

Too many calories, too few nutrients?

A systems approach to food and nutrition security in Guatemala

Elin Bergstrøm

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Lund University Centre for
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Submitted May 16, 2016

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Abstract

Obesity levels in developing countries are increasing at an alarming rate, while “old” problems such as hunger and undernutrition still persist, creating a paradoxical situation of a double burden of malnutrition. Intertwined with new sustainability challenges such as climate change and land degradation, food, health and sustainability are interconnected in a complex web of relationships, spanning multiple scales, levels and disciplines. It is argued that this complexity should be included in conceptualizations and measurements of food and nutrition security; of which a systems approach is one response to this challenge. Hammond & Dubé (2012) present a systems framework for food and nutrition security, capturing linkages between three *different* systems and the individual. Few studies have attempted to assess the applicability of such new frameworks on a particular case, leading to a gap between conceptualization and practical use. This thesis aims to fill this gap. Using the framework from Hammond & Dubé (2012) as a mental model and an analytical framework, this thesis investigates the multiple determinants of food and nutrition security in Guatemala. Further, it examines how a systems approach can contribute to the understanding of food and nutrition security. Guatemala was chosen as a case due to severe and complex health challenges, having one of the highest rate of stunting among children under five, while almost half of all adult women are overweight. The 10 linkages between the systems and the individual, presented by Hammond & Dubé (2012), were operationalized, and indicators selected based on existing frameworks for food and nutrition security and external literature. Using different databases, statistics were collected for the years 1995 and 2014 to examine change over time. While recognizing that the framework only represents a “selective abstraction of reality”, this study shows that there are multiple determinants of food and nutrition security in the Guatemalan case. The results highlight the importance of climate vulnerability and the intergenerational component of health. Coupled with processes of poverty, inequality and economic liberalization, and context-specific factors such as land-right disputes and a high percentage of indigenous people, these factors show that food and nutrition security requires a systems approach. The study also indicates that this particular framework leaves out important socio-political aspects and the household level. In sum the framework does shed light on the complexity related to food, health and sustainability, but needs to be further operationalized to have practical value for policy makers and practitioners.

Keywords: food and nutrition security, the double burden of malnutrition, Guatemala, systems thinking, a systems framework for food and nutrition security, interconnectedness

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1 Introduction

Global obesity levels are increasing at an alarming rate. Worldwide obesity rates have more than doubled since 1980 and 1.9 billion adults were defined as overweight in 2014 (WHO, 2015). At the same time, old persistent problems such as hunger are still of major concern in many developing countries (Jerneck et al., 2011). 795 million people are still undernourished (WFP, 2016), while over 2 billion suffer from “hidden hunger”; deficiencies in essential micronutrients (FAO, 2014). The abovementioned health related conditions all represent different forms of malnourishment and in many developing countries their co-existence creates a paradoxical situation of a double burden of malnutrition (Garrett & Ruel, 2005; Ramirez-Zea, Kroker-Lobos, Close-Fernández, & Kanter, 2014; Tanumihardjo et al., 2007). Whilst many developing countries in Latin America have experienced progress to reach the Millennium Development Goal (MDG) hunger targets, the opposite is occurring in Guatemala (FAO, 2015a). Here human health problems are linked to both high incidence of stunting and micronutrient deficiencies, but also to increasing rates of obesity; changes that are occurring across multiple scales and levels (Martorell, 2012; Ramirez-Zea et al., 2014).

Sustainability science is a transdisciplinary field of research that attempts to understand the complex interactions between wicked problems that intersect natural and social systems (Clark & Dickson, 2003; Jerneck et al., 2011; Kates, 2011; Miller, 2013). Food and nutrition security is threatened by various emerging sustainability challenges such as climate change, land degradation and water scarcity (Jerneck et al., 2011). The emergence of these new challenges can be seen as “escalating geo-bio-physical phenomena and processes with deep social impacts” (Jerneck et al., 2011, p. 71). As such, they have a significant impact on not only the ability to meet the growing demands of food, but how food, health and sustainability are intertwined in a complex web of relationships, spanning multiple scales, levels and disciplines (Andersson & Gabrielsson, 2012; Cash et al., 2003; Ericksen, 2008).

The complex nature of food and nutrition security requires an approach that expands previous conceptualizations. Systems thinking has been regarded as one such valuable approach; some expand upon the understanding of a food system (Ericksen, 2008; Pinstup-Andersen, 2012), whereas others find it necessary to conceptualize the food and nutrition security system (Ecker, 2012; Hammond & Dubé, 2012). While these conceptualizations provide new insights into the complex determinants of food and nutrition security, they have not been extensively tested on a particular case or context. As they have been confined to the theoretical or conceptual space, there is a need to assess their practical applicability. This thesis aims to fill this gap.

1.1 Research objective

Choosing Hammond & Dubé's (2012) systems framework to capture food and nutrition security, the objective of this thesis is to assess the applicability of the framework using Guatemala as a national case study. By doing so, it aims to highlight the multiple determinants of food and nutrition security in Guatemala, while also examining how such an approach contributes to the understanding of food and nutrition security. Using the framework by Hammond & Dubé (2012), this study is guided by the following research questions:

- What are the multiple determinants of food and nutrition security in Guatemala?
- How are the multiple determinants of food and nutrition security in Guatemala interlinked?
- In what ways does this systems framework contribute to the understanding of food and nutrition security?

A systems approach is an established tool within sustainability science (Miller, 2013; Ness, Urbelpiirsalu, Anderberg, & Olsson, 2006; Wiek, Withycombe, & Redman, 2011). The framework presented by Hammond & Dubé (2012) represent systems thinking as not only a tool for analysis, but also a way of portraying the world. This thesis aims to follow this approach and analyze how this can contribute to a better understanding of a wicked sustainability problem.

2 Background to the research problem

As touched upon in the introduction, this research approaches food, health and nutrition as a complex web of interactions. As a first step, the rest of this chapter will be dedicated to map out the elements that contribute to this complexity.

2.1 The double burden of malnutrition – a global health challenge

Portrayed as “the climate change of public health” (BBC, 2007), obesity is considered one of the most neglected public health concerns (Rayner & Lang, 2012). Overweight and obesity have historically been seen as problems of developed countries, however low- and middle-income countries are experiencing a marked increase in obesity and overweight (Chopra, Galbraith, & Darnton-Hill, 2002; Popkin & Doak, 1998; Popkin et al., 2013; Tanumihardjo et al., 2007; Uauy, Albala, & Kain, 2001), which is now approaching levels found in high-income countries (Popkin & Slining, 2013). Overweight and obesity are today linked to more deaths than underweight (WHO, 2015), confirming the need for urgent attention to this public health problem. While obesity levels increase in developing countries, “old” problems such as hunger (Jerneck et al., 2011), undernutrition and micronutrient deficiencies still persist. Malnourishment has often been associated with hunger; however it can also encompass obesity, as the term can be defined as “poorly or wrongly fed, having a poor or inadequate diet” (Tanumihardjo et al., 2007, p. 1966). This is prevalent in developing countries, which have diets that often contain sufficient calories to meet or exceed energy requirements, but lack sufficient nutritional quality (Tanumihardjo et al., 2007). As such, the abovementioned conditions are all manifestations of different forms of malnourishment.

Many countries today therefore face a double burden of malnutrition, which is characterized by the presence of both undernutrition and obesity (WHO, 2015). When occurring at the household level, this is typically exemplified by an obese/overweight mother and an undernourished/stunted¹ child (Lee, Houser, Must, de Fulladolsa, & Bermudez, 2012; Ramirez-Zea et al., 2014; Wong et al., 2015). The double burden can also occur on a national (Kroker-lobos, Pedroza-tob, Pedraza, & Rivera, 2014; Mendez, Monteiro, & Popkin, 2009) and individual level (Fernald & Neufeld, 2007). The paradoxical situation creates increased public health challenges for developing countries, as policy makers today cannot assume that households with undernourished children simply are in need of “more food” (Garrett & Ruel, 2005), as this may exacerbate obesity problems within the same household.

¹ Stunting, or low height-for-age, is failure to reach linear growth and is often defined as a height more than two standard deviations below the World Health Organization (WHO) Child Growth Standard median (WHO, 2016a)

2.2 The nutrition transition

Increasing rates of obesity are associated with a global change in diet, combined with an urban lifestyle (WHO, 2015; Popkin & Doak, 1998; Popkin et al., 2013; Uauy et al., 2001). The change in diet is often referred to as the nutrition transition, a term introduced by Popkin (1993). He identifies a general convergence towards a diet high in saturated fat, sugar and processed food, and low in fiber, fresh fruits and vegetables, often referred to as the “Western diet” (Popkin, 1993). The nutrition transition and increasing obesity levels are followed by a shift in disease patterns; from infectious diseases to diabetes and other non-communicable diseases (Chopra et al., 2002; Popkin., 2002).

The nutrition transition cannot be examined as an isolated process, but rather a phenomenon that transcends diet and occurs within a certain historical and socio-cultural context (Caballero & Popkin, 2002; Hawkes, 2006; Rayner & Lang, 2012). It is often interlinked with two broader historical transitions: the demographic and epidemiological transition (Caballero & Popkin, 2002; Popkin, 1993; Popkin, Monteiro, & Swinburn, 2013). The demographic transition is defined as “the shift from a pattern of high fertility and high mortality to low fertility and low mortality”, characteristic of an industrialized society, whereas the epidemiologic transition is the shift from a pattern of infectious diseases associated with malnutrition, hunger and poor sanitation to a pattern of degenerative and chronic diseases associated with an urban and sedentary lifestyle (Popkin, 1994, p. 286).

The nutrition transition is today prevalent in many developing countries and certain characteristics make their situation unique (Popkin, 2002; Schmidhuber & Shetty, 2005). Firstly, the speed of change is rapid; in many developing countries the shift to a more industrialized economy has occurred over 10-20 years, while in Europe and other developed countries this change took several decades (Popkin, 2002). Secondly, the coexistence of undernutrition and obesity is specific to many developing countries, a factor that can be partially explained by this rapid change (Popkin, 2004). Thirdly, there is an intergenerational relationship between mother and child whereby the nutritional status of mothers influences a child’s nutrient absorption and susceptibility to diseases (Schmidhuber & Shetty, 2005). Although contested, a fourth trend suggests that certain ethnic groups are genetically predisposed to certain diseases (Neel, 1962), which can help to explain why diabetes levels are particularly high among some indigenous communities (Ramirez-Zea et al., 2014). Lastly, the capacity of public health services in developing countries is already low and the increasingly complex health conditions therefore pose significant challenges (Schmidhuber & Shetty, 2005).

2.3 The case of Guatemala

The occurrence of a rapid nutritional transition in Latin America was identified already a decade ago (Martorell, Khan, Hughes, & Grummer-strawn, 1998; Uauy et al., 2001) and obesity is today a major problem in many Latin American countries (Kain et al., 2014). On the other hand, FAO (2015a) praises the region's recent improvement in meeting the MDG hunger target. All countries in the region have made significant progress, with the exception of Guatemala, where hunger levels are higher now than in 1990-92. Guatemala faces significant health challenges related to nutrition. The level of stunting among children under five are among the highest in the world (Ramirez-Zea et al., 2014). At the same time, adult national obesity rates are high; almost 50 percent of all women of reproductive age are obese (Ramirez-Zea et al., 2014). Considering these statistics, it is therefore not surprising that the existence of the double burden of malnutrition is identified by several studies (Lee, Houser, Must, de Fulladolsa, & Bermudez, 2010; Lee et al., 2012; Ramirez-Zea et al., 2014) and on a household level found to be one of the highest worldwide (Garrett & Ruel, 2005). This unique situation makes Guatemala an excellent case study site to examine the complexity of food and nutrition security. Moreover, the decision to use a systems approach as an analytical tool for this research is deemed both appropriate and justified, in order to fully capture the multitude of factors involved and their inter-linkages and feedbacks.

