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Assessing the performance of a local food system utilising a systems approach: A case study of El Nido, Palawan (Philippines)

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Abstract

Food security is a complex, multidimensional issue with multiple environmental, social, political and economic determinants. Food security is conceptualised as a dynamic outcome of a food system. Achieving sustainable food security, whilst not harming the social and biophysical environment is now recognized as one of the world's largest and most complex challenges.

Much of the debate on food security to-date is focused at the global level and in particular, on the supply or production of food, as the mechanism to provide food security in the future. However, food security is very much a local issue with food insecurity occurring at the household or individual level where access to food is highly dependent on livelihoods and income generation. Adverse conditions including low food availability, high undernourishment, high population growth and poor land and water resources contribute towards food insecurity at the local level. A detailed case study investigation of the Municipality of El Nido in the province of Palawan, Philippines, adds value to the models and discussions at the global level through detailed examination of the causes leading to food security at the local level.

Utilising a system dynamics methodology, this study evaluated the localised food system through analysing scenarios to: (i) identify points within the system in which it can no longer produce food or provide the population with the ability to procure food and; (ii) assess its ability to continue to function effectively and deliver on food security outcomes over a 35-year timeframe to 2050.

The research shows that as the local community moves away from the traditional localised production and livelihood systems of agriculture and fisheries, these communities are left significantly at risk as their availability and access to food declines. Key findings reveal a system vulnerable to pressures placed upon the food system and one which lacks the resilience or capacity to continue providing food availability and access over time. In particular, the analysis reveals the food system has reached or exceeded its 'tipping point'. Interventions tested in the study reveal there is little to no impact on reversing the declines in the system, or in bringing the system back into balance whereby food security, economic growth and natural resources co-exist in a sustainable manner.

There is a critical need to examine and manage local food systems through focusing on enabling capacities and protection of food systems and the ecosystems which underpin them. This is particularly important for rural areas in developing countries in which agriculture and fisheries provide critical lifelines for food security and livelihoods at the local level. Furthermore, the research links the importance of social and environmental welfare to the resilience and sustainability of food systems. Lastly, it highlights the need for governments to focus on food security as a priority and ensure policies and practical actions are implemented at a 'whole-of-system' level, to reduce the vulnerability of the food system to pressures and future shocks.

Declaration by author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly authored works that I have included in my thesis.

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Publications included in this thesis

No publications.

Submitted manuscripts included in this thesis

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Other publications during candidature

Conference Abstracts:

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Reports:

King, M., 2016, '*Exploring Food Insecurity in El Nido Municipality, Palawan Province, Philippines'.* A report prepared for the Capturing Coral Reef and Related Ecosystem Services (CCRES) Project.

King, M., 2016, *'Exploring Food Insecurity in El Nido Municipality, Palawan Province, Philippines: Barangay Case Study Report'*. A report prepared for the Capturing Coral Reef and Related Ecosystem Services (CCRES) Project.

Contributions by others to the thesis

Listed below is an acknowledgement of significant and substantial inputs made by others to the research, work and writing represented and/or reported in the thesis.

Contributor	Statement of contribution
Dr Carl Smith, The University of Queensland	Development of: • Community Participatory Workshop scripts • SESAMME mapping tool used to collect data during the Community Participatory Workshops • Simulation model used for the food system analysis in Chapter 6
Dr Russell Richards, The University of Queensland	Development of: • SESAMME mapping tool used to collect data during the Community Participatory Workshops • Simulation model used for the food system analysis in Chapter 6
El Nido Foundation	Facilitated Round One and Round Two of the Community Participatory Workshops to collect initial data for dynamic hypothesis
Mr Roy Bero, Dr Ronald Ona and Ms Precious Latras, Palawan State University	Co-facilitated Round Three of the Community Participatory Workshops to test the simulation model
Dr Vera Horigue	Developed maps of El Nido Municipality (Figure 4.1, Page 102)

Statement of parts of the thesis submitted to qualify for the award of another degree

No works submitted towards another degree have been included in this thesis.

