. Eickhout, B. Svihus, A. G. Prins, and B. P. Kaltenborn, editors. 2009. The environmental food crisis – The environment's role in averting future food crises. A UNEP rapid response assessment. United Nations Environment Programme. Birkeland Trykkeri AS, Norway.
Nissanke, M., and E. Thorbecke. 2007. The impact of globalization on the world's poor: Transmission mechanisms. Basingstoke: Palgrave Macmillan for UNU-WIDER.
Norgaard, R. B. 1989. The case for methodological pluralism. Ecological Economics **1**:37–57.
Opondo, M. M. 2000. The Socio-economic and Ecological Impacts of the Agro-industrial Food Chain on the Rural Economy in Kenya. AMBIO: A Journal of the Human Environment **29**:35–41.
Pangaribowo, E.H., N. Gerber, and M. Torero. 2013. Food and nutrition security indicators: A review. Working paper 108. Center for Development Research, University of Bonn.
Payne, P. 1990. Measuring malnutrition. IDS bulletin **21**: 14-30.
Pelto, G. H., and J.R. Backstrand. 2003. Interrelationships between power-related and belief-related factors determine nutrition in populations. Journal of Nutrition **133**: 297–300.
Pelto, G. and H. C. Freake. 2003. Social Research in an Integrated Science of Nutrition: Future Directions." Journal of Nutrition **133**:1231-34.
Perez-Escamilla, R., and A. Segall-Correa. 2008. Food insecurity measurement and indicators. Revista de Nutricion Campinas **21**:15s-26s.
Pingali, P. L. 1997. From subsistence to commercial production systems: The transformation of Asian agriculture. American Journal of Agricultural Economics **79**:628–634.
Pingali, P., L. Alinovi, and J. Sutton. 2005. Food security in complex emergencies: enhancing food system resilience. Disasters **29**:S5–24.
Pinstrup-Anderson, P. 1983. Export crop production and malnutrition. Occasional Paper Series. Volume 2, No. 10. Chapel Hill, N.C. University of North Carolina.
Pinstrup-Andersen, P. 2009. Food security: definition and measurement. Food Security **1**:5-7.
Pomareda, C. 2008. Política comercial y seguridad alimentaria en Centroamerica: opciones e implicaciones. Banco Interamericano de Desarrollo. Diálogo Regional de Política. Washington, D.C., USA.
Pottier, J. 1999. Anthropology of food: The social dynamics of food security. Blackwell Publishers Inc., USA.
Power, A. G. 2010. Ecosystem services and agriculture: tradeoffs and synergies. Philosophical Transactions of the Royal Society B: Biological Sciences **365**:2959–2971.
Powlson, D. S., P. J. Gregory, W. R. Whalley, J. N. Quinton, D. W. Hopkins, A. P. Whitmore, P. R. Hirsch, and K. W. T. Goulding. 2011. Soil management in relation to sustainable agriculture and ecosystem services. Food Policy **36**:S72–S87.
Radimer, K.L., C.M. Olson, et al. 1990. Development of indicators to assess hunger. The Journal of Nutrition **120**:1544.

Radimer, K.L., C.M. Olson, et al. 1992. Understanding hunger and developing indicators to assess it in women and children. Journal of Nutrition Education 24:36S-44S.
Raudsepp-Hearne, C., G. D. Peterson, M. Tengö, E. M. Bennett, T. Holland, K. Benessaiah, G.K. Macdonald, et al. 2010. Untangling the Environmentalist's Paradox: Why Is Human Well-being Increasing as Ecosystem Services Degrade? BioScience **60**:576–589.
Ravallion, M., S. Chen, and P. Sangraula. 2008. Dollar a day revisited. World Bank Economic Review **23**:163-184.
Raynolds, L., D. Myhre, P. McMichael, V. Carro-Figueroa, and F. Buttel. 1993. The“ new” internationalization of agriculture: A reformulation. World Development **21**:1101–1121.
Renzaho, A., and D. Mellor. 2010. Food security measurement in cultural pluralism: Missing the point or conceptual misunderstanding? Nutrition **26**:1-9.
Riely, F. N. Mock, B. Cogill, L. Bailey, and E. Kenefick. 1999. Food security indicators and framework for use in the monitoring and evaluation of food aid programs. Food and Nutrition Technical Assistance Project (FANTA). Washington D.C., USA.
Rose, D. 1999. Economic determinants and dietary consequences of food insecurity in the United States. The Journal of Nutrition **129**:517S–520S.
Ruel, M. T. 2002. Is dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs. IFPRI Discussion Paper 140. Food Consumption and Nutrition Division of the International Food Policy Research Institute. Washington, D.C., USA.
Ruel, M.T. 2003. Is dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs. Food Nutrition Bulletin **24**: 231-232.
Sandhu, H., S. Wratten, and R. Cullen. 2010. The role of supporting ecosystem services in conventional and organic arable farmland. Ecological Complexity 7:302-310.
Sartore, G. M., B. Kelly, H. Stain, G. Albrecht, and N. Higginbotham. 2008. Control, uncertainty, and expectations for the future: a qualitative study of the impact of drought on a rural Australian community. Rural and Remote Health **8**:950.
Schuftan, C. 1998. Malnutrition and income: Are we being misled? (A dissenting view with a confusing literature). Ecol. Of food and Nutrition **37**(2).
Schultink, G. 2000. Critical environmental indicators: performance indices and assessment models for sustainable rural development planning. Ecological modelling, **130**: 47–58.
Sen, A. 1981. Poverty and Famines: An essay on entitlement and deprivation. Clarendon Press, Oxford.
Sen, A. 2000. A Decade of Human Development. Journal of Human Development **1**:17–23. doi:
Sharpe, B. 1990. Nutrition and the commercialization of agriculture in Northern Province. Pages 583-602 in A. P. Wood, S. A. Kean, J. T. Milimo, and D. M. Warren, editors. The dynamics of agricultural policy reform in Zambia. Ames, Iowa State University, USA.
Sillers, D. 2006. National and International Poverty Lines: An Overview. U.S. Agency for International Development. Available at: http://www.povertytools.org/project.html#ConstructingPovertyLines. Last accessed: March 16, 2013.
Singh, B. P. 2002. Nontraditional crop production in Africa for export. In: Janick, J, and A. Whipkey, editors. Trends in new crops and new uses: 86–92. ASHS Press Alexandria, VA.
Smith, L.C., and A. Subandoro. 2007. Measuring Food Security Using Household

Expenditure Surveys. Food Security in Practice technical guide series. Washington, D.C.: International Food Policy Research Institute.
Sokal, R.R., and F. J. Rohlf. 1969. Biometry: the principles and practice of statistics in biological research. W.H. Freeman and Company, San Francisco.
Stamoulis, K. G., and A. Zezza. 2003. A conceptual framework for national agricultural, rural development, and food security strategies and policies. Food and Agriculture Organization of the United Nations. Agricultural and Development Economics Division.
Stanley, D.L., and S. Bunnag. 2001. A new look at the benefits of diversification: lessons from Central America. Applied Economics **33**: 1369-1383.
Storey, D., and W. E. Murray. 2001. Dilemmas of development in Oceania: the political economy of the Tongan agro- export sector. The Geographical Journal **167**:291–304.
Swift, M.J., and C.A. Palm. 2000. Soil fertility as an ecosystem concept: A paradigm lost or regained? In: Accomplishments and changing paradigm towards the 21st Century. Proceedings of the 17th world congress of soil science, Bangkok, Thailand
Swift, J., and K. Hamilton. 2001. Household food and livelihood security. In Devereux, S., and S. Maxwell, editors. Food Security in Sub-Saharan Africa. ITDG, London, UK.
Swindale, A., and P. Bilinsky. 2006. Household Dietary Diversity Score (HDDS) for measurement of household food access: Indicator guide, Version 2. Food and Nutrition Technical Assistance Project (FANTA). Washington D.C., USA.
Tarasuk. V. 2001. Discussion paper on household and individual food security. Health Canada, Branch Office of Nutrition Policy and Promotion, Government of Canada.
Tashakkori, A., and J.W. Creswell. 2007. The new era of mixed methods. Journal of Mixed Methods Research **1**:1-3.
Taylor, M.P. 2003. Purchasing power parity. Review of International Economics **11**:436-452.
Thurmond, V.A. 2004. The point of triangulation. Journal of Nursing Scholarship **33**:253-258.
Thrupp, L.A. 1995. *Bittersweet Harvests for Global Supermarkets: Challenges in Latin America's Agricultural Export Boom*. Washington, DC: World Resources Institute.
Thrupp, L. A. 2000. Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture. International affairs **76**:265–281.
Timmer, C.P. 1988. The agricultural transformation. In: Chenery, H.B., and T. N. Srinivasan, editors. Handbook of development economics, vol. 1. North Holland, Amsterdam.
Timmer, C. P. 1997. Farmers and markets: the political economy of new paradigms. American Journal of Agricultural Economics **79**:621–627.
Timmer, C. 2000. The macro dimensions of food security: economic growth, equitable distribution, and food price stability. Food Policy **25**:283–295.
UN (United Nations). 1975. Report of the World Food Conference, New York.
Vatn, A. 2000. The environment as a commodity. Environmental Values **9**:493–509.
von Braun, J., and E. Kennedy. 1986. Commercialization of subsistence agriculture: Income and nutritional effects in developing countries. Working Papers on Commercialization of Agriculture and Nutrition 1. International Food Policy Research Institute. Washington, D.C., USA.
von Braun, J., D. Hotchkiss, and M. Immink. 1989a. Nontraditional export crops in Guatemala: Effects on production, income, and nutrition. Research Report 73. International Food Policy Research Institute. Library of Congress Catalogue, Washington D.C., USA.
von Braun, J., D. Puetz, and P. Webb. 1989b. Irrigation technology and