3. Conceptual framework

Malnourishment, including undernutrition and obesity, is a manifestation of food insecurity (Hammond & Dubé, 2012). The definition of food security most commonly used stems from the 1996 FAO World Summit on Food, which states that “food security exists when all people, at all times have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (FAO, 1996, p.1). Based on this definition, the FAO has identified four dimensions of food security: availability, accessibility, utilization and stability (FAO, 2008). This conceptualization of food security is widely used today, guiding a wide range of policies, frameworks and measurements related to food challenges worldwide. In literature, however, food security is a much-debated term and has over time developed multiple meanings. The following section will provide a short historical overview to understand the origins of the concept and present current debates around food and nutrition security.

3.1 From food security to nutrition security

Current underlying concepts of food security are traceable to the 1940s and focused on increased productivity of major staples (CFS, 2012; Shetty, 2015). Unstable prices and supply during the food crisis in the 70s directed attention towards the importance of an adequate food supply (Shetty, 2015). Sen (1981) challenged the focus on food supply, by demonstrating how people often became food insecure not as a result of food unavailability, but because access to food was constrained. Understanding hunger in terms of entitlements, Sen (1981) emphasized the need to consider food security in relation to social, cultural and economic aspects, specifically focusing on poverty and lack of income (CFS, 2012).

The term nutrition security was introduced in the 1990s (Shetty, 2015; UNICEF, 1990). It emphasizes that individual food security does not necessarily lead to adequate nutrition, but rather is dependent on several non-food factors, such as access to clean water and sanitation facilities, care practices, overall health status and the prevalence of infectious disease (Pinstrup-Andersen, 2009; Shetty, 2015; UNICEF, 1990). The focus on nutrition shifts attention from not only the household level to the individual level, considering the human body’s ability to utilize and ingest food, but also to food quality and appropriate nutrient intake (Gross, Schoeneberger, Pfeifer, & Preuss, 2000; Shetty, 2015).

3.1.1 Defining food and nutrition security

Currently the terms food security, food security and nutrition, and food and nutrition security are being used interchangeably, leading to lack of consistency across disciplines and languages (CFS, 2012; Acharya et al., 2014). “Food security and nutrition” is often used to emphasize that different, but complementary actions are needed in order to achieve food security and improved nutrition outcomes (CFS, 2012). However, this thesis deliberately uses “food and nutrition security”. The term emphasizes how food security and nutrition security should be integrated as one single unified goal, where advocates argue for including nutrition in food security policies and programmes (CFS, 2012). It can be defined as follows;

“Food and nutrition security exists when all people at all times have physical, social and economic access to food, which is safe and consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life” (CFS, 2012, p. 8).

3.2 The multiple determinants of food and nutrition security

Food and nutrition security is a complex issue with multiple interrelated determinants at various levels and scales (Andersson & Gabrielsson, 2012; Ericksen, 2008; Hammond & Dubé, 2012). Even though the inclusion of nutrition has led to an increased emphasis on non-food factors, in the debates on how to address food and nutrition insecurity, agriculture and food production are still dominating the paradigm (Shetty, 2015). Analyzing the food system can be one such approach, whereby specific activities from production to consumption are analyzed (Ericksen, 2008). Recently, factors beyond agriculture have become more important (Ecker, 2012; Ericksen, 2008; Ericksen et al., 2009; Hammond & Dubé, 2012); thus, there is a growing recognition for the need to move beyond agricultural practices in order to improve food and nutrition security (Ericksen, et al. 2009). Whilst the current climate change debate has redirected attention back towards the agri-food system, it stresses how this system contributes to, and is being affected by, larger phenomena such as global environmental change (Ericksen et al., 2009). These efforts are occurring under the premise that food and nutrition security cannot be addressed solely through the agri-food system, but necessitates an integrated and expanded approach, which considers multifaceted determinants (Ericksen, 2008; Hammond & Dubé, 2012).

Hammond & Dubé (2012, p. 12356) exemplify this stance by stating that “interactions across and between levels and systems are critical drivers of ultimate dynamics of food and nutrition security”.

The multiple determinants of food and nutrition security require an equally complex approach to how food and nutrition security is being measured. There exist a wide range of measurements and frameworks to draw upon, which will be discussed below.

3.3 Measurements and frameworks

Efforts to measure, define and locate food and nutrition security have drawn criticism; however dynamic approaches are emerging. There are currently over 450 indicators and a multitude of indexes that measure the food and nutrition security status of any group or individual (Shetty, 2015). Indicators differ greatly in purpose, the definition they are based on, the levels they target and which aspects they aim to measure (Jones, Ngure, Pelto, & Young, 2013). They are, however, usually based on the four dimensions of food security; availability, access, utilization and stability, and often situated within three levels: the individual, household and macro level (FIVIMS, 2002; Jones et al., 2013; Pangaribowo et al., 2013).

Many current frameworks have a linear conceptualization of food and nutrition security, which fails to capture dynamic cross-level interactions and feedbacks. Most frameworks for food and nutrition security originate from the 1990 UNICEF framework on causes of malnutrition and death in women and children (Ecker, 2012; Pieters, 2013). The framework distinguishes between the individual level, the household/community level and the societal level, which respectively represent three different categories of causes; immediate, underlying and basic causes (UNICEF, 1990). The framework portrays a unidirectional chain of influence flowing from the macro to the micro level and do not include feedbacks and interlinkages between the different levels, representing a conventional way of thinking about relationships Richmond & Peterson (2001). The UNICEF framework fails short in its analysis on food quality and the impact this has on malnutrition through obesity (Pangaribowo et al., 2013). Considering rising levels of obesity, it has been argued for the need for a greater inclusion of nutrition (Kanter, Walls, Tak, Roberts, & Waage, 2015; Pinstруп-Andersen, 2009, Pinstруп-Andersen, 2014). When discussing the 2008 food crisis, Ecker (2012) questions the suitability of conventional frameworks for food related challenges. In particular Ecker (2012) argues for an extension of frameworks related to two aspects: the macro dimension of food and nutrition security and the influence of external stresses.

A systems approach is considered a promising way to fill the conceptual challenge of understanding the multiple determinants of food and nutrition security (Acharya et al., 2014; Ecker, 2012; Ericksen, 2008; Hammond & Dubé, 2012). Some find it necessary to expand the conceptualization of the food system (Ericksen, 2008; Kanter et al., 2015), while others attempt to conceptualize the food and nutrition security system (Ecker, 2012; Hammond & Dubé, 2012). The systems framework for food and nutrition security proposed by Hammond & Dubé (2012) is such an approach.

4. Analytical approach

4.1 Philosophy of science

This thesis is guided by a critical realist approach. An essential feature of critical realism is the belief that there is “a world existing independently of our knowledge of it” (Sayer, 2000, p. 2). Humans can never understand what this world really is, but can try to make sense of it in different ways (Sayer, 2000). Sayer (2000) therefore sees social scientists as having the role of construing rather than constructing the world, in attempting to understand the complex, open and messy character of social systems. This leads to different incorrect, yet credible, conceptualizations of the world. The importance of combining different ways of knowledge and learning is emphasized by sustainability science (Kates et al., 2001), making critical realism a suitable approach for this thesis.

Critical realism offers an alternative to other assumptions about what the world is (Sjöström, 2015), as it can be argued that “we have no access to what the world is, to ontology, only to descriptions of the world...that is to say, to epistemology” (Checkland in Mingers, 2006). Descriptions of the world can be called mental models; “a simplification of how the world works around us”, which we use to learn, understand and analyze situations and make decisions (Haraldsson, 2000, p. 7). Mental models can never provide a true picture of reality; “all models are wrong, but some are useful” (Deming in Richmond & Peterson, 2001, p. 5).

4.2 Systems thinking

An abstraction that challenges conventional mental models is systems thinking (Haraldsson, 2000). Systems thinking emerged within biology in the 1940s (Checkland, 1999) and has since developed in multiple directions. Following ideas from critical realism, a system does not provide a true picture of the world, but “may or may not turn out to be useful as a descriptive device for making sense of the real world wholes” (Checkland, 1999, p. 48). Systems thinking represents a specific way of structuring logic, which attempts to understand interactions between different elements situated in a web of relationships (Haraldsson, 2000). By doing so, it constructs a mental model focused on portraying complexity in a logical and understandable way (Haraldsson, 2000; Richmond & Peterson, 2001). A systems approach is useful when looking at problems within sustainability science, as understanding the interactions between natural and social systems requires understanding the whole system itself, not only components of it (Clark & Dickson, 2003). Recognizing that a system is more than the sum of its parts is one of many core systems concepts (Checkland, 1999; Meadows, 2008).

4.2.1 Mental models within systems thinking

A mental model using systems thinking differs from the conventional view on how relationships are manifested. Instead of causal factors working independently on the effect, they are all part of an “intertwined set of relationships”, situated in a “web of reciprocal causality” (Richmond & Peterson, 2001, p. 20). The systems framework by Hammond & Dubé (2012) utilized in this thesis can be viewed as such a web, portraying linkages between different systems and the individual. The linkages do not only occur from the system to the individual, but also from the individual to the system, showing how they shape each other in bidirectional ways. These relationships are also not linear, but often constitute reinforcing feedback loops. A feedback loop “denotes a causal chain, wherein a change in one part of the system affects another component, which, in turn, affects the original component” (Hammond & Dubé, 2012, p. 12358).

Due to the complex nature of food and nutrition security, a systems approach “offers the potential to provide a deeper analytical understanding of the dynamics ultimately driving the food and nutrition of individuals and populations” (Hammond & Dubé, 2012). In order to understand and come up with solutions to complex problems, linear and mechanistic thinking should be replaced by an organic and holistic way of thinking.

The application of systems thinking can be grouped into various categories, such as soft and hard systems approaches. This thesis is specifically guided by the soft systems approach, which focuses on learning about, exploring and understanding social processes, as opposed to finding blue-print solutions to specific problems (Checkland, 1985). Exploring systems also means exploring the layered structure of them, realizing that the parts confining the system can be smaller wholes, or smaller systems in themselves (Checkland, 1999). This can be exemplified by the food and nutrition security system presented by Hammond & Dubé (2012), which include three separate systems. A hard systems approach often entails using simulations, modelling and other computer techniques to address quantifiable problem (Zexian & Xuhui, 2010).