Research Involving Human or Animal Subjects

Ethical clearance for research involving human participants was obtained from The University of Queensland's Behavioural & Social Sciences Ethical Review Committee (BSSERC) on 18 February 2016 (Approval Number: 2015000582). A copy of the ethics approval letter is attached at Appendix A.

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Keywords

food security, food systems, systems dynamics, systems thinking, agricultural systems, fisheries systems, participatory modelling

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Fields of Research (FoR) Classification

FoR code: 0701, Agriculture, Land and Farm Management, 50%

FoR code: 0704, Fisheries Science, 50%

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List of Abbreviations

ADB	Asian Development Bank
CAS	Complex adaptive systems
CBMS	Community-based Monitoring System
CLD	Causal loop diagram
CLUP	Comprehensive Land Use Plan
CMMA	Community Managed Marine Area
CMT	Core Modelling Team
CPUE	Catch per unit effort
CPW	Community participatory workshop
DENR	Department of Environment and Natural Resources
ECAN	Environmentally Critical Areas Network
ENF	El Nido Foundation
FAO	Food and Agriculture Organization
FIS	Food Intake Surveys
HIES	Household Income and Expenditure Surveys
HLPE	High-Level Panel of Experts on Food Security and Nutrition
IFPRI	International Food Policy Research Institute
LGU	Local Government Unit
MAO	El Nido Municipal Agricultural Office
MDGs	Millennium Development Goals
MPA	Marine protected area
MTO	El Nido Municipal Tourism Office
NPV	Net present value
ODE	Ordinary differential equations
PCSD	Palawan Council for Sustainable Development
PhP	Philippines peso
PSA	Philippines Statistical Authority
PSU	Palawan State University
SESAMME	Socio-ecological Systems App for Mental Model Elicitation
UP	University of the Philippines
WHO	World Health Organization

1 Introduction

1.1 Background to the problem

1.1.1 Attaining food security in the face of global pressures

Food is fundamental to human wellbeing and development (Misselhorn et al. 2012) and is designated as a basic human right (Mathur 2011). Food security exists when '*all people at all times have physical or economic access to sufficient, safe and nutritious food to meet all their dietary needs and food preferences for an active and healthy life*' (FAO 2006a). Food security is a complex, multidimensional issue (ADB 2012; Botti Abbade and Dewes 2015), and involves the physical availability of food, the ability to access or pay for that food (Moir and Morris 2011; Nelson et al. 2016), as well as the utilisation of food, and stability of food (FAO 2006b; Barrett and Lentz 2015; Nelson et al. 2016).

It is argued that food insecurity, or the inability to access food of sufficient quantity and quality to satisfy minimum dietary needs, is therefore the most basic form of human deprivation (ADB 2012), and there are larger economic costs associated with food insecurity (FAO 2009) compromising the productivity of individuals and the growth of entire economies (FAO et al. 2015). It is recognised that food must be produced sustainably to meet the food needs of every person on the planet and all people must have economic and physical access to the available food (Pinstrup-Andersen and Pandya-Lorch 1998; FAO et al. 2015). However, despite this recognition of people's basic right to food, undernutrition and micronutrient deficiencies still remain (Myers et al. 2017) with chronic food insecurity still existing in parts of the world (Ericksen 2008b; Alexandratos and Bruinsma 2012). Globally, 795 million people remain malnourished, many of them residing in developing countries (FAO et al. 2015) with around 65 percent residing in Asia (Fan et al. 2013; OECD 2013). In addition to this, at the global level, 108 million people in 2016 were reported to be facing crisis level food insecurity or worse, a 35 percent increase compared to 2015 (FSIN 2017).