commercialization of rice in the Gambia: Effects on income and nutrition. Research Report no 75. International Food Policy Research Institute. Washington, D.C.
Watts, M.J., and H.G. Bohle. 1993. The space of vulnerability: the causal structure of hunger and famine. Progress in Human Geography **17**:43-67.
Watson, C.A., D. Atkinson, P. Goslin, L.R. Jackson, and F.W. Rayns. 2002. Managing soil fertility in organic farming systems. Soil Use and Management **18**:239-247.
Webb, P., J. Coates, and R. Houser. 2002. Allocative responses to scarcity: Self- reported assessments of hunger compared with conventional measures of poverty and malnutrition in Bangladesh. Boston: Tufts University Friedman School of Nutrition Science and Policy.
Webb, P., J. Coates, E.A., Frongillo, B. L. Rogers, A. Swindale, and P. Bilinsky. 2006. Measuring household food insecurity: why it's so important and yet so difficult to do. The Journal of Nutrition 1404S-1408S.
Weingärtner, L. 2010. The concept of food and nutrition security, in K. Klennert (ed.), *Achieving Food and Nutrition Security: actions to meet the global challenge – A training course reader (3rd Edition)*, Inwent, Bonn.
Whittemore, R., S.K. Chase and C.L. Mandle. 2001. Validity in qualitative research. Qualitative Health Research **11**: 522-537.
Wiesmann, D., L. Bassett, T. Benson, and J. Hoddinott. 2009. Validation of food frequency and dietary diversity as proxy indicators of household food security. International Food Policy Research Institute (IFPRI). Rome, Italy.
Wolfe, W. S., and E.A. Frongillo. 2001. Building household food-security measurement tools from the ground up. Food & Nutrition Bulletin, **22**:5–12. Nevin Scrimshaw International Nutrition Foundation.
Wood, S., P. Ericksen, B. Stewart, P. Thornton, and M. Anderson. 2010. Lessons learned from international assessments. Pages 46-62 *in* J. Ingram, P. Ericksen, and D. Liverman, editors. Food security and global environmental change. Earthscan, Washington, DC, USA.
World Bank. 2009. Guatemala poverty assessment: Good performance at low levels. Report No.43920-GT. Central America Department.
World Bank. 2013. PPP conversion factor, private consumption (LCU per international dollar). Data retrieved March 16, 2013, from World Bank DataBank database: http://data.worldbank.org/indicator/PA.NUS.PRVT.PP?page=1
World Food Programme (WFP). 2008. Food consumption analysis: Calculation and use of the food consumption score in food security analysis. United Nations: Vulnerability Analysis and Mapping Branch. Rome, Italy.
World Food Programme (WFP). 2009. Comprehensive Food Security and Vulnerability Analysis Guidelines. Chapter 5. Food Security Analysis Service, Rome, Italy.
World Food Programme (WFP). 2011. Guatemala: Overview. Last accessed: June 17, 2013. Available at: http://www.wfp.org/countries/guatemala/overview
Yin, R.K. 2009. Case Study Research: Design and Methods. Thousand Oaks, SAGE Publications Inc.
Young, H. 2001. Nutrition and intervention strategies. In: Devereux, S., and S. Maxwell, editors. Food Security in Sub-Saharan Africa. ITDG, London.
Zhang, W., T. Ricketts, C. Kremen, and K. Carney. 2007. Ecosystem services and dis-services to agriculture. Ecological Economics **64**:253-260.

APPENDICES

APPENDIX A. HOUSEHOLD FOOD SECURITY SURVEY

I. GENERAL HOUSEHOLD INFORMATION

HOUSEHOLD COMPOSITION AND EDUCATION

1. Name of the household head who eates and sleeps regularly in this household			
2. Please specify the names, ages, and sexes of all people who eat and sleep regularly in this household.			
3. What level of studies have you completed (...)? 1) None 2) Primary (Grade 1 -3) 3) Primary (Grade 4- 6) 4) Basico 5) Diversificado –incomplete 6) Diversificado – complete 7) Superior – incomplete 8) Superior - complete			
4. Can you read and write? 1) Yes 2) A Little 3) No			
5. Have you worked in agricultural parcels for the benefit of the household in the past 12 months? 0) No 1) Yes			

HOUSEHOLD AND LAND TENURE

6. The home where you live is (…): 1) Owned by the household and completely paid off 2) Owned by the household but with regular payments→ 1B 3) Inherited or gifted 4) Loaned or borrowed 5)Rented → 1B 6)Other	
7. How much do you pay per month in rent? (quetzales)	
8. How long have you lived in the community? (year of the arival)	
9. Is there someone from this household who works agricultural lands for household production? 0) No 1) Yes	
10. Who is the most informed person about agricultural activities on the part of the household? (name)	
11. Are you the person most aware of household agricultural activities? 0) No 1) Yes	
12. How much agricultural land does the household currently possess or rent? (manzanas)	
13. The terrain where you farm is (…): Please specify from largest to smallest land area 1)Your own 2)Rent 3)Communal 4)Private 5)The state's 6)Municipal	
14. What type of document credits the possession of this land? 1)Receipt 2)Public deed 3)Registered deed 4)Municipal certificate 5)Communal property title 6)Other, specify? 7)No document	

HOUSEHOLD MATERIALS, WATER, AND ENERGY

15. What are the exterior walls of the house primarily made of? 1)Blocks 2)Concrete 3)Wood 4)Bajareque 5)Metal lamina 6)Other, what?	
16. What material is the roof primarily made of? 1)Metal lamina 2)Tiles 3)Cement 4)Palms or plants 5)Other, what?	
17. What material is the interior floor made of? 1)Cement or mud brick 2)Cement 3)Bare ground, dirt 4)Ceramic 5)Wood 6)Other, what?	
18. What type of stove do you have? 1)Improved stove 2)Ground fire 3)Polleton 4)Propane stove 5)Kerosene stove	

19. What type of sanitation system do you have? 1)Toilet connected to drainage network 2)Latrine or open well 3)Washable toilet 4)None 5)Other, what?				
20. Is the household connected to: [a] a water distribution system [b]a water drainage system [c] an electricity system 0)no 1)yes				
21. Where do you obtain the majority of your drinking water? 1)Purchase (containers) 2)Pipe inside the house 3)Pipe outside the house, but on the property 4)A communal pipe 5)River, spring 6)Well public or private 7)Water tanker 8)Rainwater 9)Other, what?				
22. Where do you obtain the majority of the water for household use? 1)Pipe inside home 2)Pipe outside, but in yard 3)Pipe from public area (communal) 4)River, spring 5)Public or private, well 6)Tanker 7)Rainwater 8)Other, what?				
22b. How far is the site where you collect water from the household? How long does it take to walk there? (meter/minute)				
23. Do you treat water before you drink it? If so, how? 1)No, none 2)Yes, boil. 3)Yes, filter. 4)Yes, chlorinate. 5)Yes, sodis 6)Other, what?				
24. In the last month, has the household used firewood or sticks for cooking or other uses? 0)no 1)yes				
25. Does the household collect firewood? 0)no 1)yes				
25b. How far is the site where you collect firewood most frequently (from the household)? How long does it take to walk there? (meter/minute)				
26. In the last 5 years, the distance between the house and the site for firewood collection has? 1) Remained the same 2) Increased a Little 3) Decreased a Little 4) Increased a lot 5) Decreased a lot 6) Not sure				
27. How did the household obtain firewood in the past month? 1) Purchased 2)Collected 3)Gifted/Given 6)Other, what?				