4.3 Hammond & Dubé's (2012) systems framework for food and nutrition security

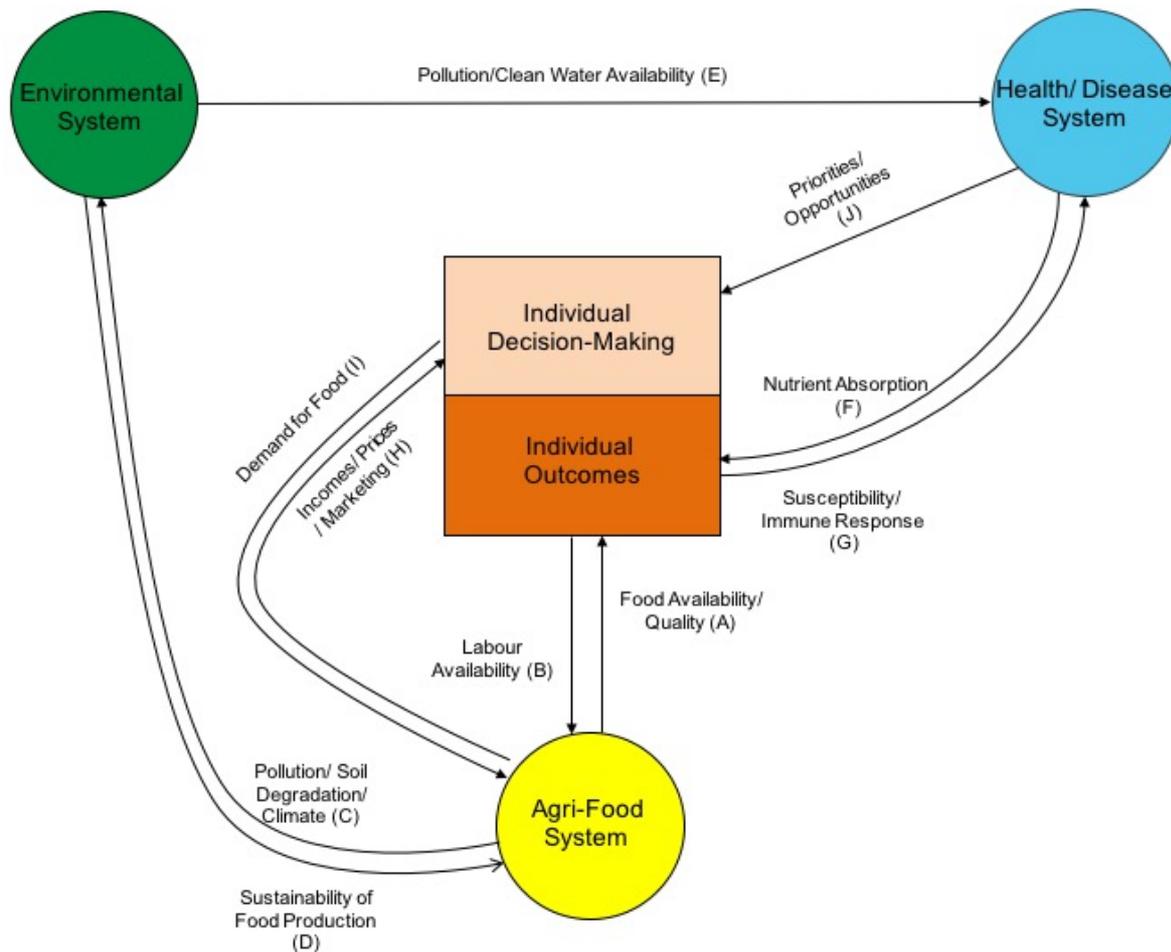


Figure 1: A systems framework for food and nutrition security. Adapted from Hammond & Dubé (2012)

The systems framework for food and nutrition security developed by Hammond & Dubé (2012) is used as an analytical lens to the case of Guatemala, and can be distinguished from other frameworks for food and nutrition security by using a systems approach. Although systems thinking aims at capturing the complex whole, a system still represent “a selective abstraction of reality” (Richmond & Peterson, 2001). While there exist no system boundaries in the real world, where everything is connected to everything, boundaries have to be set when doing systems analysis in order to provide clarity (Meadow, 2008). The boundaries are set depending on the purpose of the analysis and the problem discussed. Hammond & Dubé (2012) includes *three* systems in their framework, arguing that the agri-food system, environmental system and the health and disease system are the most important drivers of food and nutrition security, thus representing the boundaries of the framework. The inclusion of three *separate* systems acknowledges that influential factors outside the immediate food system are

part of “distinct dynamic systems” themselves (Hammond & Dubé , 2012, p. 12356), made up of important internal dynamics and feedback loops. This may represent a different and more advantageous approach than other frameworks trying to capture the complexity of food and nutrition security.

The framework can be considered a mental model of food and nutrition security; “a process of enquiry into the world” (Checkland, 2000, p. 17). When constructing a mental model it is fundamental to consider which elements to include and how the relationship between them is represented (Richmond & Peterson, 2001, p. 10). The framework from Hammond & Dubé (2012) includes elements at both system and individual level. The three systems are identified as key drivers of food and nutrition security and are centered around two points of influence: on influences via individual decision-making, such as what to purchase, consume and prioritize; and influences on individual outcomes irrespective of decision-making, such as health status and food availability (Hammond & Dubé, 2012).

Interdisciplinarity is a core component of systems thinking (Haraldsson, 2000; Meadows, 2008) and Hammond & Dubé (2012) argue that the three systems presented are mainly being studied and approached in isolation, without any attention given to linkages and relationships between them. Due to the complexity of food and nutrition security, a systems approach is argued to be of great value, as it will “connect interrelated systems across disciplinary lines, and explicitly examine interaction effects and feedbacks” (Hammond & Dubé, 2012, p. 12357). The relationships between the elements in Hammond & Dubé's (2012) study are therefore presented as 10 key linkages including several feedback loops, which represent essential ways in which the systems and the individual assert influence on each other. Hammond & Dubé (2012) argue for the framework to be used as a focus for new data collection and put emphasis on the value of systems modelling, as this method has been extensively used within some of the systems, but has to little extent been applied to food and nutrition security in a transdisciplinary manner.

4.3.1 Boundaries of the systems

The agri-food system is identified as a central driver of food and nutrition security (Hammond & Dubé, 2012). Taking inspiration from Ericksen (2008), Hammond & Dubé (2012 p. 12356) conceptualize the agri-food system as “a series of interrelated processes, including production of raw food materials through farming and raising of livestock, processing and packaging for consumption, distribution and utilization by consumers”. Emphasis is put on how the structure and dynamics of agribusinesses are

shaped by economic growth, realizing that their role and importance change during different stages of economic development (Hammond & Dubé, 2012).

Hammond & Dubé (2012) do not provide a clear definition of the environmental system, rather they identify three dynamic pathways which they see as having great influence on food and nutrition security and can thus be viewed as the boundaries of the system. These are the sustainability and future potential of agricultural food production, the availability of water, and climate effects (Hammond & Dubé, 2012, p. 12360). Whilst not providing a concrete definition, Hammond & Dubé (2012) use the health and disease system to situate the complexity and interrelatedness between nutrition, health and epidemiology. The emphasis is put on infectious diseases such as malaria, HIV and diarrheal diseases, which have important linkages to nutrition outcomes.

5 Methodology

5.1 Research approach

This study adopts a case study design, which can be defined as an “empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context” (Yin, 2009, p. 18). Involving collection and analysis of data, case study research focuses on how a particular phenomenon occurs within a given situation (Bryman, 2015). The lack of research testing new frameworks for food and nutrition security prompted the choice of a case study design, as this could apply the framework to a “real-life context”. Ericksen (2008, p. 243) also argue that “a systematic approach to analyzing integrated food systems through the use of case studies can reveal critical processes and factors that govern them”. To further examine these processes over time, the linkages in the framework by Hammond & Dubé (2012) were measured for both 1995 and 2014.

A literature review on the various concepts utilized in this thesis was conducted to get an overview of current debates around food and nutrition security, and the multiple ways it is being measured. This was done through searching different scientific databases such as LUB Search and Scopus, using relevant key words such as “food and nutrition security”, “nutrition transition”, “the double burden of malnutrition”, “food security indicators”, “systems thinking” and “food systems”. Through searching the literature, Guatemala came up as an interesting arena for studying food and nutrition security, whilst the systems framework presented by Hammond & Dubé (2012) was found as an innovative way of doing it.

5.2 The Hammond framework as both a tool and a mental model

The framework by Hammond & Dubé (2012) represents not only the lens for analysis, but also the specific research design. A research design can be said to be a “blueprint” for the research, addressing problems such as “what questions to study, what data are relevant, what data to collect and how to analyze the results” (Philliber, Schwab, & Samsloss in Yin, 2009, p. 26). The framework provides guidance on these questions and therefore represents the approach taken by this study. However, ways in which to measure the identified linkages are not specified by Hammond & Dubé (2012), thus the following section will provide some clarity on how this was done in this case study on Guatemala.

5.3 Indicator selection

The linkages between the three systems and individual food and nutrition outcomes can be seen as “conceptual indicators”, as they are only broadly described by Hammond & Dubé (2012) and therefore require further operationalizing to be measurable on a national level.

The selection of indicators attempted to follow the description given by the framework; however, where this was deemed insufficient, external literature was consulted. It was used to provide guidance regarding two challenges; how to measure certain linkages and, where indicators were abundant, which ones to choose. The selection of indicators for this study drew heavily upon indicators utilized by other frameworks and measurements related to food and nutrition security, of which these were found particularly helpful: recommendations for national indicators provided by Food Insecurity and Vulnerability Information Mapping System (FIVIMS, 2002), various indicators used in statistical pocketbooks by the FAO (FAO, 2014; FAO, 2015b) and the systematic presentation of food and nutrition security indicators by Pangaribowo et al. (2013). Figure 2 illustrate a brief overview of the indicators identified, collected and analyzed in regard to the Guatemalan case.

The data collected on factors contributing to food and nutrition security in Guatemala come from a variety of different sources, but primarily from the World Data Bank and the FAO. Although, the national Guatemalan statistical website did provide some data, lack of data for many indicators and a poorly developed website made it largely unviable for this study. The following section provides further description of the indicator selection process for each system.

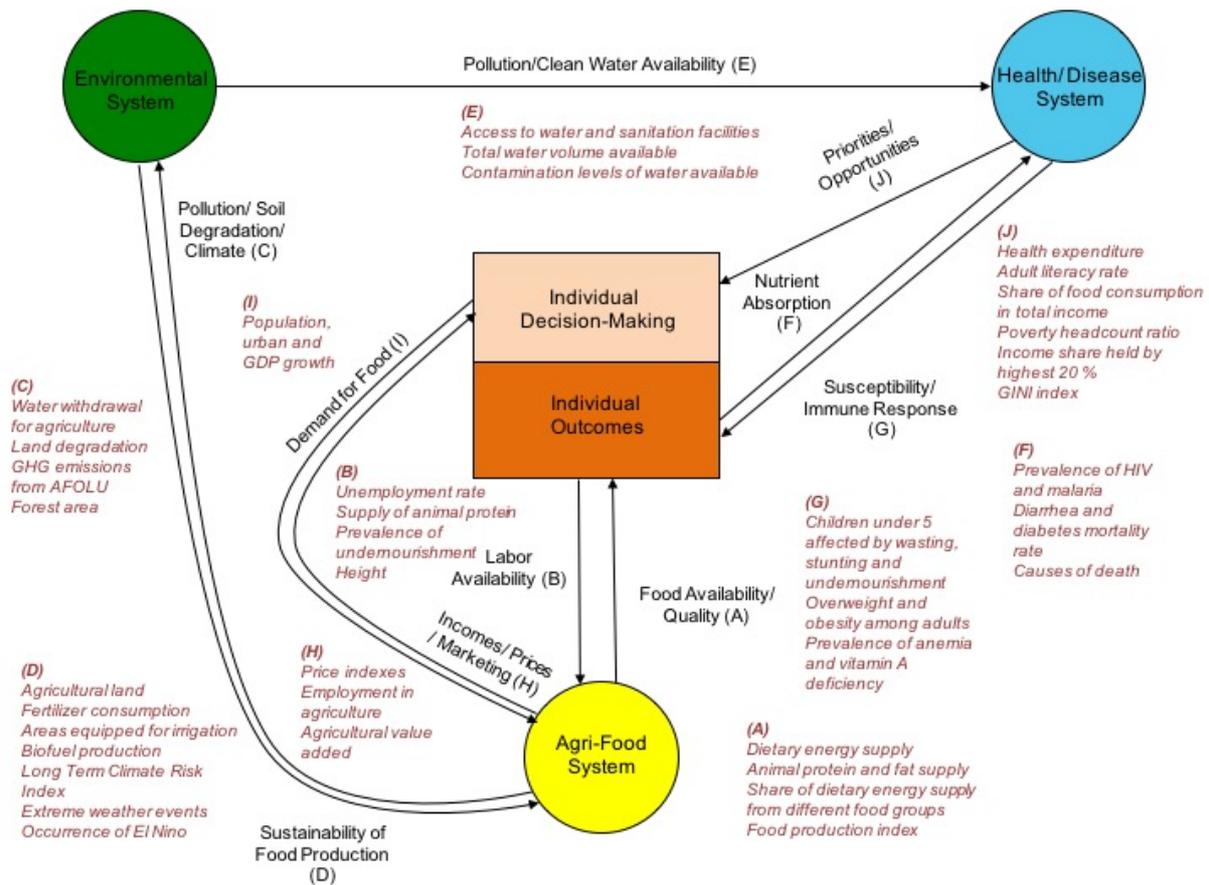


Figure 2: Indicators used to analyze food and nutrition security in Guatemala. Adapted from Hammond & Dubé (2012)

5.3.1 The Health and disease system

The linkages included in the health and disease system are (F) *Nutrient Absorption*, (G) *Susceptibility/Immune Response* and (J) *Priorities/Opportunities*. The relationship between nutrition and disease is “complex and bidirectional” (Hammond & Dubé, 2012; Müller & Krawinkel, 2005; Schaible, & Stefan, 2007). Infectious diseases can lead to malnourishment, which further increases susceptibility of infection and transmission, situating poor health and poor nutrition in a vicious feedback loop (Hammond & Dubé, 2012). Nutritional status during pregnancy and the first two years of life is deemed to have most impact on further health, growth and development (Hoddinott, Maluccio, Behrman, Flores, & Martorell, 2008; Pangaribowo et al., 2013; Pinststrup-Andersen, 2012), thus many of the indicators in this system cover women and children.