Food and nutrition security is now high on the global policy agenda (Godfray et al. 2010a; Tomlinson 2013; Godfray and Garnett 2014; Townsend et al. 2016) and with the global population projected to increase to over nine billion people by 2050 (UN 2013, 2017), and increasing wealth to purchase more varied, high-quality and resource-intensive diets (Garnett et al. 2013; Foresight 2011), the question across much of the literature has been how does the world nutritiously feed this growing global population (Evans 2009; Godfray et al. 2010a, 2010b; Beddington 2010; Foley et al. 2011; Gregory and George 2011; Cuesta 2014). This is now recognized as one of the world's (Godfray et al. 2010a; Walqvist et al. 2012; Behnassi 2013; OECD 2013), particularly Asia's (Fan et al. 2013), largest and most complex challenges in the coming decades, particularly as food systems cope with increasingly affluent and urban populations causing a shift towards higher consumption of calories, fats and animal products (Behnassi 2013; Barron et al. 2013; Garnett et al. 2013), and given the recognition of environmental problems such as climate change, water and land scarcity, and ecosystem degradation (Beddington 2010; Godfrey 2010a; Foresight 2011; Foley et al. 2011; Garnett et al. 2013; Ringler et al. 2014; van Wijk 2014).

Satisfying the demand for food over coming decades will be increasingly challenging particularly as the global food system will face an unprecedented concurrence of pressures (Hanjra and Qureshi 2010; Foresight 2011; World Bank 2013a; Willenbockel 2014), from both natural and human-induced drivers (FAO 2009). These pressures include:

a. **Population growth:** The world's population is projected to increase by slightly more than one billion people over the thirteen year period from 2017 to 2030, reaching 8.6 billion and further increasing to 9.8 billion in 2050 (UN 2017) with most growth occurring in developing countries (UN 2017; Beddington et al 2012). Increases in population will see increases in food demand and therefore food production, and changes to food composition. As the global population becomes increasingly urbanised, this has implications on land use, food production systems and access to food (Beddington et al 2012).

b. **Economic growth:** At the global level, impacts on the food system have already been felt particularly in the last decade with rising incomes and rapid urbanization in developing countries (Szabo 2015; Poulsen et al 2015; Friel and Ford 2015; Tacoli and Agergaard 2017), particularly in Asia (HLPE 2009), creating changes in the structure of global food demand. Economic growth generally stimulates demand for products, including food. As disposable incomes grow, consumers' ability to purchase food products increases causing not only a demand for more food but also for different food (Umberger 2015; Gerbens-Leenes et al 2010). Per capita income growth in developing countries means that the number of middle-income and high-income consumers will increase over the next several years (Umberger 2015), and as incomes rise, a shift towards more affluent food consumption patterns occurs (Gerbens-Leenes et al 2010).

c. **Changing consumption patterns:** Urbanisation, economic growth and globalisation of food markets are influencing the quantity of food demanded by consumers as well as their preferences for food products and food attributes (Umberger 2015). As disposable household incomes increase, very low-income households firstly increase the amount of food they consume, and then the diversity of their diet (Umberger 2015). Consumption changes driven by growth of the middle-class will lead to increasing global demand for imports of high-value food products as well as agricultural commodities for livestock feed (Alexandratos and Bruinsma 2012; Behnassi 2013; Umberger 2015).

d. **Increasing food prices:** Real prices of food have increased as a result of changes in biofuel and climate policies, rising energy prices, declining food stocks, and market speculation (OECD 2013; Ringler et al. 2014). Ringler et al. (2014) argue that poor people typically spend 50–70 percent of their income on food, and their wages have not adjusted quickly enough to compensate for their shrinking purchasing power, thus adding to access to food issues.