II. EMPLOYMENT, ASSETS, AND INCOME

1. What is the principal occupation of men in this household? 1. Farmer 2. Rancher 3. Labourer 4. Independent 5. Carpenter 6. Marchant/sales 7. Mason 8. Teacher 9. Other?				
2. What is the principal occupation of women in this family? 1. Housewife 2. Merchant 3. Farmer 4. Labourer 5. Teacher 6. Domestic worker 7. Other?				
3. How many household members earn money?				
4. In the last 12 months, how has the household obtained the majority of its money?				
4b. Over the last 12 months, what has been the second most important source of money for the household? See Codes 1-19.				
5.These sources of income are: 1. Stable throughout the year 2. Seasonal 3. Other, what?				
6. Has a member of the household received pay for work during the last 30 days? 0. No 1. Yes				
Name	**# Days worked in the last month**	**Daily salary (quetzales)**	**Total (calculated)**	
LOANS				

7a. Does the household currently have a debt to pay from a loan? 0. No 1. Yes	
7b. Who made the loan?	
7c. What was the total amount of the loan?	
7d. How much does the household pay each month to pay off the loan?	

ASSETS
8. Do you currently possess one of the following items in your household? **0. NO 1. YES**

a. Refrigerator		c. Television		e. Radio		g. Cellphone	
b. Bicycle		d. Motorcycle		f. Automobile		h. Fumigator sprayer	

OTHER SOURCES OF MONTHLY INCOME. 9. How much did the family earn from these sources in the last month?

A. Family remittances		E. Sale of prepared food in an eatery		H. Sale of vegetables/crops from a family garden	
B. Artisanal sales		F. Mi Familia Progresa		I. Renting lands to other people	
C. Sale of herbs, wild forest products		G. Midwifery/ watching kids		J. Other (e.g., bonuses)	
D. Sale of hens and broilers					

III. FOOD SECURITY

AVAILABILITY

1. In the last 12 months, has the households food production met household food needs? 1. Yes 2. No 3. Partially 4. Other, what?	
2. In the last 12 months, have you planted crops in a household garden? 0. No. 1. Yes.	
2b. In the last 12 months, what crops did you grow in the household garden? Use crop codes.	
3. In the last 12 months, the crops grown in the household garden have been for? 1. Household consumption 2. Local sale 3. International sale 4. Other, what?	

CONSUMPTION

4. In the last 12 months, has the household planted corn for your own consumption? 0. No 1. Yes	
5. Does the corn you harvest last for the whole year? 0. No 1. Yes	
6. In the last 7 days, how many pounds of corn have been cooked in the home?	
7. In a good season, how many pounds of corn are cooked in the home in one week?	
8. In a bad season, how many pounds of corn are cooked in the home in one week?	
9. Where does the corn that the household eats come from normally? 1. Own production and harvest 2. Purchased 3. Aid/gifted	

10. In the last 12 months, has the household planted bean for your own consumption? 0. No 1. Yes	
11. Does the bean you harvest last for the whole year? 0. No 1. Yes	
12. In the last 7 days, how many pounds of bean have been cooked in the home?	
13. In a good season, how many pounds of bean are cooked in the home in one week?	
14. In a bad season, how many pounds of bean are cooked in the home in one week?	
15. Where does the bean that the household eat come from normally? 1. Own production and harvest 2. Purchased 3. Aid/gifted.	

ACCESS
The Household Food Insecurity Access Scale (HFIAS)

	Question	Option	Code
16.	In the past four weeks, did you worry that your household would not have enough food?	0 = No (skip); 1 = Yes	
16b.	How often did this happen?		
17.	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	0 = No (skip); 1 = Yes	
17b.	How often did this happen?		
18.	In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?	0 = No (skip); 1 = Yes	
18b.	How often did this happen?		
19.	In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	0 = No (skip); 1 = Yes	
19b.	How often did this happen?		
20.	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	0 = No (skip) 1 = Yes	
20b.	How often did this happen?		
21.	In the past four weeks, did you or any other household member have to eat fewer meals in a day because there was not enough food?	0 = No (skip) 1 = Yes	
21b.	How often did this happen?		
22.	In the past four weeks, was there ever no food to eat of any kind in your household because of a lack of resources to get food?	0 = No (skip) 1 = Yes	
22b.	How often did this happen?		
23.	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	0 = No (skip) 1 = Yes	
23b.	How often did this happen?		
24.	In the past four weeks, did you or any household member go a whole day and night without	0 = No (skip)	

	eating anything because there was not enough food?	1 = Yes	
24b.	How often did this happen?		

MONTHS OF ADEQUATE HOME FOOD PROVISIONING (MAHFP)							
25.	In the past 12 months were there months in which you did not have enough food to meet your family's needs? **0 = NO 1 = YES**			**IF ANSWER IS NO, STOP HERE.**			
25b.	If yes, which were the months (in the past 12 months) in which you did not have enough food to meet your family's needs? 0. Enough 1. Not enough food						
May		February		November		August	
April		January		October		July	
March		December		September		June	

UTILIZATION AND HYGIENE

26. Does the household use manure on its farm plots? 0. No 1. Yes	
27. Where do you normally store the manure prior to application? 1. In the agricultural parcel 2. Outside the home but on the immediate property 3. Inside the home 4. Other, what?	
28. Is there currently soap in the place where people wash their hands normally? 0. No 1. Yes	
29. In your household, how many flies are there currently? 1. Many 2. Some 3. Very few 4. None	
30. What do you do with household waste (usually)? 1. Throw it out 2. Burn it 3. Bury it 4. Sort and recycle it 5. Other, what?	

STABILITY / VULNERABILITY

31. In the last 12 months, have there been moments when the household has not had enough money to buy food or to cover other essentials?	
32. In the last 12 months, have you had to take one of the following actions to obtain food or satisfy other necessitities?	

A. Looking for additional work, work longer hours		F. Reduce spending on fertilizers, pesticides, animal food		K. Eat less preferred food	
B. Start a small business		G. Reduce health spending		L. Take children out of school so they can work.	
C. Migrate elsewhere		H. Eat fewer times per day		M. Borrow food	
D. Sell household possessions (e.g., television)		I. Reduce portion sizes for adults		N. Go entire days without eating	
E. Sell animals more than usual (e.g., small animals)		J. Reduce portion sizes for children		O. Ask for aid from NGOs or other groups. Which groups?	

	A	B	C
33. What have been the principal difficulties for the household in the last 12 months? For example, problems could relate to agriculture, prices, the envirionment, or jobs. **DO NOT LIST OPTIONS. SEE CODE LIST.**			

34. In the last 12 months, have you or members of your household received benefits such as (…)? **NO = 0 YES = 1**	
34. **(B)** Do you or members have your household presently receive (…)? **NO = 0 YES = 1**	

A. Microcredit loans		F. Money transfers for social assistance programs by NGOs or other groups		K. Free health services/medications	
B. Free technical/agricultural extension services		G. School scholarships		L. Free hygiene supplies (e.g., soap)	
C. Free seeds, fertilizers, or agricultural tools		H. Food for school programs (to consume at school or to take home)		M. Other assistance. Specify.	
D. Metal lamina, wood, or other materials for home construction/repair		I. Free food ration for the home (e.g., for small children, lactating/pregnant mothers)			
E. Mi Familia Progresa		J. Food for work		O	

35. Do you or a member of the household participate in a group or organization, for example: the church, a committee, communal agriculture groups, etc? **NO = 0 YES= 1**	
36. What groups do you participate in and/or are a member?	
37. If suddenly you needed a small amount of money (for example, to pay forone weeks of spending), do ou believe that someone would help you to cover these costs? 1. *Definitely yes 2. Probably 3. Not sure 4. Probably not 5. Definitely not.*	
38**.** If the household suffered an important economic loss, for example, a harvest loss, who do you believe would help you to fill/cover necessities? SEE CODE LIST.	
39. In general, do you consider yourself happy? 1. Very happy 2. Partially happy 3. Neither happy nor unhappy 4. Somewhat unhappy 5. Not sure	
40. Do you think you can change the future of your life? 1. Definitely yes 2. Probably 3. Not sure 4. Probably not 5. Definitely not 6. There are other people who have the power	