In linkage (F) *Nutrient Absorption*, Hammond & Dubé (2012) put emphasis on the prevalence of diarrheal disease, HIV and malaria. These diseases are included as indicators, as they also occur in other measurements of food and nutrition security (FIVIMS, 2002; Pangaribowo et al., 2013)

Malnourishment might manifest through infectious diseases (Hammond & Dubé, 2012); cause of death is therefore regarded as an indicator. Hammond & Dubé (2012) do not include non-communicable diseases in this linkage. Considering the global trend in disease patterns towards non-communicable diseases this study finds it important to include this as an indicator.

Linkage (G) *Susceptibility/Immune Response* is understood as nutrition status. Wasting, stunting and underweight among children under five are prevalent indicators of this (Pangaribowo et al., 2013; FIVIMS, 2002; FAO, 2016), along with measures of various micronutrient deficiencies, of which vitamin A deficiency and anemia are most prevalent (Pangaribowo et al., 2013, FAO, 2014; UNICEF, 1990). All of these indicators are therefore included in this study. The prevalence of overweight and obesity is included by some (Pangaribowo et al., 2013). Considering the rising global obesity trends, it is considered important to include this factor.

According to Hammond & Dubé (2012, p. 12358) health status can affect opportunities regarding employment and income through individual decision making, while also altering relative priorities and spending. Linkage (J) *Priorities and Opportunities* can therefore examine aspects related to education, health care services and income/poverty. Access to health care services and income (Ecker, 2012; Babu, Gajanan, & Sanyal, 2014) are both considered to impact relative spending and are therefore included as indicators. Education is also considered in this linkage; not only because of implications for employment opportunities and income, but also due to its relationship with nutritional status (Black et al., 2008; Ecker, 2012).

5.3.2 The Environmental system

The environmental system includes linkage (E) *Pollution/Clean Water Availability* and (D) *Sustainability of food production*. Environmental dynamics can impact health through pollution and the available amount of water, where access to clean water and sanitation are mentioned as specifically important, (Hammond & Dubé, 2012). These aspects are all included as indicators, and with the specific focus on water from Hammond & Dubé (2012), water contamination is considered a proxy for pollution.

In relation to linkage (D) *Sustainability of food production*, Hammond & Dubé (2012) identifies three main pathways the environmental system and climate influences the agri-food system; the sustainability of food production levels and methods, particularly emphasizing land availability; the available amount of water for irrigation; and climate effects such as temperature, precipitation and the prevalence of extreme weather events. Percentage of agricultural land is included as an indicator

for land availability, while area equipped for irrigation is a suitable indicator to measure water availability for irrigation. Fertilizer consumption is also considered in this study, as it can be an indicator of the sustainability of food production levels and methods (Foley et al., 2005). The El Niño-Southern Oscillation (ENSO) cycle is the most dominant factor for climate variability in Latin America (IPCC, 2007), causing changes in temperature and precipitation (FAO, 2009) and is therefore included as an indicator, in addition to the total number of extreme weather events.

5.3.3 The Agri-food system

Linkage (I) *Demand for food* is by Hammond & Dubé (2012) described as “the aggregation of individual decision making in response to price and quantity” (p. 12358). On a macro-level, the demand for food is seen to be a product of three key processes and as such will represent the indicators selected; population growth (Pieters, 2013), income and economic growth (Babu, Gajanan, & Sanyal, 2014; FAO, 2015b) and the rate of urbanization (Pieters, 2013, Pinstруп-Andersen, 2012).

Linkage (B) *Labour availability* focuses on the way in which health and nutritional outcomes influence worker productivity (Hammond & Dubé, 2012). The rate of unemployment is included as a measure of work force availability. This linkage will also be operationalized by short stature, due to an established relationship in literature between height and economic productivity and employment opportunities (Victora et al., 2008; Dalgaard & Strulik; 2011; Martorell, 2012). Better nutrition is found to raise productivity (Strauss, 1986) thus the prevalence of undernourishment is included.

The agri-food system shapes the quantity and quality of food available through production and distribution, constituting linkage (A) *Food Availability/Quality* (Hammond & Dubé, 2012). Dietary energy supply is included as a measurement of quantity in this linkage. Cereal yields and food production indexes have normally been used to measure food availability, however determining the share of energy supply from cereals and animal protein can move beyond cheap calorie sources (Pangaribowo et al., 2013, FAO, 2016). Additionally, they provide a more qualitative view on food availability and can be associated with processes of the nutrition transition. For these reasons, average fat supply, share of animal protein and share of dietary energy supply from cereals and other food groups related to the nutrition transition, such as meat, sugar and sweeteners, are therefore measured. Imports and exports will also be measured to represent the external and internal balances of a country, which are considered important on a macro level (Ecker, 2012, FAO, 2014). In order to understand change in food supply, it can be valuable to consider the distribution of total supply. Therefore, using Food Balance sheets from the FAO, which intend to present “a comprehensive picture

of the pattern of a country's food supply" (FAOSTAT, 2015), the distribution of food supply for some of the food groups measured are presented.

In linkage (H) *Income/Prices/Marketing*, food prices, advertising, marketing and income to farmers, represent other channels where the agri-food system influences food and nutrition outcomes (Hammond & Dubé, 2012). This linkage is partly understood as food accessibility and will therefore include common measurements such as; the food price index, the consumer price index and measures of food price volatility are common ways of measurements (Ecker, 2012; Jones et al., 2013; Pangaribowo et al., 2013). National measures farmers income were not found, but were replaced by indicators attempting to measure the value added of agriculture and the overall employment in the sector. Indicators to measure advertising and marketing were not found and were thus excluded from this study.

In linkage (C) *Pollution/Soil Degradation/Climate*, Hammond & Dubé (2012) consider the impacts of food production on environmental health, emphasizing pollution and soil degradation from intensive farming, water use, emissions of greenhouse gases and elimination of carbon reservoirs as important indicators for this linkage, which were thus included in this study. In addition, deforestation is believed to have significant impacts on the environmental system, and is therefore considered in this study (Ruano & Milan, 2014).

6 A systems approach to food and nutrition security – the case of Guatemala

The following section consists of three parts: first; a description of the results, second; analysis of the results and third; the research limitations of applying this framework using empirical data focusing on Guatemala. A complete presentation of the results can be found in Appendix 1. Guided by systems thinking and the emphasis on certain feedback loops and linkages by Hammond & Dubé (2012), this section aims to shed light on the multiple determinants of food and nutrition security in Guatemala and how they are interlinked, thus addressing research question one and two.

PART ONE: RESULTS

6.1 The health and disease system

The linkages included in the health and disease system are (F) *Nutrient Absorption*, (G) *Susceptibility/Immune Response* and (J) *Priorities/Opportunities*. Linkage (G) *Susceptibility/Immune Response* is understood as nutritional status and shows that the level of stunting among children under five in Guatemala has decreased since 1995 (FAOSTAT, 1995a), but still affected approximately one in two children in 2014 (FAO, 2014). Approximately half of the adult population was identified as either obese or overweight in 2014, a number significantly higher among women (56.2 percent) than men (47.6 percent) (World Data Bank, 2014c). The prevalence of anemia among children under five increased from approximately 34 percent (FAOSTAT, 1995a) to 47 percent (FAO, 2014) between 1995 and 2014, meaning that almost half of all Guatemalan children suffer from this micronutrient deficiency. Anemia among pregnant women decreased slightly, but almost 1/3 of all pregnant women suffered from this deficiency in 2014 (FAO, 2014).

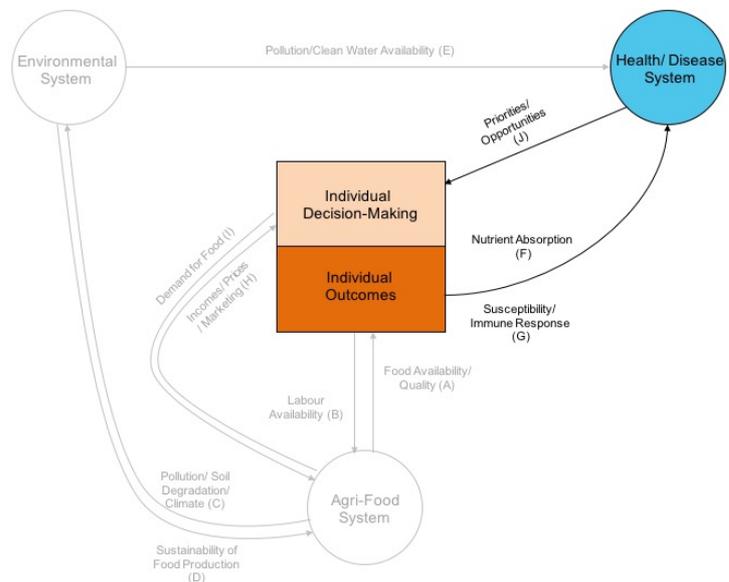


Figure 3: The Health and disease system. Adapted from Hammond & Dubé (2012)

Using data from the World Data Bank (2000a; 2012a), (F) *Nutrient Absorption* shows that number of deaths caused by communicable diseases, maternal, prenatal and nutritional conditions, have declined from 43 percent in 2000 to 34.4 percent in 2012. Non-communicable diseases, however, increased during the same period, causing 47.2 percent of all deaths in 2012 (World Data Bank, 2000a; 2012a). This occurred alongside an increased diabetes mortality rate, growing from 37.6 in 2005 to 54.8 in 2014 (INE, 2005; 2014). Approximately half of all deaths of children under the age of five (WHO, 2014) stemmed from diarrheal disease (13.9 percent) and acute lower respiratory infections (26 percent) and other communicable, perinatal & nutritional conditions (14.2 percent) in 2014.

Linkage (J) *Priorities/Opportunities* shows that the public health expenditure in Guatemala is low, only 37.8 percent of total health expenditure was provided by the public sector in 2013 (World Data Bank, 2013a). Guatemalans are therefore dependent on the private sector, where out-of-pocket health expenditure makes up 83.3 percent of private health expenditure (World Data Bank, 2013a). Guatemalan households also spend a significant amount of their economic resources on food; the share of food consumption out of people’s total income was as high as 44.6 percent in 2006 (FAOSTAT, 2006a). A majority of the population do not have sufficient economic resources in the first place, as 59.3 percent of the population was categorized as living below the national poverty line in 2014 (World Data Bank, 2014a), representing a surprisingly slight increase from 1995 (World Data Bank, 2014a). In 2011 Guatemala had a GINI index of 52.4 and the income share held by the highest 20 percent was almost 60 percent (World Data Bank, 2011b).