   Furthermore, as a driver, global food commodity prices play an important role as producer incentives. Up to 80 percent of the produce of smallholder farmers is sold at local markets, however, these markets are not disconnected from global markets and prices (Barron et al 2013). As consumers, smallholder farmers and rural populations in developing countries are affected by price hikes, without necessarily being able to benefit from them as producers (Barron et al 2013).

e. **Increased competition for land, water and energy:** On the production side, increased competition for land, water, energy, and other inputs into food production will intensify, and the effects of climate change (Sheales and Gunning-Trant 2009; Foresight 2011; Garnett et al. 2013; Ringler et al. 2014) will significantly impair food systems (IPCC 2007; Ringler et al. 2014) not only at a global or regional level, but also at the local level.

f. **Climate Change:** All aspects of food security will be potentially affected by climate change, including food access, utilisation and price stability (Porter et al 2014). Future food production will be under risk and uncertainty from climate change (Barron et al 2013) with global climate change having an adverse effect on both agricultural production and fisheries, as rising temperatures, changing rainfall patterns and increasing evidence of extreme weather events, rising sea levels and ocean acidification impact food production systems (Beddington et al 2012; Behnassi 2013). At the local level, smallholder and subsistence farmers and artisanal fisherfolk will suffer complex, localised impacts of climate change (Easterling et al 2007).

g. **Environmental impacts:** The environmental impacts of farming and food production can impact negatively on the environment, as food demand leads to increased demand for water and land use, and increased production leads to soil erosion and degradation, loss of biodiversity, increased GHG emissions and water pollution (Behnassi 2013).

Whilst much of the dialogue calls for increases in food production as the foundation of food security strategies (FAO 2009; Bruinsma 2009; Beddington 2010; Tilman et al. 2011; Foresight 2011; Misselhorn et al. 2012; ADB 2012; Garnett et al. 2013; World Bank 2013; Barron et al. 2013; Behnassi 2013; Godber and Wall 2014; FAO 2016a), these studies predominantly focus upon the supply side of grain crops, rather than other aspects of the food system such as fisheries or livestock, or other crops. In particular, the issue of physical and economic access to food, utilisation of food or stability of food (Feldman and Biggs 2012; Sage 2013; Tomlinson 2013) is not considered in the calls to increase the supply of food. Despite there being more than enough food currently produced per capita to adequately feed the global population (Godfray et al. 2010a; FAO 2011; Alexandratos and Bruinsma 2012; Moomaw et al. 2012; Cuesta 2013) and even to satisfy the diversified demand of a demographically changing world (Godfray et al. 2010a), there still remains persistent or periodic food insecurity (Ericksen 2008b; Alexandratos and Bruinsma 2012) due to a lack of access to food and income disparities.

Food insecurity afflicts communities throughout the world wherever poverty prevents assured access to food supplies (Behnassi 2013), and remains widespread, in large measure due to extreme poverty (Barrett and Lentz 2015). Food insecurity and poverty are therefore closely intertwined (Southgate and Coxhead 2009) with approximately 1.4 billion people living on less than US$1.25 a day, with 2011 figures estimating 1 billion people remained hungry (IFAD 2012). Furthermore, the number of undernourished people increased from approximately 848 million to 923 million between 2003 to 2007, largely due to the food price crisis (FAO 2008; Southgate and Coxhead 2009). In 2014-2016 this number had declined slightly but still remains high, as 795 million people (the majority of whom reside in developing countries) remain undernourished – just over one in nine (FAO et al. 2015). Poverty incidence deprives people of access to adequate, good quality food, denying them the nutrition they need to live healthy lives. The lack of nutrition undermines productivity, keeps incomes low, and traps people in poverty, and the lack of food security is thus both a cause and an effect of poverty (ADB 2012). The problem today is that many people either do not have the land to cultivate or enough income to buy food (FAO 2006; Godfray et al. 2010a).

Addressing the implications of these increasing socioeconomic and environmental pressures in a pragmatic way that promotes resilience to shocks and future uncertainties (Foresight 2011), is vital if major pressures to the food system are to be anticipated and managed. Much of the literature focuses on the need to double agricultural production by 2050 (FAO 2009; Foresight 2011; Garnett et al. 2013; Tomlinson 2013; World Bank 2013), that is, increase it by 70 percent on today's levels (FAO 2009), through agricultural intensification. Whilst increasing agricultural production is an important strategy to alleviate food insecurity (Ingram 2011), it is also argued that it remains too narrow in focus to solve the food security problem (Tomlinson 2013; Garnett et al. 2013), and is not taking a holistic, systems approach to the problem.