	A	B
41**.** Currently, what are the priority necessities to improve the well-being of your family? For example, priorities can be linked to: agriculture, health, prices, environment and/or work. SEE CODE LIST		

WILD PRODUCTS

42. In the last 12 months, have you or a member of this household collected wild products from the forest, such as bara, aciento, blackberries, pacaya de ternera (or others) for any use (such as artisanry, eating, medicine)? **NO = 0 YES = 1**	**CODE**

43. Specifically, in the last 12 months has someone collected (…) for the household? **NO = 0 YES = 1**
44. In the last 12 months, have some of the collected (…) been sold? **NO = 0 YES= 1**
45. In the last 12 months, what was the total amount of money received from selling (…)? **QUETZALES**

Product		**2. COD.**	**3. COD.**	**4. QUET.**		**Product**	**2. COD.**	**3. COD.**	**4. QUET.**
A	Bara de canastas				**B**	Hongos (ej. Orejo de pino, Oreja de gato, Oreja de burro, Silip)			
C	Pamaque				**D**	Barretillo			
E	Aciento				**F**	Mirto			
G	Pino para canastas				**H**	Begonia silvestre			
I	Musgo				**J**	Sangre de Cristo			
K	Escasas orquídeas (parasitas)				**L**	Altamisa			
M	Pacaya de ternera				**N**	Manzanillo			
O	Macuy de montaña (hierba mora)				**P**	Apacin			
Q	Mora silvestres				**R**	Arroyan			
S	Pacaya disciplina				**T**	Ocote			
U	Palmito de palma				**V**	Hierba de Danto			

UTILIZATION: HOUSEHOLD DIETARY DIVERSITY SCORE AND FOOD CONSUMPTION SCORE

Name of the mother ______________ Name, age, and sex of child

Name		Age		Sex	

Household Dietary Diversity Score	
46. Was yesterday a special day where members of the household ate more or less than usual? **NO=0; YES = 1**	47. Yesterday, did you or a member of your household eat (…) that was prepared in the home? NO =0; YES = 1 **EXCLUDE FOOD BOUGHT/PREPARED OUTSIDE THE HOME**
CODE	

Food Consumption Score for children For one randomly selected child, age 1-8	
48. In the last 7 days, how many days did this child eat (…)? INCLUDE ALL SOURCES OF THE FOOD	49. Where does the (…) this food for the child come from normally? MARK THE MOST COMMON SOURCES.

FOOD	**47. COD**	**48. # OF DAYS**	**49. NORMAL SOURCE**		**47. COD**	**48. # OF DAYS**	**49. NORMAL SOURCE**
Corn tortillas, tamales, corn				Meat (chicken, beef, sausages, ham, etc)			
Atoles de masa				Fish or seafood			
Beans, peas, or peanuts				Acidic fruits (pineapple, lemon, orange)			
Powdered milk, cheese, cream, or other dairy				Other fruits (papaya, mango, banana, melon, etc)			
Oils, butter, margarine, avocado,				Vegetables (tomatoes, carrot, cabbage, squash, etc)			
Eggs				Broccoli			
Potatoes				Sodas			
Plantains				Coffee, tea			
Pacaya				Snacks (chips, etc.)			
Bread				French fries, fried chicken			
Rice				Sugar, candy, jams, honey, marshmallow			

Interviewer:

Please use the following codes to register sources. If there is more than once source, list them from major to minor.

A – Own production / garden
B – Bought in Chilascó
C – Bought in Salamá
D - Gifted/
E – Barter or trade
F - Lent / debt
G –Found in waste/ wild foods

APPENDIX B. AGRICULTURAL SURVEY

I. AGRICULTURAL PRODUCTION

1. In the last month, have you planted corn for the household? **NO = 0 YES = 1**	
2. In the last 12 months, have you planted bean for the household? **NO = 0; YES= 1**	
3. In the last 12 months, have you planted broccoli for the household? **NO = 0; YES = 1**	
4. In what year did you start planting broccoli for the household?	
5. Have you planted broccoli for the household in the past? **NO = 0; YES = 1**	
6. When was the last year that you planted broccoli for the household?	
7. In the last 12 months, have you planted potato for the household? **NO = 0; YES = 1**	
8. In what year did you start planting potato for the household?	
9. Have you planted potato for the household in the past? **NO = 0; YES= 1**	
10 When was the last year that you planted potato for the	
11. How many years have you been a farmer?	
12. ASK IF APPLICABLE. 15 years ago, what crops did you plant on your land? LIST THE FOUR MAJOR CROPS. MARK **00** IF DID NOT FARM.	
13. 10 years ago, what crops did you plant on your land? LIST THE FOUR MAJOR CROPS. MARK **00** IF DID NOT FARM.	
14. 5 years ago, what crops did you plant on your land? LIST THE FOUR MAJOR CROPS. MARK **00** IF DID NOT FARM.	
15. 2 years ago, what crops did you plant on your land? LIST THE FOUR MAJOR CROPS. MARK **00** IF DID NOT FARM.	
16. What is the area of land that you currently own, rent, or rent out to others? USE THE TENURE AND LOCATIONS CODES TO MARK TENURE TYPE AND LOCATION.	

	AREA	**TENURE**	**LOCATION**		**AREA**	**TENURE**
A. Crops				D. Pasture/ livestocks		
B. Natural forest				E. Fallow		
C.Managed/artificial forest				F. Household land and patio		

17. Calculate the total land (in manzanas)	
18. Calculate the total land owned (in manzanas)	
19. Calculate the total rented land (in manzanas)	
20. Calculate the total land rented to others (in manzanas)	

OWN (AGRICULTURAL PARCELS)

21. In the last 12 months, have you worked in your own lands on behalf of the household?	
22. LIST THE PARCELS OR LOTS THAT YOU OWN INCLUDE PATIO LANDS (E.G. FAMILY GARDENS).	
23. What is the area of this parcel?	
24. What type of document credits ownership of this land to you? 1. Receipt 2. Deed 3. Deed recorded 4. Communal property tile 5. Do not have 6. Other, what?	
25. How long have you owned this parcel?	
26. How long does it take you to walk to this parcel from your home by foot?	
27. What do you consider is the quality of the soil on this land? 1. Good 2. Okay 3. Bad 4. Other	
28. How long has it been since you let this land lay fallow?	
29. What is the topography of the parcel? 1. Flat 2. Mostly flat 3. Ondulated 4. Steep 5. Very steep	
30. If you were to sell this parcel, how much could you receive for it?	

RENTED (AGRICULTURAL PARCELS)

31. In the last 12 months, have you worked in lands rented by the household? **NO = 0 YES = 1**	
32. **LIST THE PARCELS OR LOTS THAT YOU RENT FROM SOMEONE ELSE.**	
33. What is the area of this parcel?	
34. How long does it take you to walk to this parcel from your home by foot?	
35. What do you consider is the quality of the soil on this land? 1. Good 2. Okay 3. Bad 4. Other	
36. How long have you owned this parcel?	
37. What is the topography of the parcel? 1. Flat 2. Mostly flat 3. Ondulated 4. Steep 5. Very steep	
38. How do you pay to rent/work on this land? 1. Money 2. Harvest 3. Money and harvest 4. Work 5. Don't pay 6. Other, specify.	
39. In the last 12 months, how much money have you paid in order to rent/use this land?	
40. Over the last 12 months, what quantity, if any, of the harvests did you have to give the property owner?	

RENTED TO OTHERS (AGRICULTURAL PARCELS)

41. In the last 12 months, have you rented land to others? **NO = 0 YES = 1**	
42. **LIST THE PARCELS OR LOTS THAT YOU RENT OUT TO SOMEONE ELSE.**	
43. What is the area of this parcel?	
44. In the last 12 months, how much money have you received as rent for this parcel?	
45. What crops the other farmer plant in the rented field in the last 12 months?	