6.2 The environmental system

The environmental system covers (E) *Pollution/Clean Water Availability* and (D) *Sustainability of Food Production*. In Guatemala access to sanitation facilities has improved during the period studied, but, according to the World Data Bank (2014a) there are still significant differences between access to services in urban (77.5 percent) versus rural areas (49.3 percent) in 2014. While almost the entire population had access to an improved water source in 2014, there were still around 13 percent of

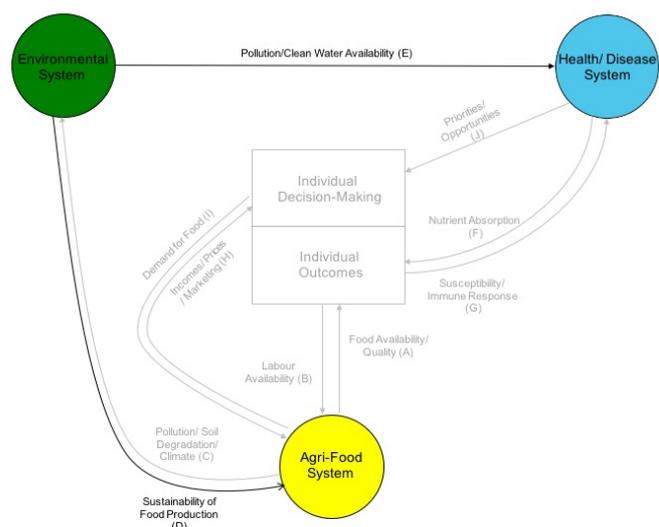


Figure 4: The Environmental system. Adapted from Hammond & Dubé (2012)

the rural population with no access (World Data Bank, 2013a). Only 65 percent of the total water volume was available for use in 2012 of which 40 percent is contaminated (PAHO, 2012), meaning that clean water can be considered a scarcity in Guatemala. Agricultural land as a percentage of total land area has decreased from 41.7 percent in 2000 to 34.72 percent in 2013 (World Bank Group, 2000; 2013). During this period, fertilizer consumption increased from around 100 kilograms per hectare arable land in 2002 to 255.5 kg in 2013 (World Data Bank, 2002a; 2013a). The relative area equipped for irrigation in Guatemala represented only 7.1 percent of total agricultural area in 2010 (FAOSTAT, 2010b). Moreover, Guatemala experienced 88 extreme weather events between 1995 and 2014, representing the 10th most affected country by extreme climate events during this period (Kreft, Eckstein, Dorsch, & Fischer, 2015).

6.3 The agri-food system

The linkages included in the agri-food system are (A) *Food Availability/Quality*, (H) *Incomes/Prices/Marketing*, (B) *Labour Availability*, (I) *Demand for Food* and (C) *Pollution/Soil Degradation/Climate*. The results indicate that the Guatemalan population has experienced a change in diet over the last 25 years. The most significant change is seen in the consumption of cereals, which made up 57.2 percent of total dietary energy in 1995 (FAOSTAT, 1995c), whereas in 2014 it only accounted for 45.9 percent (FAO,

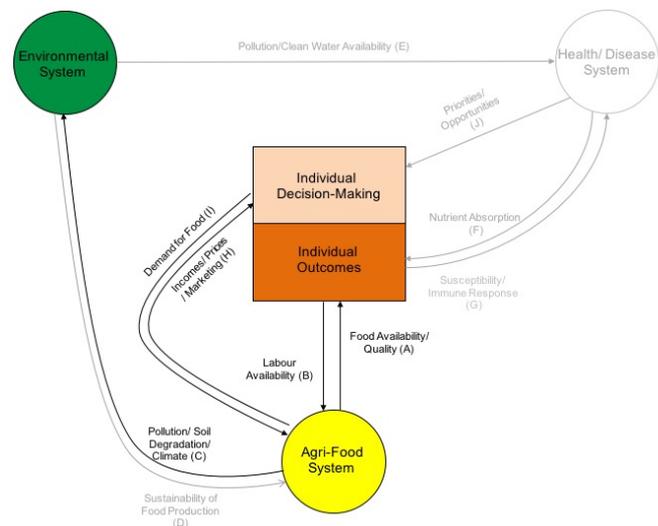


Figure 5: The Agri-food system. Adapted from Hammond & Dubé (2012)

2014). An increased share of dietary energy came from vegetable oils and animal fats in 2014 (FAO, 2014) and the average share of fat supply increased from 38.88 (FAOSTAT, 1995c) to 58 grams (FAO, 2014) per capita per day from 1995 to 2014. A slight increase in the share of animal protein is also evident (FAOSTAT, 1995c; FAO, 2014). The total amount of calories consumed per person per day was 2462 in 2014 (FAO, 2014), an increase of 186 calories from 1995 (FAOSTAT, 1995c).

Illustrated by the food production index (World Data Bank, 1995a; 2013a), more food is produced in Guatemala in 2013 than in 1995, but some significant changes in the composition of food supply is evident. Table 1 comprises data from FAOSTAT (1995c; 2013c), illustrating trade balances and the utilization of food supply for certain food groups. It reveals an overall shift from a reliance on domestic

production to a growing dependency on imports, in addition to an increased share of cereal supply going to food manufacturing and feed. 83 percent of maize supply came from domestic production in 1995, while this share decreased to almost 70 percent in 2013. During the same time imports almost doubled, reaching 30 percent of total supply in 2013. In 1995 almost all of the total maize supply was available for human consumption, but this significantly changed up until 2013, as food manufacturing and feed accounted for 42 percent of total supply, leaving only half available for human consumption. The total supply of both meat and vegetable oil increased, but a similar increase in exports of vegetable oils is evident.

Table 1: Food balance sheet of various food groups, 1995 and 2013 (Adapted from FAOSTAT, 1995c; 2013c)

Food Type	Year	Total supply (1000 metric tons)	Domestic production (% supply)	Import (% supply)	Export (% production)	Food for human consumption (% supply)	Food for manufacturing (% supply)	Feed (% supply)
Cereals, excluding beer	1995	1605	66.2	31.7	7.9	90.2	3.6	2.4
	2013	3216	51.2	48.1	8.4	62.9	18.4	16
Maize and products	1995	1211	83	15.4	5.4	91.6	3.1	0.5
	2013	2466	69.8	30.2	0.6	54.7	22.5	19.5
Vegetable oils	1995	62	41.9	80.6	29.7	53.2		
	2013	181	8.8	89.5	96.5	64.6		
Meat	1995	193	95.3	4.7	3.2	95.9		
	2013	443	72	28	7	95.7		

Guatemala experienced a low degree of unemployment, only 2.9 percent of the total population was registered as unemployed in 2014 (World Data Bank, 2014a). According to the Guatemalan National Survey of Maternal and Child Health, almost 1/3 of all women were shorter than 145 cm in 2008/2009, while this number was significantly higher among indigenous women, reaching 48.3 percent (Martorell, 2012). The prevalence of undernourishment among the Guatemalan population is the same for 1995 and 2014, constituting approximately 15.5 percent of the population (World Data Bank, 1995a; 2014a). (I) *Demand for Food* illustrate a growing Guatemalan population, rising urbanization and GDP growth; however, the annual growth rate for all indicators are lower in 2014 than in 1995 (World Data Bank, 1995a; 2014a).

People employed by agriculture significantly increased from 1990. In 2014 the sector employed 32.3 percent of the population and is one of the main sources of livelihood for the Guatemalan population (FAO, 2015). The added agricultural value decreased slightly from 2000 and constituted only 11 percent of GDP in 2014 (FAO, 2015).

PART TWO: ANALYSIS

The following discussion of the results is based on the three systems and crosscutting dynamics and feedback loops identified by Hammond & Dubé (2012). Realizing that there are multiple interlinkages and themes that could be discussed, the focus of this analysis will be on the most outstanding results. It does not aim to develop links of causality; rather it identifies possible correlations between different processes within the framework and draws upon conceptually established feedback loops using empirical findings. This is done by bringing in evidence from external literature identified to be significant components of the conceptual framework and the literature review.

6.4 The vicious cycle of malnourishment and infectious diseases

For Hammond & Dubé (2012), a core component of the health and disease system is the feedback loop between nutrition and infectious diseases; whereby malnutrition reduces immune function and increase susceptibility and severity of infectious diseases, which can further worsen nutritional status even when access to food is adequate (Müller & Krawinkel, 2005; WHO, 2016b). Developing countries usually have a high prevalence of infectious diseases, and high levels of stunting and anemia among children under the age of five, as well as deaths caused by diarrheal disease and acute lower respiratory infections, illustrate how this “complex and bidirectional” relationship between nutrition and infectious diseases (Hammond & Dubé 2012, p. 12359) is evident in Guatemala.

Infections such as diarrhea and acute lower respiratory infections often occur due to contaminated surroundings, poor hygiene practices, and water related challenges (PAHO, 2012; Global Water Partnership, 2013; WHO, 2016b), and can lead to stunting through malabsorption of nutrients and decreased immune function (Prendergast, 2015). Guatemala experiences severe water related challenges; the level of access to sanitation facilities among the rural population is low, while connection to a sewage system may not make the situation better, as not all of the waste entering the system are treated, causing flows of sewage into rivers and other water bodies and end up pollute drinking water supply (PAHO, 2012; Global Water Partnership, 2013). Considering 85 percent of the solid waste generated is disposed of without any proper treatment, this causes further contamination

(PAHO, 2012). These problems can be manifested in the high share of contamination of the available water seen in Guatemala.

Stunting and other forms of malnourishment in children can be caused by an insufficient supply of macronutrients (Müller & Krawinkel, 2005) and lead to increased susceptibility and transmission of diseases through a various of mechanisms, such as decreased immune function, reduced treatment response and increased oxidative stress (Katona & Katona-apte, 2008; Schaible & Kaufmann, 2007). Low breastfeeding and complementary feeding practices can also lead to stunting (Black et al., 2008) of which both have a low prevalence in Guatemala (Martorell, 2012).

6.5 The double burden of malnutrition – evidence of an epidemiological transition

The high levels of obesity and stunting indicate that the double burden of malnutrition exists on a national level in Guatemala. The study by Ramirez-Zea et al. (2014) also identifies the paradox at a household level. Illustrated by the results, this is followed by a change in disease patterns, indicating that Guatemala is in the middle of an epidemiological transition, experiencing facets from both ends of the transition. An increased share of Guatemalans live in urban areas, a change often linked to the epidemiological transition. While Hammond & Dubé (2012) put emphasis on the link between nutrition and infectious diseases, this illustrates how obesity and non-communicable diseases are of increased concern to Guatemala. The following section will therefore explore aspects that could be associated with this change and discuss how these emerging challenges might be situated within complex relationships.

6.5.1 A growing epidemic of diabetes

Diabetes is a growing health problem in Guatemala (Chary, Greiner, Bowers, & Rohloff, 2012) and an increase in the mortality rate might be associated with a growing prevalence of diabetes among the rural population, of which many are indigenous (Little, 2012). The health care system in Guatemala is in general considered to provide inadequate care and services, especially in rural and remote areas (Little, 2012). Medical costs are high, and diabetes treatment is often unavailable in these areas due to limited infrastructure and inconsistent supply of medicines (Chary et al., 2012). The results indicate that due to low public health and high private out-of-pocket health expenditures, coupled with a high share of food consumption in total income, diseases like diabetes may create certain trade-offs between providing the household with food or paying for necessary, but expensive, health care.

Socio-economic status and the cultural context place the indigenous population at a higher risk of such trade-offs. *Susto*, a feeling of anxiety, stress or fear which arises from a traumatic experience is by many Mayans believed to cause diabetes (Chary et al., 2012; Little, 2012). Due to a lack of health education, many rural indigenous communities have insufficient knowledge about the disease, making them vulnerable to various sources of medical advice, such as that herbal remedies can cure diabetes (Greiner, 2012). Additionally, modern health care practices are not sensitive to these beliefs, creating a mismatch and distrust between people and practitioners (Little, 2012). There also exists suspicion of the government due to historical oppression and language barriers between indigenous communities and medical practitioners (Little, 2012).