The approach fails to take the whole of the food system (i.e drivers, feedbacks, interactions, delays) into account, and in particular ignores the fisheries production system - a key component for food security and livelihoods for many in developing countries (Foale et al. 2013; Cruz-Trinidad et al. 2014). Furthermore, increasing agricultural production ignores questions of distribution or the associated ecological costs of production systems, with the approach emphasizing agricultural outputs (food, fuel, and feed) as interchangeable and tradable commodities rather than constituting national food security elements (Sage 2013). Additionally, it ignores matters of diet or nutritional security by focusing primarily on grain crops (excluding crops such as vegetables and fruits) and focuses only on agricultural production as a production output (Sage 2013; Tomlinson 2013). Lastly, the focus on intensifying agricultural production at the global scale as the mechanism to provide a food secure future continues to ignore the dynamics at the local level (e.g. household and community) where the majority of food is grown for self-sufficiency and livelihood purposes, and where the impacts of the socioeconomic and environmental drivers will be felt the most.

In determining solutions to ensure countries are food secure, most policy options and solutions remain embedded at the global level or regional level (Evans 2009; Godfray et al. 2010b; Alexandratos and Bruinsma 2012; ADB 2012; Guillou & Matheron 2014; FAO 2016a; Townsend et al. 2016). The viability of food production, the maintenance of ecosystems services and the reduction of poverty involve increasingly complex interactions between land users and their socioeconomic and biophysical environment (van Wijk 2014). Whilst land and marine environments play a significant role in the changing global food economy, and determines food availability (van Wijk 2014), these environments are managed nationally or locally, and not at the global level, thus bringing about a disconnect between global policy and projections, and the management reality. Additionally, policy and decision makers will be required to determine where current and new policies for food security will be the most efficient to meet demand whilst still maintaining the ecosystems which support the production systems, and this occurs at the national and local levels.

Whilst the issue of ensuring a food secure future for all people should be at the forefront of debate (FAO 2009; ADB 2012; FAO et al. 2015), currently the debate resides at a level whereby the impacts will not necessarily be felt by those in need on the ground, in local communities. The impacts of a loss of food security and livelihoods, as well as growing poverty and malnutrition will be felt at this level, and the solutions will therefore, need to be localised. This will become increasing challenging for local policy makers as the capability of people to access food can be limited or hindered by structural and social conditions (Nelson et al. 2016) and this will impact on local communities' abilities to provide self-production or access to markets through improved livelihoods generating income to procure food.

1.1.2 Food security at the local level

Much of the dialogue on the future of food focuses upon ensuring global production systems can provide enough food to meet the demand of people at a global level. However, it is at the local level, that is, household and community level, or in the case of this study, the boundary is defined as the municipal level, which will be the most affected by the pressures from global change processes on food production systems due to their low capacity to adapt (Ringler et al 2010; FAO 2013; van Wijk 2014), low resource endowment, production orientation and objectives, education, past experience and management skills (van Wijk 2014). Food security also holds immediate household and personal importance, particularly for the poor where it defines how daily budgets are allocated (ADB 2013) and is a key indicator for the functioning and sustainability of smallholder systems (van Wijk 2014) across the world. In these localised areas it is the ability to access food of sufficient quantity and, quality to satisfy nutritional needs rather than the need to grow or capture more (van Wijk 2014) which provides food security. The foremost reason for households lacking access is poverty and deficient incomes (OECD 2013).