BOUGHT AND SOLD (AGRICULTURAL PARCELS) – LAST 12 MONTHS

46. In the last 12 months, have you bought or sold land? NO = 0 YES = 1	

47. LIST PARCELS BOUGHT OR SOLD IN THE LAST 12 MTHS	
48. (SOLD) What is the area of this parcel?	
49. (SOLD) How much money did you sell the land for	
50. (BOUGHT) What is the area of this parcel?	
51. (BOUGHT) How much money did you buy the land for?	

II. AGRICULTURAL PRODUCTION

1. **LIST THE NAMES OF ALL THE PARCELS.**	
2. In the last 12 months, what crops did you plant in this parcel?	
3. In the last 12 months, how many harvests of (…) did you have?	
4. In what months did you harvest (…)?	
5. In the first harvest from this parcel, how many quintales of (…) did you harvest?	
6. In the second harvest from this parcel, how many quintales of (…) did you harvest?	
7. In the third harvest from this parcel, how many quintales of (…) did you harvest?	
8. In the fourth harvest from this parcel, how many quintales of (…) did you harvest?	
9. What is the primary destination of production for this crop? 1. Household consumption 2 Local sale 3. Bring to Salama 4. Bring to Guatemala 5.Transformation 6. International export 7. Other	
10. Did this parcel contain broccoli, tomato, or potato in the last 12 months? **NO = 0 YES=1 WHAT?**	
11. **LIST EVERY CROP FROM PREVIOUS.** How many quintales of (…) did you sell in the last 12 months?	
12. What was the total sale price of the (…)?	
13. How many quintales of (…) did you leave for household consumption?	
14. How many quintales of (…) wer lost or damaged before the harvest?	
15. How many quintales of (…) were left for animals?	
16. How many quin. of (…) did you leave for seed?	

III. INPUTS AND EXPENDITURES

SEEDS

1. Specify parcel number/name	
2. How much did you spend on seed or transplants for this parcel in the last 12 months? Specify by crop and price	
3. In the last 12 months, what types or varieties of corn did you plant in this parcel? 1. Yellow 2. White 3. Garden (Overo) 4. Mountain 5. Don’t farm corn	
4. In the last 12 months, what types of varieties of bean did you plant in this parcel? 1. Frijol del suelo 2. Frijol rallado 3. Frijol enredador 4. Piloy (negro) 5. Chui (amarillo) 6. Don’t farm bean 7. Other, specify.	
5. In the last 12 months, what broccoli companies did you work with in order to plant in this parcel? 1. MAYA-PAC/	

Alcosa 2. Neo Alimentación 3. Legumex S.A. 4. Alimentos Sumar S.A. 5. Intermediary 6. Don't farm broccoli 7. Other, specify	
6. In the last 12 months, what types or varieties of potato did you plant in this parcel? 1. Papa Toyoca 2. Papa Icta 3. Papa Loma 4. No potato 5. Other?	

FERTILIZERS

7. Specify parcel number/name	
8. In the last 12 months, have you applied chemical fertilizers to this parcel?	
9. How much triple quince (15-15-15) did you use in this parcel in the last 12 months (or per harvest)?	
10. How much urea (46-0-0) did you use in this parcel in the last 12 months (or per harvest)?	
11. How much veinte cero (20-20-0) did you use in this parcel in the last 12 months (or per harvest)?	
12. How much 15-0-25 did you use in this parcel in the last 12 months (or per harvest)?	
13. How much 18-8-12 did you use in this parcel in the last 12 months (or per harvest)?	
14. How much 27-0-12 did you use in this parcel in the last 12 months (or per harvest)?	
15. Specify parcel number/name	
16. How much (…) did you use in this parcel in the last 12 months (or per harvest)? A) Gallinaza cruda B) Ferti-organico C) Compost	
17. How much did you spend on (…) for this parcel in the last 12 months (or per harvest)? A) Gallinaza cruda B) Ferti-organico C) Compost	
18. In the last 12 months, what quantity of gallinaza from your own household did you use in this household?	
19. In the last 12 months, what quantity of compost from your own household did you use?	

PESTICIDES

20. PARCEL #

21.Please tell me if you used the following pesticide in the previous 12 months. If yes, what quantity did you use?

HERBICIDES	1. BRAVO	17. TIODAN	25. SPINOACE, 26.	34. PROCLAIM	43.TAMARON
1. GRAMOXONE*	2. ROVRAL	18.	SPINTOR	35. MYCOTRAL	44.LORSBAN
2. GLIFOSATO*	10. METALAXYL	ENDOSULFAN	27. KRISOL	36. SERENADE	45. AGROMIL
3. RANGER*	11. BELLIS	19. TIODAN	28. KARATE	37.	46.DIAZINON
FUNGICIDES	12. SILBACUR	20.	29. ECOTECH	CLORPYRIFOS	47. BASUDIN
4. AMBIL*	**INSECTICIDES**	MALATHION	30. XENTARI	38. TERBUFOS	48. AMBUSH
5. AMISTAR	13. VOLATON	21. LANNATE	31.	39. AGROFOS	
6. ALTO*	14. SEVIN	22. GUSAFIN	PERFEKTHION	40. TERBUGRAN	
7.	15. AVAUNT	23. ADMIRE,	32. DIBROM	41.CARBOFURAN	
CALDOBORDELÉS*	16. RIENDA	24.CONFIDOR	33. DIBROXONE	42. DIBROM	

PRODUCT	H1	H2	H3	H4	**TOTAL**	**PRODUCT**	H1	H2	H3	H4	**TOTAL**

EXPENDITURES

22. In the last 12 months, how much did you spend in TOTAL on (…)?					
ACTIVITY	TOTAL		TOTAL		TOTAL
A.Transport and freight payment		F.Production of agricultural sub-products		J. Fences and sheds	
B.Product storage and drying		G.Gas and oils		K. Fees for veterinary services	
C.Rental of agricultural machinery		H. Animal feed (e.g., corn, salt, concentrates, etc.)		L. Production of livestock by products	
D.Maintenance and repair of machinery		I. Vaccines, remedies, or veterinary products		M. Agricultural labour – How many? What was the daily wage (GTQ/day)?	
E. Rent working animals (for farm)					

LIVESTOCK

23. In the last 12 months, have you raised animals like chickens, ducks, goats, rabbits, pigs, cows, etc?								
NO	**24. What animals**?	**NO = 0 YES = 1**	**25. How many (…) do you have currently?**	**26. How much could you sell 1 (…) for ?**	**27. In the last 12 months, how many (..) did you sell and at what price did you sell each one?**		**28. In the last 12 months, how many of your (…) did the household consume?**	**29. How many (…) did you buy in the last 12 months?**
1	Bulls, cows or calves							
2	Goats							
3	Pigs							
4	Rabbits							
5	Fowl							
6	Turkeys							
7	Ducks							
8	Horses or donkeys							
9	Other, what?							

ANIMAL SUB-PRODUCTS

30. In the last 12 months, have you prepared a product from livestock? NO= 0; YES = 1 - Milk; Cheese; Egg; Honey; Leather; Butter; Wool; Sausage; Other, what?	
31. In the last 12 months, in total, how many (…) did you sell?	
32. For how much did you sell each unit?	

IV. ENVIRONMENT

1. Do you currently use any of the following practices on your agricultural land? **NO = 0 YES = 1**					
Compost piles		Plant perpendicular to slope		Plant trees within the parcel	
Bury organic matter to prepare the soil		Reforest		Plant fruit trees within the parcel	
Plant vegetation along boundaries/fencelines		Allow land to rest fallow If so, how much time? _____________		Use Gramaxone	
Soil conservation using hedgerows		Use native seeds		Controlled burns prior to planting	
Soil conservatoin using terraces		Use improved seeds		Management of natural regeneration	
		Harvest by the moon		Plant by the moon	

PESTS

2. . What crops are most affected by pests? 1. Corn 2. Bean 3. Broccoli 4. Tomato 5. Potato List in order of most to least.	
3. What pests/sicknesses most affect broccoli crops? 1. Gallina ciega 2. Plutell 3. Gallina ciega and Plutella .4. Others, what?	
4. Have you had problems with the fungus camotillo (clubroot) in your broccoli parcels? If so, in what parcel, since when, and why? **NO = 0 YES=1**	
For he following questions, please answer if you are in agreement. NO = 0 YES= 1	
5. Pest cause more damage to broccoli fields than to corn and bean fields	
6. There are more pests today than there were 5 years ago.	
7. There are insects that eat pests that eat the corn (who help control pests).	
8. There are insects that eat the pests of broccoli (who help control pests)	
9. Agricultural practices determine the levels of pests in fields.	