These socio-economic aspects may help to shed light on the growing mortality rate from diabetes in the country. However, examining changes in disease patterns and nutrition also require attention to the individual level. A human's ability to utilize food is an important determinant of food and nutrition security and can be influenced in various ways. The following section explores this level in more detail, putting specific emphasis on how nutritional outcomes of individuals may be influenced by previous generations.

6.6 The Intergenerational component of health

Malnutrition can be considered a life-cycle phenomenon (Benson in Pinstруп-Andersen, 2012); where the effect of undernutrition spans at least three generations (Victora et al., 2008), showing that there is a strong intergenerational component to health (Popkin et al., 2013). Two theories are specifically cited in the health science literature when trying to understand why some individuals are more susceptible to develop certain diseases; the thrifty genotype hypothesis and the thrifty phenotype hypothesis. The next chapter will engage with these theories in the context of the findings in Guatemala.

6.6.1 The thrifty genotype

The thrifty genotype hypothesis was first introduced by Neel (1962) and argues that some people may have a genetic predisposition for an efficient metabolism (Schmidhuber & Shetty, 2005). A diabetic genotype can develop because genes associated with insulin resistance is beneficial in times of food scarcity, as it helps to accumulate fat storage (Schmidhuber & Shetty, 2005; Little, 2012). Therefore, the overproduction of insulin of certain individuals may be a trace of past times of high food scarcity. Although the hypothesis is contested (Ave, 2008; Schmidhuber & Shetty, 2005; Southam, Soranzo, & Montgomery, 2009), it is mentioned as a possible cause for why developing countries, and particularly

indigenous populations within these countries, may suffer disproportionately from current dietary changes (Ramirez-Zea et al., 2014; Schmidhuber & Shetty, 2005). A disproportionate occurrence of diabetes among various indigenous populations may suggest such a genetic predisposition (Ramirez-Zea et al., 2014; Stern & Haffner, 1990). Considering the high percentage of indigenous among the Guatemalan population, the thrifty genotype hypothesis may shed light on the increasing rates of non-communicable diseases in the country.

6.6.2 *The thrifty phenotype*

Another hypothesis exploring the complex nature of nutrition and disease is “the thrifty phenotype” hypothesis (Barker, 1997). It argues that hunger or undernutrition during pregnancy may lead to changes in the development of the fetus so that food energy is more efficiently utilized later in life (Schmidhuber & Shetty, 2005). Considering that over half of all adult women in Guatemala currently are considered obese or overweight, and results indicate they are typically of short stature and anemic, “the thrifty phenotype hypothesis” may provide some valuable insights into the intergenerational relationship between mother and child. Furthermore, these aspects can have various implications for the next generation.

Through fetal overnutrition, maternal obesity is also suggested to place the offspring at a higher risk of later-stage obesity (Popkin et al., 2013). The prevalence of maternal anemia in Guatemala is high and can lead to: (i) decreased iron in the child, (ii) increased morbidity and neonatal, infant and maternal mortality, and (iii) increased risk of preterm birth and low birthweight (Martorell, 2012). Such micronutrient deficiencies may also result in increased obesity risk in the offspring (Fernald & Neufeld, 2007). Adult short stature in mothers is a risk factor for cesarean delivery (Black, 2008), and can be caused equally by an inadequate diet and infections during the intrauterine and early postnatal period (Victoria et al., 2008; Li, 2003). The prevalence of short stature in adult women in Guatemala therefore suggests that many most likely experienced an intrauterine period where their mother had an inadequate diet, however, the size of their mother can also be a contributing factor (Victoria et al., 2008). Therefore, yesterday’s nutrition problems can be seen as an important source of information for today’s obesity problems. Since almost 15 percent of the total Guatemalan population was considered undernourished in 2014, this warrants longitudinal studies from a research perspective.

6.7 From undernutrition to obesity

The complex nature of nutrition and health related challenges can not only be dealt with from a research perspective; it also necessitates policy makers to consider trade-offs in policy design, as the attempt to reduce undernutrition may have the “double-edged effect of increasing levels of obesity in those same countries” (Hammond & Dubé, 2012, p. 12359).

Promising efforts to address food and health related challenges are happening in Guatemala, and its National System for Food Security and Nutrition is seen as an example of a multisector and multiactor approach to food and nutrition security (SUN, 2015). The 2012-2016 Plan for the Zero Hunger Pact aims to reduce chronic and acute malnutrition in children, prevent seasonal hunger, promote food and nutrition security and prevent and respond to food emergencies due to climate change and natural disasters (Gobierno de Guatemala, 2013). However, there is no consideration of how this plan might impact or exacerbate the already high obesity rates in the country (Gobierno de Guatemala, 2013).

The attention to climate change in the Zero Hunger Pact is highly necessary in the context of Guatemala, an aspect that will be further elaborated upon in the following section.

6.8 Climate variability

Guatemala has a mountainous landscape and is dominated by a volcanic range spanning from the northwest to the southwest (Ruano & Milan, 2014). Due to differences in altitude it encompasses various climate zones, leading to great variations in temperature, rainfall and topography within the country (Ruano & Milan, 2014). This makes an analysis based on national level data non-generalizable. Still it is important to highlight the role various environmental factors can have on the different systems.

Vulnerability to climate change (Gobierno de Guatemala, 2013; Bosque, 2011), proneness to natural disasters and an influential El Niño cycle (FAO, 2009), threatens food and nutrition security and causes great socio-economic damage in Guatemala (Bosque, 2011). According to the Long Term Climate Risk Index, Guatemala was the 10th most affected country by extreme weather events between 1995 and 2014 (Kreft, Eckstein, Dorsch, & Fischer, 2015). Almost 40 percent of the population is exposed to five or more climatic threats simultaneously and over 80 percent of the GDP is located in at-risk areas (World Bank Group, 2016). Climate change is expected to increase temperatures, decrease precipitation and increase the magnitude and frequency of extreme weather events (Bosque, 2011). Population vulnerability to extreme weather is affected by population growth, poverty and

environmental degradation (Alexander, 1993), aspects of high prevalence in Guatemala. The risk from food and waterborne diseases is also likely to grow (IPCC, 2007); making Guatemala especially vulnerable due to already poor water management and high contamination levels. The country therefore faces severe climate related challenges.

In 2014 Guatemala experienced a severe drought exacerbated by the El Nino effect (World Bank, 2016), which often leads to decreased annual rainfall and an extended dry season in Guatemala (Pedreros et. al 2010). The drought (Box 1) is an example of how an extreme weather event impact water availability and agricultural incomes and increase the likelihood of insufficient nutrition due to decreased food production in poor regions (IPCC, 2007).

Box 1: A Case Study of the 2014 drought and its impact on food and nutrition security

The 2014 drought in Guatemala influenced food and nutrition security through several linkages, leading to a loss in food production, reduced incomes and increased prices of certain staple foods.

Parts of Guatemala are situated within the Dry Corridor (PAHO, 2012), the area in Central America most affected by natural hazards (FAO, 2016). The 2014 drought had severe impacts on these areas; losses between 50 and 100 percent for maize and beans were reported (WFP, 2015). Considering that subsistence agriculture is the main source of livelihood (FAO, 2016) and the share of food consumption in total income can be as high as 65 % for some households, farmers are highly vulnerable to climatic variations (WFP, 2015). Increased prices of maize and beans due to speculations in crop losses worsened the situation and lead to reduced food consumption and meal size and the consumption of cheaper and less preferred food (WFP, 2015).

Due to commercial reserves and good integration with international markets, no market shortage of maize and beans were recorded (WFP, 2015). This can be illustrated by the increase in imports showed in Table 1. Increased connection to the international market can therefore ensure a stable supply during crisis, potentially decreasing vulnerability to extreme events for a part of the population.

6.9 Water challenges – a crosscutting issue

Water is an important component in all three systems identified by Hammond & Dubé (2012) and the poor management of national water resources in Guatemala (USACE, 2000; Global Water Partnership 2013; PAHO, 2012) therefore creates challenges within various sectors. Guatemala has no general water bill or governing entity for the water sector, leading to a lack of policies and regulations, which manifests in unsustainable extraction levels (Global Water Partnership, 2013). In addition, the most populated areas in Guatemala do not correspond to areas with the most water resources (Global

Water Partnership, 2013), and as the population continue to grow and urbanization rates increase, pressures on already strained water supply will increase.

Even though access to clean water is high, a water quality survey of the piped water supply system in 2008 found insufficient chlorine levels and a high degree of bacterial contamination (PAHO, 2012). The national sewage system is of poor functionality (PAHO, 2012) and as shown in the results, access to sanitation facilities in rural areas are low. At the same time, approximately 85 percent of all solid waste was not treated in 2009, causing contamination of water bodies and rivers from waste and sewage, contributing to the prevalence of water borne diseases such as diarrhea (PAHO, 2012).

Most of the GDP generated from agriculture comes from agro-industrial crops associated with irrigated land (Global Water Partnership, 2013) and the sector is therefore economically dependent on water. The water related challenges are highly connected to dynamics within the agri-food system; deforestation increases runoff and infiltration (Global Water Partnership, 2013); soil erosion from intensification of agriculture increases sediments carried by water bodies, leading to decreased water quality; and eroded soils clogs drainage systems and water channels resulting in poor functioning and high maintenance costs (USACE, 2000).

6.10 The cycle of intensification and degradation

Increasing demand for food together with limited land available for agriculture can lead to unsustainable farming practices that degrade ecosystems, increase land degradation, pollutants and soil erosion, aspects that put further pressure on food production and limits the agricultural potential (Hammond & Dubé, 2012). This feedback loop is evident in Guatemala.

6.10.1 Intensification

Increasing demand for food and conflicting land right issues create a decreasing share of agricultural land in Guatemala (Pope et al., 2015; Wittman & Johnson, 2008). Illustrated by the results, GDP and population growth, and a rising urban population, result in greater food demand. Land available to meet this growing demand is linked to conflicts about land rights in the country. Expropriation of indigenous land in the 1990s created an economic elite owning most of the land and while other countries in Latin America went through redistributive land reforms, this did not happen in Guatemala, leaving the rural population with inadequate land access (Krznicaric, 2006). As a result, traditional sustainable farming practices such as the use of fallow periods, are being abandoned for more intensive cultivation (Pope et al., 2015; Wittman & Johnson, 2008). Previously, crops experienced

fallow periods of five to 20 years to let the soil recover. Recently, increasing demand for food has led to a shortening of fallow periods and the application of fertilizers in order to keep the soil with nutrients (Pope et al., 2015). Expansion of agriculture and the need for more fuel-wood have also resulted in increased forest removal (Pope et al., 2015).

Maize plays an important role in Guatemalan history, culture and economy and makes up an important part of the Guatemalan diet. Maize is usually produced through a traditional agricultural practice called milpa, a practice argued to be “sustainable across time, does not deplete the resource base, is compatible with biodiversity conservation, and enables one farm family to produce enough to feed itself and two to three other families” (Schwartz & Corzo, 2015, p. 69). Structural adjustment loans during the 1980s forced Guatemala to liberalize its economy, which required opening up the Guatemalan maize market and decrease state support and protection of domestic maize producers, having a profound impact on small-scale maize farmers as they got competition from cheap and subsidized foreign imports (Isakson, 2013). The adoption of non-traditional export crops, such as snow peas and broccoli, was therefore seen as a promising income-generating strategy for many Guatemalan farmers. In addition, irrigation projects were developed by USAID (U.S. Agency for International Development) and the Guatemala government removed tariffs on fertilizers after pressure from international actors (Isakson, 2014). The results of this restructuring are now being seen, as increased pressure on soils inevitably leads to land degradation.

6.10.2 Degradation

Guatemala is one of the most ecologically diverse countries worldwide (Bosque, 2011), but expansion and intensification of agriculture reduce biodiversity, affect carbon, nitrogen and hydrological cycles (Tilman et. al, 2002) and can lead to processes of land degradation, deforestation and water contamination (Foley et al., 2005).