Furthermore, food security in rural areas in developing countries is dependent upon agriculture and fisheries both for food and incomes. Smallholder farming and fisheries are critical lifelines for food security at the local level (refer Sections 2.1.3.1 and 2.1.3.2), with 75 percent of the world's 1.2 billion poor dependent upon agriculture as the main source of income and employment (Easterling et al. 2007; United Nations Global Compact 2012). As with agriculture, fisheries are also critical to food security and poverty reduction (Garcia and Rosenberg 2010; McClanahan et al. 2013; Bene et al. 2015; Bene et al. 2016). In the Coral Triangle region of Asia alone, over one hundred million people living along the coastal zones use fisheries to support their livelihoods and incomes and provide food (Hoegh-Guldberg et al. 2009; Foale et al. 2013; Cruz-Trinidad et al. 2014), as well as provide critical safety valves in times of economic or social hardship or disturbance (Sadovy 2005; Gill et al. 2017; Reef Resilience Network 2018).

Given the importance of smallholder farmers and fishers to the local economies, food security and livelihoods, it is critical that adaptive capacity at the local level is enhanced (Sage 2013). As rural and coastal communities face increasing challenges such as degradation of the environment, climate change, competition from imports, overfishing, changing consumption patterns, there remains a gap in knowledge as to how these communities will be able to effectively respond to these challenges and ensure a viable future.

1.1.3 Understanding food security as part of a system

Food security is an intrinsic element of the food system, underpinned by the system components that link the food chain activities of producing, processing, distributing and consuming food across a range of social and environmental contexts (Liverman and Kapadia 2010). Food security and with its pillars of availability, access, utilisation and stability, is an essential outcome of the food system (Ericksen 2008a; Ingram 2011).

Food systems themselves are recognised as being complex adaptive systems (Clancy 2013) dealing with the challenge of how to provide access to food for the growing population without diminishing the environment upon which the system relies. Embedded within the food system are multiple sub-systems including complex social-ecological systems (Ericksen 2008a; Prosperi et al. 2016) which are themselves composed of sub-systems involving multiple interactions between human and natural components (Allen and Prosperi 2016), linked through feedback mechanisms (Tendall et al. 2015). This coupling within the system evolves over time as a complex adaptive system with interactions, emergence, evolution and adaptation varying over spatial scales (Liu et al. 2015).

In exploring food security as a core outcome embedded within the food system, a food system approach is utilised in this study. Food system approaches are seen as a mechanism to improve food system outcomes and sustainability, to deal with competing priorities and address complex relationships across food system components (Ericksen et al. 2010; Garnett et al. 2013; Tendall et al. 2015). The framework provides for a systemic approach to a complex issue and enables analysis across scales and levels in the food system and provides a framework to help identify key vulnerabilities and interactions in the context of food security (Ericksen and Ingram 2009; Ingram 2011; Toth et al. 2016; Allen and Prosperi 2016).

Additionally, the methodology in this research which utilises aspects of system dynamics (refer Section 3.3), enables this framework to be examined in detail working with the local community to capture their shared ‘mental model’ (Jones et al. 2011) of the food system including the interactions between drivers and the effects on food system activities and outcomes generating feedbacks (Ingram 2011).

The systems approach can capture the interconnectedness and interdependencies across components, scales, sectors and feedbacks (Liverman and Kapadia 2010; Ingram 2011; Misselhorn et al. 2012) present across both human and environmental spheres, all of which directly impact the food security outcomes of availability, access and utilisation.

1.2 Research problem and research aims

The research will be undertaking a critical assessment of the food system within a community reliant on both fisheries and agricultural systems to provide both food and livelihoods to its local population.   The aim of the research therefore is to utilise systems thinking and systems dynamics to assess the performance of a localised food system over time and its ability to continue to function effectively to meet the food security outcomes. Given the complex and broad nature of the food system and the food insecurity problem, the scope of this research is bounded by assessing the local system against the food security outcomes of availability and access.