V. INCOME AND WELL-BEING

1. In the last 12 months, how have you obtained most of the money to support your family? 1b. What what the second most important source of money for your household?	

2. In the last 12 months, how much money/income did your household have per month, on average? 1. Less than Q500 2. Q500 – Q1,000 3. Q1,000-Q2,000 4. Q2,000 – Q, 3000 5. More than Q3, 000	
3. Compared with your household, other members of the community are in an economic position that is (…)? 1. Much better **2.** A little better 3. The same 4. A little worse 5. Much worse	
4. Before broccoli came to Chilascó, the economic situation in the community was: 1. Much better 2. A little better 3. Equal 4.A little worse 5. Much worse	
5. How do you see the change in Chilascó from farming broccoli? 1. Positive 2. Negative 3. The same	
6. Who benefits the most from the production of broccoli? 1. The household 2. The companies 3. The coyote 4. Everyone 5. Other, who?	
Please state whether or not you agree with the following statements. **NO = 0 YES= 1**	
7. In Chilascó, there are big differences between the rich and the poor.	
8. The companies that export broccoli take advantage of the farmers.	
9. The companies that export broccoli never lose.	
10. The companies that export broccoli alway offer fair prices.	
11. A person who takes risks is better off economically.	
12. Does farming broccoli help you to feed your family? Why? 1. Yes 2. No 3. Yes and No 4. Other, what?	
13. In general do you consider yourself to be a happy person? How much? 1. Very happy 2. Partially happy 3. Neither happy nor unhappy 4. Somewhat unhappy 5. Very unhappy 6. Not sure	
14. Do you believe you have the power to change the future of your life? 1. Definitely yes **2.** Probably **3.** Not sure **4.** Probably no **5.** Definitely no 6. Others have the power	
15. Presently, what are your priority needs in order to improve the wellbeing of your household? For example, priorities could relate to agriculture, health, prices,the environment, etc. SEE CODE LIST.	

APPENDIX C. ADULT-EQUIVALENT HOUSEHOLD SIZE CALCULATION

Household size was adjusted to 'adult-equivalents' by comparing recommended daily energy requirements (kcal day^{-1}) for household members according to age and gender, and comparing this to a reference of 3100 kcal/ day^{-1} recommended for men, ages 18-64, in Guatemala (INCAP, 2006). Table C.1 shows the recommended energy requirements and the weights used to calculate adult-equivalent household size.

Table C.1. Calculating adult-equivalent household size using recommended daily energy requirements from INCAP (2006).

	Daily energy requirement (Kcal/day)	**Weight**		**Daily energy requirement (kcal/day)**	**Weight**
Infants			**Toddlers**		
• 0-5 months	Estimated	0.194	• 3-4	1500	0.484
• 6-11 months	Estimated	0.282	**Children**		
• 1- 2 years	1200	0.387	• 5-6	1675	0.540
Males			**Females**		
• 7-9	2000	0.645	• 7-9	1700	0.548
• 10-11	2200	0.709	• 10-11	1900	0.612
• 11-12			• 11-12		
• 12-13	2350	0.758	• 12-13	2000	0.645
• 14-15	2650	0.855	• 14-15	2100	0.677
• 16-17	3000	0.967	• 16-17	2150	0.694
• 18-64	3100	1	• 18-64	2100	0.677
• 65 years +	2300	0.742	• 65 years +	1850	0.597

APPENDIX D. LIST OF WILD EDIBLE FOREST PRODUCTS

In order to identify the common wild edible forest products collected around Chilascó, I refined a preliminary list of local products (Quezada Jerez, 1994) by interviewing a local elderly man as well as a representative of Guatemala's forest service. The local names and medicinal purposes (if known) are provided in the table below.

During the food security questionnaire, participants were asked whether or not a household member had collected one of the itemized wild edible forest products. They were also asked about the quantity of the product collected, whether or not they had sold that product, and the annual income derived from the sale of the product. However, participants found it difficult to estimates quantities of the collected products, likely because the question was framed for a 12-month period. The total number of foods collected was tallied as an indication of the dependence of the household on wild edible food products, noting that this tally may not reflect a need for the food per se, but may also reflect a cultural tradition.

Table D.1. Wild edible forest products collected by locals of Chilascó.

Product	Description
Wild foods	
Mushrooms	Mushrooms (in general) are collected in the forest nearby.
Pamaque	A bitter herb.
Pacaya de Ternera	A wild food that is collected during holy week (a rich food)
Mora Silvestres	Wild berries.
Pacaya de siplina	Another type of pacaya (a rich food).
Medicinal herbs	
Macuy	An herb commonly used to supplement and flavour beans.
Barretillo	Used to fight stomachaches (Quezada Jerez, 1994).
Altamisa	Used as a painkiller
Sangre de Cristo	Used to fight fevers and infections (Quezada Jerez, 1994)
Mirto	Used to fight stomach aches (Quezada Jerez, 1994)
Bledo	-
Hierba de Dante	-
Manzanilla	Used to fight colds, phlegm and infections (Quezada Jerez, 1994).
Apacin	For headaches (Quezada Jerez, 1994)

APPENDIX E. AGRICULTURAL PRICES USED TO ESTIMATE NET ANNUAL HOUSEHOLD INCOME

Table E.1. Local sale prices for crops and animals. To convert from Guatemalan quetzals (GTQ) to American dollars (USD), I used an exchange rate of 1 USD = 7.8285 GTQ (as of 2011-09-09, accessed from www.xe.com).

CROP	UNIT	PRICE (GTQ) (Average)	CROP	UNIT	PRICE (GTQ) (Average)
Corn	1 qq	200	Güisquil	Head	1.5
Bean	1 qq	800	Radish	1 bulto	25
Broccoli	1 qq	100	Güicoy	Head	3
Potato	1 qq	150	**ANIMALS**		
Cabbage	Head	1	Horse	Big horse	1900
Ejote	1 qq	70	Pig	Small pig	200
Pea	qq	50	Chicken	Small chicken	10.75
Cauliflower	Head	2	Ducks	1 duck	30

Table E.2. Local agricultural input costs for transplants, fertilizers, and herbicides.

Product	Unit	Price (GTQ)	Product	Unit	Price (GTQ)	Product	Unit	Price (GTQ)
Seeds and Transplants			Glifosato	`L	60	Lorsban	1L	135
Broccoli transplants	1 plant	0.11	Balear	1L	125	Tamaron	1L	220
Fertilizers			Rival	50g	17	Spinoace	150 mL	146
15-15-15	1 qq	239	Root Out	1L	55	Gusafin	1L	81
Urea (46-0-0)	1 qq	235	Jaripeo	50g	15	Malathion	1L	60
(20-20-0)	bag	50	Ambil			Thiodan	1L	70
Chicken manure	bag	45	Volaton	1L	176	Karate	100mL	50
Herbicides			Dibron	1L	235	Confidor	13g	60
Gramaxone	1L	52	Malathion	1L	55	Spintor	150 mL	191
Ranger	1L	60	Lannate	1L	120	Lannate	1L	125
Paraquat	1L	52	Rovral	1kg	575	Endosulfan	1L	85
Amistar	100 g	225	Dibroxone	1 L	190	Sevin	100g	30
Silbacur	1 L	475	Avaunt	250 gr	681	Perfekthion	1L	155
Metalaxyl	1 L	175	Terbufos	1 Kg	22.5	Diazinon	1L	100

APPENDIX F. CALCULATING NET ANNUAL HOUSEHOLD INCOME

Covarrubias et al. (2009) recommend calculating rural income on the basis of seven categories:

$$\boldsymbol{Income} = (Agricultural\ wages) + \big(Non\text{-}\ agricultural\ wages\big) + (Crop\ production) + (Livestock\ production) + \big(Self\text{-}\ employment\big) + (Transfers) + (Other\ Income).$$

Household surveys were used to collect the data required to calculate each category (see Table F.1 for listing of specific questions).

Table F.1. The income categories, associated data inputs, and survey questions used to measure household income as part of household surveys (described in reference to McKay 2000).