Illustrated by the results, almost 35 percent of the total land in Guatemala is degraded, happening through various processes of soil erosion. Deforestation is often caused by an expansion of agriculture, and while this may increase food production in the short term, it accelerates land degradation through water erosion (Pope et al., 2015) and soil erosion (USACE, 2000), having significant impact on agricultural productivity in the long-run. Deforestation coupled with extreme weather events, such as periods with high rainfall intensity, exacerbates the decrease in soil fertility (Ruano & Milan, 2014). Reducing fallow periods are also associated with soil erosion and have led to reduced biodiversity and decreased yields during cropping periods (Wittman & Johnson, 2008).

While the use of chemical fertilizer have increased production for some, others have experienced declining yields over the past decades, as high nitrogen application may lead to reduced crop yields (Wittman & Johnson, 2008; Carey, 2001). The use of fertilizers in Guatemala also affect public health due to a lack of restrictions; almost 40 percent of pesticides used are not longer sold or allowed in food in other countries (Carey, 2001). Additionally, use of chemical fertilizers and pesticides leads to toxic build up in the soil, which can contaminate run off into water bodies and pollute groundwater (Carletto, Kirk, Winters, & Davis, 2010; Carey, 2001).

Not only do agricultural intensification processes lead to processes of degradation in Guatemala; the use of wood for fuel and cooking also causes deforestation, while unsustainable practices of slash and burn agriculture are common (Pope et al., 2015).

Changing dynamics within the agri-food system does not only have an impact on the environment, it also shapes the quantity and quality of food available. These influences will be elaborated upon in the following sections.

6.11 Identifying the nutrition transition

The declining share of dietary energy coming from cereals and increased consumption of vegetable oils, animal fats and proteins, indicate that Guatemala is in the beginning of a nutrition transition. The situation is in correspondence with the signs identified by Drewnowski & Popkin (1997); where developing countries are identified as being in the beginning of the nutrition transition, usually characterized by increased production, imports and consumption of vegetable oils, rather than growing imports and consumption of meat and milk, which is normally associated with a Western diet.

6.12 Availability-Nutrition-Productivity Nexus

Hammond & Dubé (2012, p. 12358) states that “poor food availability can lead to malnourished and unhealthy workers, which can decrease production and further limit availability of food”. This feedback loop can be identified in Guatemala.

Fewer cereals available for human consumption due to changes in food supply, coupled with volatile food prices, indicate poor food availability in Guatemala. Cereals, particularly maize, are an important staple food in Guatemala. Illustrated by the distribution of food supply in Table 1, fewer cereals and maize are available for human consumption, while an increasing share goes to feed and food manufacturing. This can be linked to the growth in non-traditional export crops, resulting in less

production for human consumption and increased purchasing dependency. The diet usually eaten by maize farmers is considered a “healthy, nutrient-complete package” (Wilkes in Isaksson, 2013), now increasingly replaced by purchased food. The reliance on food imports and seasonal price variations therefore make Guatemala susceptible to food price changes (Alcaraz, 2015). Guatemalans were affected by the 2008 food price crisis, experiencing a greater difficulty with purchasing food between Alcaraz, 2015). Participation in CAFTA (Central American Free Trade Agreement) also influenced food availability; stabilizing input prizes for food processors, while increasing the prize for the staple tortilla (Isakson, 2014).

Most of the indicators regarding nutritional status consider children and women during pregnancy, making it difficult to suggest the health of workers. However, the prevalence of short stature, obesity, and undernourishment among the total population may provide some insights into the current work force productivity. Height and body mass index are found to be specific predictors of economic success (Thomas & Frankenberg, 2002), whereas short stature is negatively associated with work performance and a greater chance of being unemployed (Dalgaard & Strulik, 2010). Being food and nutrition secure enhances labor productivity and has been found to have a positive impact on wages (Strauss, 1986).

The intergenerational aspect of health, suggests that a lifecycle perspective on worker productivity may be valuable. As suggested in section 6.6.2, adult Guatemalan women may have experienced inadequate nutrition as a fetus or during the first few years of life (Victora et al., 2008). Insufficient nutrition during these early periods has been found to lead to reduced economic productivity and less schooling, providing insights into current worker’s productivity in Guatemala (Victora et al., 2008). Nutrition interventions during early years of life are found to have significant impact on future human capital and economic productivity; increasing worker capacity, improving comprehension, mental development and increasing schooling and wages (Hoddinott et al., 2008; Martorell, Melgar, Maluccio, Stein, & Rivera, 2010). Considering that almost half of all Guatemalan children are stunted, a longitudinal perspective of this kind warrants discussion of current conditions of children and the implications this may have as future workers.

6.13 Summary

The high frequency of extreme climate events and vulnerability to climate change, coupled with intensification of agriculture degrading natural resources, have significant impact on the sustainability of food production in Guatemala. Due to the intergenerational component of health and nutrition,

past and current nutritional problems will affect future generations, necessitating a long term lifecycle perspective on nutritional problems.

The socio-political context is important in Guatemala. Factors such as a disadvantaged indigenous population, a history of conflicts and land rights disputes, and lack of state management, make these issues cross cutting over all systems. Processes of economic liberalization also indicate how processes outside Guatemala to a greater degree shape conditions within the country.

6.14 Research limitations

The research presented in this thesis has various limitations influencing the research process in different ways. These limitations are related to different aspects of the study; the framework, the specific case study and the methods utilized.

6.14.1 Framework limitations

By applying the systems framework from Hammond & Dubé (2012) to the case of Guatemala, various limitations of the framework were recognized. These limitations guided the research in specific directions, while also providing points of discussion regarding a systems analysis of food and nutrition security.

6.14.1.1 Exclusion of the household level

Important dynamics for food and nutrition security are lost due to an exclusion of the household level, which could further have further implications for the design of policies. The household level is considered an important unit of analysis when it comes to food and nutrition security (UNICEF, 1990; Pangaribowo et al., 2013). Aspects such as intra household distribution of food (UNICEF, 1990, FAO, 2008), decisions regarding money allocation (Weingärtner, 2005), household resources (Pieters, 2013) and gender roles (UNICEF, 1990) are considered important determinants of individual food and nutrition security. Hammond & Dubé (2012) do not explicitly include the household level and therefore miss these dynamics, which may be of importance to food and nutrition security in Guatemala. Mothers are often found to make household purchasing decisions, but can be under strict economic control by their husbands, as men are considered to have the economic responsibility within the household, while the women's role is mainly domestic (Wehr, Chary, Webb, & Rohloff, 2014). Not taking dynamics like these into account have consequences for how food and nutrition security is measured and addressed. Considering that the framework by Hammond & Dubé (2012) aim to be the

basis of policy efforts, decision makers might not consider these aspects, thus reducing the possible intended effects.

Many surveys relevant to the measurement of food and nutrition security are done on a household level, such as the 2006 Living Conditions Survey conducted by the Guatemalan Institute of Statistics. Some of this data would be difficult to situate in the framework by Hammond & Dubé without a specific consideration of the household level.

6.14.1.2 Framework boundaries

The boundaries of the framework make it difficult to explain certain aspects of importance to Guatemala. These aspects are of a socio-political character and can therefore be seen as underlying drivers of food and nutrition security in the country. The analysis shows that economic liberalization, land right conflicts and trade agreements are all examples of socio-political processes which have significant impact on the systems. Political factors, social norms and cultural preferences are mentioned as important by Hammond & Dubé (2012), but it is not clear where these are situated in the framework. Although innovative modelling techniques such as ABM (agent-based modelling) may have the ability to take some of these aspects into account (Hammond & Dubé, 2012), the framework is still based on a “hard” systems approach, proposing modelling as a solution. Illustrated by this case study, food and nutrition security is determined by various unquantifiable socio-political and socio-cultural processes.

6.13.1.3 Poor definitions and operationalizing of the linkages

Hammond & Dubé (2012) provide poor guidance to the user of the framework. There are no clear definitions of the environmental system and the health and disease system, creating confusion around system boundaries. Some of the linkages are poorly operationalized; *(I) Demand for Food* is described as “the aggregation of individual decision making in response to price and quantity” (Hammond & Dubé, 2012, p. 12358), providing little guidance on how it can be measured. Much of the indicator selection, and thus results and analysis, are therefore left to interpretation of what could best represent a good measurement of the linkage, representing a limitation of this study. The “freedom” given by Hammond & Dubé (2012) can be considered a potential to adapt the framework to the specific context of the study. Meadows (2009) argues that “boundaries are of our own making, and they can and should be reconsidered for each new discussion, problem or purpose” (p. 99). The potential for adaptations is not stated as an intended consequence of the freedom of the framework and the need for context-specific considerations is not mentioned by Hammond & Dubé (2012). Guidance on how

to adapt the framework to a specific context or spatial scale is therefore not provided, making the practical use of the framework difficult.

Furthermore, Hammond & Dubé (2012) give no indication of magnitude or temporality of the linkages, creating challenges for the user of the framework. Time can be considered implicit in the framework, but the linkages occur over different timescales, making it difficult to analyze the occurrence of feedbacks and how they potentially influence each other. The magnitude of the linkages is context-specific, but there are no suggestions from Hammond & Dubé how this may be taken into account. These limitations create challenges for both policy makers and modelers, by making it unclear which policy aspects to focus on or what data to include in the model.

6.14.2 Case study limitations

Using a systems approach to study food and nutritional security in Guatemala where data included ranges from the national to local level also restricts the accuracy and outcome of the research in various ways.

The data collected in this thesis is measured on a national level, which inherently lead to some limitations. Illustrated by the various years included in the results, national data availability is poor and inconsistent. This makes it difficult to provide a clear picture of the food and nutrition security situation in the country at a specific point in time. It suggests a challenge at a broader scale, as access and quality of statistical data in developing countries are usually poor. The reliance on “hard” statistical data to analyze food and nutrition security is therefore both difficult to obtain and interpret. Further, national data is often based on average and aggregated numbers, hiding important differences within the country. Regional and local discrepancies in Guatemala are particularly high, making this limitation even more significant in this case. The variation in climate zones throughout the country, the differences between the indigenous and non-indigenous population coupled with one of the highest rates of income inequality in the world, exemplifies these context specific discrepancies. In particular, the indigenous population in Guatemala is more socio-economically disadvantaged than the non-indigenous population due, to years of discrimination, civil war and conflicts, (Krznic, 2006). The Western highlands are identified as the region where the double burden of malnutrition is the highest, mostly populated with indigenous people (Ramirez-Zea et al., 2014) and with a high degree of vulnerability to climate events, such as earthquakes (Bosque, 2011).

In addition, external literature used for this study analysis drew primarily on research done at a regional or local level in Guatemala. Some regions are more studied than others, such as the Highlands of Guatemala (Brown et al., 2014; Etten, 2006; Pope et al., 2015; Taylor, Milan, & Ruano, 2014; Wittman & Johnson, 2008). This creates an imbalanced portrayal of Guatemala based on available scientific research related to food challenges, as other regions and/or bigger cities are not covered in similar ways. Furthermore, nutrition-related research in Guatemala predominantly covers women; there are surprisingly few studies covering men. Inconsistent national data, coupled with uneven regional research cannot therefore be considered representative of the entire country. This thesis indicates that further comparative research to improve our understanding of food and nutrition security in the country.

8 Reflections on a systems approach to food and nutrition security

Illustrated by the various aspects covered in results and analysis, the systems framework by Hammond & Dubé (2012) highlights how food and nutrition security in Guatemala is situated within a complex set of relationships, spanning multiple scales, levels and systems. A valuable contribution of such an approach is the identification of different feedback loops, in which important processes between different systems and individual food and nutrition security are considered. In the words of Lien & Nerlich (2004, p. 8), it specifically highlights the need to not considering social processes in isolation;

“One who sets out to study food only as consumption, production, globalization, embodiment, nutrition, family life or economics is likely to be trapped by the same boundaries that structure the very field that she or he tries to illuminate. Fresh insight into contemporary dilemmas requires research that challenges such sectorial boundaries.”