Name	Income Component	Data Inputs	Collected in Chapter 2	Survey, *(Section)*	Question
Agricultural + **Non-agricultural wages**	Income from wage employment	Wage income in cash	Yes	FS, *(II)*	6
		Wage income in kind	No*	-	-
		Bonuses	Yes	FS, *(II)*	9j
Crop + **Livestock production**	Household agricultural net income	Revenue from the sale of crops	Yes	AG, *(II)*	1, 5-8, 11
		Revenue from the sale of processed crop products	No	-	-
		Revenue from the sale of animal products	Yes	AG, *(III)*	27, 30-32
		Consumption of self-produced food	Yes**	AG, *(II)*	1, 5-8, 13
		Minus			
		Expenditure on inputs for crop cultivation	Yes	AG, *(III)*	2, 9-14, 16,17, 21, 22
		Expenditure on inputs for processed crop products	No	-	-
		Expenditure on livestock inputs	Yes	AG, *(III)*	22, 29
		Depreciation of agricultural capital equipment	No	-	-
Self-employment	Nonfarm self-employment income	Revenue in cash from sale of output	Yes	FS, *(II)*	9a-j
		Revenue in kind from sale of output	No	-	-

		Consumption of own produced output *Minus* Expenditure on inputs Depreciation of capital equipment	No No No	- - -	- - -
Transfers	Income from private transfers	Income from private interhousehold transfers in cash and kind (where no repayment is expected)	No	-	-
Other Income	Other income	Miscellaneous income (income from pensions, unemployment, etc.)	Yes	FS, *(II)*	9a-j
	Imputation for natural commodities	Food commodities	Yes	FS, *(III)*	42-45
		Nonfood commodities	Yes	FS, *(III)*	42-45
	Actual and imputed rental income	Income from renting out household assets	Yes	AG, *(I)*	44
		Imputed rent of owner-occupied dwellings	No	-	-

*Payment in-kind is rare in the case study community (Chilascó), as revealed by preliminary focus groups and pilot surveys.

** The monetary value of staple crop consumption was imputed using average sale prices in the region (see Appendix E for a list of prices used).

APPENDIX G. AGRICULTURAL PARCEL GEOGRAPHIC COORDINATES

Table G.1. The geographic coordinates and topography of agricultural parcels used for soil sampling.

	Sample	Latitude	Longitude	Altitude (ft.)	Parcel size (ha)	Slope (o)	Topography
BROCCOLI	FA	N 15 08.231'	W 090. 07. 282'	6077	0.12	22	Mostly flat
	FB	N 15 07.549'	W 090 06. 389'	6298	0.23	31	Steep
	FE	N 15 07.895'	W 090 07. 397'	5975	0.48	22	Steep
	FG	N 15 07. 326'	W 090 07. 316'	6184	0.12	25	Undulating
	FH	N 15 07. 831'	W 090 06. 357'	6048	0.23	27	Very steep
	FK	N 15 07. 152'	W 090 07. 456'	6218	0.48	15	Steep
	FI	N 15 08. 399'	W 090 06. 661'	6179	0.35	23	Steep
	FU	N 15 07. 235'	W 090 06. 373'	6203	0.23	21	Undulating
PURE CORN	FJ	N 15 07. 776'	W 090 06. 686'	5893	0.09	20	Undulating
	FM	N 15 08. 549'	W 090 07. 439'	6108	0.23	16	Steep
	FN	N 15 07. 655'	W 090 06.587'	6005	0.18	33	Very steep
	FP	N 15 07.569'	W 090 06. 972'	6121	0.23	17	Steep
	FR	N 15 07. 266'	W 090 06.373'	6247	0.23	29	Steep
	FQ	N 15 07 126'	W 090 05. 853'	6368	0.23	26	Steep
	FS	N 15 07. 208'	W 090 05. 964'	6318	0.23	29	Steep

APPENDIX H. LIST OF STATISTICAL TESTS AND RESULTS

Table H.1. Correlations of food access and food utilization indicators for all households and among non-adopter and adopter households.

		All	**Non-adopter**	**Adopter**
Net annual income X HFIAS	Pearson Correlation	-.258	-.245	-.268
	Sig. (2-tailed)	.065	.217	.195
	N	52	27	25
Net annual income X MAHFP	Pearson Correlation	-.258	.206	.310
	Sig. (2-tailed)	.065	.304	.132
	N	52	27	25
Net annual income X HDDS	Pearson Correlation	.371**	.479*	.387
	Sig. (2-tailed)	.007	.011	.056
	N	52	27	25
HFIAS X MAHFP	Pearson Correlation	-.497**	-.313	-.668**
	Sig. (2-tailed)	.000	.112	.000
	N	52	27	25
HFIAS X HDDS	Pearson Correlation	-.349*	-.369	-.340
	Sig. (2-tailed)	.011	.058	.097
	N	52	27	25
MAHFP X HDDS	Pearson Correlation	.362**	.374	.356
	Sig. (2-tailed)	.008	.054	.081
	N	52	27	25
Net annual income X FCS	Pearson Correlation	0.473**	0.297	0.571**
	Sig. (2-tailed)	0.002	0.216	0.009
	N	39	19	20

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table H.2. Significance testing for variables across non-adopter and adopter households.

VARIABLE	NORMALITY*	EQUAL VARIANCE**	TEST TYPE	TEST-STATISTIC	DF	STRENGTH	P-VALUE
DEMOGRAPHIC VARIABLES							
Primary source of household income	-	-	Chi-square	$X^2 = 28.20$	1 N=52	V=0.736	**0.000**
Household size	Y	Y	T-test	t=-1.351	50	-	0.183
Household size (adjusted to adult-equivalents)	Y	Y	T-test	t=-0.355	50	-	0.724
Number of children per household	Y	Y	T-test	t=-1.190	50	-	0.240
Number of income earners per household	Y	Y	T-test	t=-0.364	50	-	0.718
Male household head							
• Age	Y	Y	T-test	t=1.03	50	-	0.309
• Primary occupation	-	-	Chi-square	$X^2 = 7.23$	3 N=52	V=0.380	**0.065**
• Illiteracy	-	-	Chi-square	$X^2 = 2.096$	1 N=52	-	0.148
Female household head							
• Age	Y	Y	T-test	t=0.683	50	-	0.498
• Primary occupation		-	- Chi-square	$X^2 = 2.95$	3 N=52	-	0.566
• Work in agricultural fields	-	-	Chi-square	$X^2 = 0.234$	1 N=52	-	0.629
• Illiteracy		-	Chi-square	$X^2 = 0.618$	1 N=52	-	0.432
FOOD AVAILABILITY INDICATORS							
Corn production (kg yr^{-1})	N	Y	Mann Whitney U	U = 229.500 Z = -1.802	49	-	0.072
Bean production (kg yr^{-1})	N	Y	Mann Whitney U	U = 279.000 Z = -1.076	50	-	0.282

VARIABLE	NORMALITY*	EQUAL VARIANCE**	TEST TYPE	TEST-STATISTIC	DF	STRENGTH	P-VALUE
Corn yield (kg ha^{-1})	N	Y	Mann Whitney U	U = 272.50 Z=-0.99	49	-	0.322
Bean yield (kg ha^{-1})	N	Y	Mann Whitney U	U = 224.50 Z = -0.648	43	-	0.517
Corn consumption (kg yr^{-1} per capita)	Y	Y	T-test	T=0.409	50	-	0.684
Bean consumption (kg yr^{-1} per capita)	N	Y	Mann Whitney U	*U* =303.00 *Z* =-0.632	50	-	0.527
Corn consumption (kg yr^{-1} per a.e.)	Y	Y	T-test	t = -0.381	50	-	0.705
Bean consumption (kg yr^{-1} per a.e.)	N	Y	Mann Whitney U	U = 337.000 Z = -0.009	50	-	0.993
Number of wild edible forest products collected	Y	Y	T-test	t= -1.000	47	-	0.322
FOOD ACCESS INDICATORS							
Net annual household income (USD yr^{-1})	Y	Y	T-test	t= -1.91	50	-	**0.062**
Net annual on-farm income (USD yr^{-1})	N	N	Mann Whitney U	U = 199.00 Z=-2.537	50	-	**0.011**
Annual off-farm income (USD yr^{-1})	Y	Y	T-test	t = 0.470	50	-	0.641
Agricultural land (ha)	Y	Y	T-test	t = -1.660	50	-	0.103
Household rented land (nominal, yes or no)	-	-	Chi-square	X^2 = 0.662	1 N=52		0.416
Household rented out land (nominal, yes or no)	-	-	Chi-square	X^2 = 6.657	1 N=52	Cramer's V = 0.358	**0.010**
Corn yields between	Y	N	Mann	*U=119.00*	30	-	0.790

VARIABLE	NORMALITY*	EQUAL VARIANCE**	TEST TYPE	TEST-STATISTIC	DF	STRENGTH	P-VALUE
corn households that rented out and did not rent out land			Whitney U	*Z= -0.266*			
HFIAS (continuous)	Y	Y	T-test	t=0.526	50	-	0.601
HFIAS (ordinal)	-	-	Chi-square	X^2 = 1.334	3 N=52	-	0.721
Household hunger scale (ordinal)	-	-	Chi-square	X^2 = 0.058	1 N=52	-	0.810
Coping strategies index (ordinal)	-	-	Mann Whitney U	U = 253.00 Z= -1.613	50		0.107
Household Dietary Diversity Score	Y	Y	T-test	t=0.352	50	-	0.726
FOOD UTILIZATION INDICATORS							
Food consumption score	Y	Y	T-test	t = -0.457	37	-	0.651
FOOD SYSTEM STABILITY INDICATORS							
Manure use per hectare (kg ha^{-1} yr^{-1})	Y	Y	T-test	t = -2.554	50	-	**0.014**
Inorganic fertilizer use per hectare (kg ha^{-1} yr^{-1})	Y	Y	T-test	t = -2.577	50	-	**0.013**
Nitrogen application rate (kg ha^{-1} yr^{-1})	Y	Y	T-test	t = -2.450	49	-	**0.018**
Phosphorus application rate (kg ha^{-1} yr^{-1})	Y	Y	T-test	t = -2.725	49	-	**0.009**
EIQ	N	N	Mann Whitney U	*U*= 146.00 *Z*= -3.097	49		**0.002**
More pests today than			Chi-	X^2 = 5.069	1	0.315	**0.079**

VARIABLE	NORMALITY*	EQUAL VARIANCE**	TEST TYPE	TEST-STATISTIC	DF	STRENGTH	P-VALUE
five years ago			square		N=51		
Soil potassium (ppm)	Y	Y	T-test	t = -2.010	13	-	**0.066**
pH	Y	Y	T-test	t = 0.171	13	-	0.867
P	Y	Y	T-test	t = -0.897	13	-	0.386
Ca	N	N	Mann Whitney U	U = 26.5 Z = -0.177	13		0.860
Mg	N	N	Mann Whitney U	*U* = 18.00 Z = - 1.173	13	-	0.241
Cu	N	N	Mann Whitney U	*U* = 17.5 Z = -1.75	13	-	**0.08**
Zn	N	N	Mann Whitney U	*U* = 15.0 *Z* = -1.525	13	-	0.127
Fe	Y	Y	T-test	t = 0.124	13	-	0.903
Mn	Y	Y	T-test	t = -0.826	13	-	0.423
Organic matter	Y	Y	T-test	t = -1.301	13	-	0.216
Mix/mulch greens in soil	-	-	Chi-square	$X^2 = 0.981$	1 N=51	0.139	0.322
Vegetation along borders	-	-	Chi-square	$X^2 = 0.039$	1 N=51	0.028	0.843
Active barriers	-	-	Chi-square	$X^2 = 0.\ 510$	1 N=51	0.1	0.475
Terraces	-	-	Chi-square	$X^2 =0.002$	1 N=51	0.006	0.967
Reforest	-	-	Chi-square	$X^2 =1.199$	1 N=51	0.153	0.274
Allow land to rest	-	-	Chi-square	$X^2 =0.013$	1 N=51	0.016	0.91
Plant trees inside parcel	-	-	Chi-square	$X^2 = 2.706$	1 N=51	0.235	0.100

VARIABLE	NORMALITY*	EQUAL VARIANCE**	TEST TYPE	TEST-STATISTIC	DF	STRENGTH	P-VALUE
Plant fruit trees	-	-	Chi-square	$X^2 = 0.000$	1 N=51	0.000	1.000
Use Gramoxone to prepare soil	-	-	Chi-square	$X^2 = 1.801$	1 N=51	0.188	0.180
Slash and burn	-	-	Chi-square	$X^2 = 1.094$	1 N=51	0.146	0.296
Broccoli companies take advantage of farmers	-	-	Chi-square	$X^2 = 0.945$	1 N=52	0.135	0.635
Broccoli companies never lose	-	-	Chi-square	$X^2 = 0.949$	1 N=52	0.135	0.622
Broccoli companies offer fair prices	-	-	Chi-square	$X^2 = 1.131$	1 N=52	0.147	0.568
Broccoli farming helps families	-	-	Chi-square	$X^2 = 5.122$	1 N=52	0.314	0.077
Who benefits the most from broccoli production	-	-	Chi-square	$X^2 = 0.040$	2 N = 41	0.008	0.980

*Normality was assessed using the Kolmogorov-Smirnov test and by visually inspecting Q-Q plots.
**Homoscedasticity was tested using the Levene's Test for Equality of Variances.

APPENDIX I. CALCULATING POVERTY LINES

Poverty lines: Two absolute international poverty lines have been established by the World Bank and are used to track international progress towards the Millennium Development Goals. These include the extreme poverty line set at $1.25/day per capita (2005 Purchasing Power Parity - PPP) and the general poverty line set at $2.00/day per capita (2005 PPP) (Ravallion et al. 2008). Purchasing power parity is an economic theory concerned with the relative value of currencies, and PPP exchange rates help convert the purchasing power of a unit of currency so that it is roughly the same in the foreign economy as in the domestic economy (Taylor 2003). A given international poverty line may be converted into local currencies using PPP exchange rates, and this helps ensure that the new poverty line figure corresponds to a similar standard of living in each country. Although there is room for error in these calculations, PPP exchange rates facilitate international comparisons of income (Sillers 2006). I translated the international poverty lines into Guatemalan currency (the Quetzal) using Guatemala's consumption PPP exchange rate for 2005 (4.54 per international dollar) (World Bank 2013). Thereafter, I adjusted the poverty lines for inflation to the year 2011 using the national Consumer Price Index (CPI) for the 2000 base year. Using the methodology described by Sillers (2006), the $1.25/day 2005 PPP line for Guatemala in July 2011 was:

$$(2005\ PPP\ exchange\ rate) \times \$1.25 \times \frac{CPI_{July\ 2011}}{CPI_{Ave.2005}}$$

$$\left(\frac{GTQ4.54}{\$1.00}\right) \times \$1.25 \times \left(\frac{202.32}{141.16}\right) = GTQ8.13$$

Overall, the $1.25/day (2005 PPP) and $2.00/day (2005 PPP) in Guatemala in July 2011 were equivalent to GTQ 8.13 and GTQ 13.01 per person per day, respectively. Net annual household income was then divided by 365 (days per year) and the number of household members, and expressed in GTQ per capita per day.

APPENDIX J. ADDITIONAL RESULTS FROM CHAPTER 2

Table J.1. The types of coping strategies employed by non-adopter (N= 27) and adopter (N= 25) households when confronted by shortfalls in either income or food over the previous 12 months.

	Non-adopter	**Adopter**
	% Of households	*% Of households*
Migrate for work	19	24
Sell possessions	7	4
Smaller portions for adults	48	56
Smaller portions for children	15	40**
Withdraw children from school to work	11	8
Ask for institutional help	0	12

P-value: *0.1, **0.05, ***0.001

Table J.2. The soil characteristics associated with a subset of agricultural lands representative of broccoli farming by adopter households (N=8) and corn and bean farming by non-adopter households (N=7).

		Non-adopter		**Adopter**	
	Unit	**Mean**	**SEM**	**Mean**	**SEM**
pH	-	5.33	0.09	5.30	0.14
P	ppm	3.16	0.4	3.93	0.71
K	ppm	102.43	6.91	146.75*	19.63
Ca	Meq /100 gr.	3.08	0.39	3.90	0.88
Mg	Meq /100 gr.	0.62	0.12	0.91	0.2
Cu	ppm	0.1	-	0.25	0.07
Zn	ppm	1.86	0.30	3.50	0.78
Fe	ppm	4.64	1.49	4.44	0.84
Mn	Ppm	2.74	0.94	4.13	1.33
Organic matter	%	18.42	2.78	22.64	2.12

Statistically significant at: * P <0.1, ** P <0.05, *** P <0.001