The systems approach by Hammond & Dubé (2012) can therefore be considered a valuable analytical-descriptive tool, which shows that improved understanding of coupled human-environment systems is necessary to develop a sustainable food and nutrition security system (Wiek, Ness, Brand, & Farioli, 2012).

Development of policies are usually confined to specific sectors, with specific goals, leading to situations where “potential synergies and feedbacks between components that could be harnessed for policy impact might go overlooked” (Hammond & Dubé, 2012, p. 12356). The complex nature of food and nutrition security necessitates understanding of how certain policies might lead to trade-offs or unintended consequences. To approach this challenge, mapping of within- and cross-boundary knowledge is important on a conceptual level, which can provide “a basis for effort to broaden the scope of policy and science” (Hammond & Dubé, 2012). The systems driving food and nutrition security have various goals, and it is therefore a need to address trade-offs among them. This case study of Guatemala shows that improved nutrition should not only be incorporated into food policy goals (Pinstrup-Andersen, 2012), but also considered as a goal or possible trade off among other systems. It requires policy makers to consider policy effects outside their specific sector, understanding how they might have consequences on other aspects.

The inclusion of three *different* systems by Hammond & Dubé (2012) may provide some advantageous insights. Recognizing that the multiple aspects influencing food and nutrition security make up distinct systems on their own, necessitates a consideration of the internal dynamics and feedback loops within these systems. Illustrated by the case of Guatemala, improving malnutrition without addressing the prevalence of infectious diseases, may not have the desired effect. By including the environmental system, Hammond & Dubé (2012) also shows the important connection between climate change and food and nutrition security, which can offer a pathway to increase the legitimacy of climate concerns in a policy arena.

Applying the framework from Hammond & Dubé (2012) on the case of Guatemala shows how there is a gap between conceptualization and practical applicability of the framework. Poor operationalizing and guidance for the user make it difficult to apply to a specific context. Although modelling may provide a deeper understanding of dynamics related to food and nutrition security, this thesis illustrates the challenges of being reliant on quantitative statistical data, questioning the usefulness of such an approach. A complementary soft systems approach, listed as one of many tools for sustainability science (Ness et al., 2006) is recommended, in order to understand the qualitative aspects of social processes and dynamics.

9 Conclusion

Using the systems framework developed by Hammond & Dubé (2012) the objective of this thesis was to increase our understanding of the complex nature of food and nutrition security by applying it to a particular case and the convergence of certain specific food and health related challenges made Guatemala a suitable national case to study. The study shows how food and nutrition security is dependent on a number of complex interlinked processes, spanning multiple scales, levels and systems. Frequent extreme weather events, coupled with increased pressures on land, soil and water from agricultural intensification has worsened the sustainability of food production in Guatemala. Furthermore, the study also identifies the importance of the intergenerational component of health, nutrition and development for existing and future nutritional problems, especially the complex relationship between mother and child. The role of the current socio-political context, shaped by past conflicts, poor state management and land right disputes, is seen as key underlying factors, cutting across these processes, and making some groups more vulnerable than others. The influence of economic liberalization and subsequent food price volatility, highlight how dynamics outside the country increasingly shape national conditions.

Although comprehensive in both its approach and analysis the case study was confronted with a number of limitations that reduces the applicability of the findings. Firstly, due to poor availability of data and discrepancies in both geographic and socio-economic realities on the ground, reduces the accuracy of the food and nutrition security situation in Guatemala at a specific point in time. Secondly, because the framework has been developed for the purpose of modelling, scale level data has been omitted from the framework, thus making intra-household analysis impossible to do, despite its clear significance for understanding the dynamic complexity of food and nutrition security on the ground.

Notwithstanding, the systems approach utilized in this thesis represents a valuable descriptive-analytical tool, able to provide insights into the complex nature of food and nutrition security. By focusing on feedback loops and linkages within and between systems it is possible to show how social processes needs to be considered in relation to other dynamics, as they often form complex interconnected relationships. In addition, it highlights the need for a transdisciplinary lens to policy making, as some policy efforts in one area may create trade-offs in others. Moreover, this study has highlighted that one of the core problems within systems thinking is where to set the system boundaries; that it is dependent on for whom the system is made for, for what purpose and on which time scale (Meadows, 2009). Manipulating the system boundaries to fit a specific policy context may

therefore distort outcomes and lead to confusion rather than efficient pathways to solving a wicked sustainability problem. Systems knowledge is important for sustainability (Turner et. al, 2003), but knowledge mapping needs to be coupled with other solution-oriented techniques, as a better understanding of the problem does not offer a solution to the problem, an assumption often taken in sustainability science (Wiek et al., 2012). The identified limitations of the framework suggest that there is currently a gap between conceptualization and practical applicability, requiring further operationalizing, by complementing their hard approach with a softer one, in order to be applicable both for policy and modelling purposes. Nevertheless, Hammond & Dubé's (2012) framework still represents a valuable starting point in efforts directed towards understanding and achieving food and nutrition security.

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11 Appendix 1: Results

The Health and Disease System

Linkage	Indicators	1995	2014	Source
Nutrient absorption (F)	Prevalence of HIV, total (% of population ages 15-49)	0.1	0.5	World Data Bank (a)
	Diarrhea mortality rate	12.9 (2005)	4.3	INE
	Diabetes mortality rate	37.6 (2005)	54.8	INE
	Prevalence of diabetes mellitus (% of adults)	n.d.	8.2 (2007)	PAHO (2012)
	Diarrhea treatment (% of children under 5 who received ORS packet)	21.5	37.1 (2009)	World Data Bank (a)
	Malaria cases reported	24,178.0	4,931.0	World Data Bank (a)
	Cause of death, by non-communicable diseases (% of total)	38.7 (2000)	47.2 (2012)	World Data Bank (a)
	Cause of death, by communicable diseases and maternal, prenatal and nutrition conditions (% of total)	43.0 (2000)	34.4 (2012)	World Data Bank (a)
	Distribution of causes of death, children aged 1-59 months (% of deaths):			WHO (2014)
	Diarrheal disease	21.1 (2000)	13.6	
	Acute lower respiratory infections	32.9 (2000)	26	
	Other communicable, perinatal & nutritional conditions	11.1 (2000)	14.2	
	Other non-communicable diseases	8.5 (2000)	11.1	
	Susceptibility/Immune response (G)	Children under 5 years of age affected by wasting (%)	3.80*	1.1**
Children under 5 years of age who are stunted (%)		55.40*	48**	*FAOSTAT (a) ** FAO (2014)
Children under 5 years of age who are underweight (%)		21.70*	13**	*FAOSTAT (a) ** FAO (2014)
Overweight and obesity, adults (T/M/F) (%)			52.0/47.6/ 56.2	World Data Bank (c)

	Prevalence of vitamin A deficiency (% of total population)	15.80	n.d	FAOSTAT (a)
	Prevalence of anemia among pregnant women (%)	39.30*	30.4**	*FAOSTAT (a) ** FAO (2014)
	Prevalence of anemia among children under 5 years of age (%)	34.10*	47.1**	*FAOSTAT (2014) ** FAO (2014)
Priorities/Opportunities (J)	Health expenditure, public (% of total health expenditure)	41.5	37.8 (2013)	World Data Bank (a)
	Out-of-pocket health expenditure (% of private expenditure on health)	92.4	83.3 (2013)	World Data Bank (a)
	Adult literacy rate (population 15+ years, both sexes, %)	69.1 (2002)	77.0 (2013)	World Data Bank (a)
	Share of food consumption in total income (Engel ratio) (%)		44.6 (2006)	FAOSTAT (a)
	Poverty headcount ratio at national poverty lines (% of population)	56.0	59.3	World Data Bank (a)
	Income share held by highest 20 %	59.7 (2000)	57.2 (2011)	World Data Bank (b)
	GINI index (World Bank estimate)	54.8 (2000)	52.4 (2011)	World Data Bank (b)

The Environmental System

Linkage	Indicators	1995	2014	Source
Pollution/Clean water availability (E)	Improved water source (% of population with access) (T/U/R)	80.3/91.7/71.7	92.7/98.4/86.8	World Data Bank (a)
	Improved sanitation facilities (% of population with access) (T/U/R)	50.9/71.9/35.0	63.7/77.5/49.3	World Data Bank (a)
	Total water volume available (% of total water volume)		65 (2009)	PAHO (2012)
	Contamination (% of total water volume available)		40 (2009)	PAHO (2012)
Sustainability of food production (D)	Agricultural land (% of land area)	41.7 (2000)	34.72 (2013)	World Bank Group (2016)
	Fertilizers consumption (kilograms per hectare of arable land)	99.8 (2002)	255.5 (2013)	World Data Bank (a)
	Total area equipped for irrigation (% of agricultural area)	2.86	7.17 (2010)	FAOSTAT (b)
	Long-term climate risk index (CRI) (1995-2014)	32.50		Kreft, Eckstein, Dorsch & Fischer (2015)
	Total number of extreme weather events (1995-2014)	88		Kreft, Eckstein, Dorsch & Fischer (2015)
	Occurrence of the El Nino phenomenon	yes	yes	Ruano & Milan, (2014)

The Agri-food System

Food availability/Quality (A)	Dietary energy supply (kcal/cap/day)	2276*	2462**	*FAOSTAT (c) ** FAO (2014)
	Average share of animal protein (g/cap/day)	13.04*	18**	*FAO (c) ** FAO (2014)
	Average fat supply (g/cap/day)	38.88*	58**	*FAOSTAT (c) ** FAO (2014)
	Share of dietary energy supply (%):			*FAO (c) ** FAO (2014)
	Cereals	57.2*	45.9**	
	Sugar and sweeteners	19.2*	20.6**	
	Meat and offals	3.1*	4.1**	
	Vegetable oils and animal fats	3.8*	9.2**	
	Food production index (2004-2005 = 100)	72.6	151.3 (2013)	World Data Bank (a)
	Food exports (% of merchandise export)	65.2	42.4	World Data Bank (a)
	Food imports (% of merchandise imports)	11.9	13.6	World Data Bank (a)
Incomes/Prices/Marketing (H)	Consumer price index (2010 = 100)	36.0	119.0	World Data Bank (a)
	Domestic food price index	5.39 (2000)	7.11	FAOSTAT (a)
	Domestic food price volatility index	8.00 (2000)	5.50	FAOSTAT (a)
	Agricultural value added (% of GDP)	14 (2000)	11	FAO (2015b)
	Employment in agriculture (%)	12.9 (1990)	32.3	FAO (2015b)
	Agricultural value added per worker (constant US \$)	1477 (1990)	2009	FAO (2015b)
Labor availability (B)	Unemployment, total (% of total labor force)	3.5	2.9	World Data Bank (a)
	Height < 145 cm, women ages 15-49 (%) (I = Indigenous, N = non-indigenous, T=total)	n.d	(T) 31, (I) 48.3 (N) 19 (8) (2008/2009)	Martorell (2012)

	Prevalence of undernourishment (% of population)	15.5	15.6	World Data Bank (a)
	Average supply of animal protein (g/cap/day)	13.04*	18**	*FAOSTAT (c) ** FAO (2014)
Demand for food (I)	Population growth (annual %)	2.5	2.0	World Data Bank (a)
	Urban population growth (annual %)	3.4	2.9	World Data Bank (a)
	Urban population (% of total population)	43.1	51.1	World Data Bank (a)
	GDP growth (annual %)	4.9	4.2	World Data Bank (a)
Pollution/Soil degradation/Climate (C)	Water withdrawal for agricultural use (% of total water withdrawal)	52.50*	57**	* FAOSTAT (b) ** FAO (2015)
	Land degradation (% total land)		35	World Bank (2009)
	Net GHG emissions from AFOLU (CO2 eq. Mt)	22 (1990)	24	FAO (2015)
	Forest area (% of land area)	44 (1990)	33	FAO (2015)