Within this context, the research will assess how the community currently uses and interacts with the fisheries and agricultural food systems, and how these systems react to the feedbacks generated by these interactions, and to endogenous or exogenous shocks to the system. Ultimately the research will assess the performance of the food system by testing scenarios aimed at identifying the points within the system where it can no longer produce and / or procure food to feed the local population, and to test possible interventions to build long-term outcomes.

The research questions therefore are:

Research Question 1	**What are the factors contributing towards food security globally and in Southeast Asia in particular?** a. What is food security? b. What is the current state of food security at the global and regional level? c. How does this translate to the local context?

Research Question 2	**What are the dynamics affecting food security in a southeast Asian community?** a. What are the social-ecological drivers affecting a community's food system and its behaviour over time? b. What are the interactions and feedback loops between these drivers within a local community that explain the behaviour over time?
Research Question 3	**What scenarios would affect the ability of local communities to produce and procure food?** **a.** How does the food system perform over time? **b.** What interventions can be introduced into the food system to change the outcomes?

1.3 Significance and Relevance of the Research

A major challenge in addressing food security, is that practitioners do not have a singular framework to address it. There is no one clearly agreed upon framework for assessing or measuring either food systems or food security as an outcome of the food system. For example, approaches cover global environmental change (Ericksen 2008a, 2008b; Ingram 2011; Tendall et al. 2015), production sectors (Sundkvist et al. 2005), food and nutrition systems (Sobal et al. 1998; Rutten et al. 2011; Hammond and Dube 2012); policy, institutional and production systems (Babu and Blom 2014), vulnerability and resilience mapping of food systems and food security (FAO et al. 2015; Toth et al. 2016; Schipanski et al. 2016), or multiple frameworks outlining potential impacts of climate change on agricultural or fisheries systems (Hoegh-Guldberg et al. 2007; Kang et al. 2009; Jaggard et al. 2010; FAO 2010b; Nelson et al. 2010; Lobell et al. 2011; Cinner et al. 2013; Porter et al. 2014). Recognising there is no singular framework or model to assess food security, this research will therefore utilise the food system approach to conceptualise the problem at the case study site.

Much of the debate on food security is focused at the global level, and in particular, on the supply side of the food security equation (Pinstrup-Anderson 2009). These debates do not consider the local level situations particularly as some countries already experience adverse initial conditions, low national average food availability, high undernourishment, high population growth, and also poor land and water resource endowments (Alexandratos and Bruinsma 2012). Food security is very much a local problem (FAO 2006), and the continued focus on these higher levels ignores the dynamics at the local level where the majority of food is grown for self-sufficiency and livelihood purposes, and where the impacts of the socioeconomic and environmental drivers will be felt the most (Tomlinson 2013).

This research aims to fill a gap in the knowledge by undertaking a critical assessment of a local food system to ascertain the vulnerability of the food systems capacity to continue to provide both food and livelihood options for the population under the current and future socioeconomic and environmental conditions. Particular ways in which the research is novel include:

- There is a focus on both fisheries and agricultural systems and their role in food systems. Much of the research currently focuses on only one specific system and does not explore the combination.
- The research focuses on the ecological and socio-economic dimensions of the food security problem through understanding the interactions between both systems and how they impact on each other.
- The research explores food systems at the local level where impacts are felt the most. The local level is often overlooked in global and regional projections and needs to be considered in any decision-making forums.
- The approach used adopts a systematic method in providing a framework for exploring the social-ecological problem of food security.
- The study is undertaking the application and assessment of the food system framework to an on-ground study site, to identify the vulnerabilities within the food system and the system's potential to build resilience in the face of systemic shocks.

The research will contribute to a broader understanding and body of knowledge of how local communities, dependent on dual food production systems, will cope with the issue of food security from a self-sufficiency perspective; how vulnerable these populations will be under multiple threats for food security and livelihoods; how they will cope with these system shocks, and; what ultimately needs to be prioritised by governments to ensure these communities build resilience to these system shocks.

1.4 Outline of thesis

The structure of this thesis is outlined in Figure 1.1.

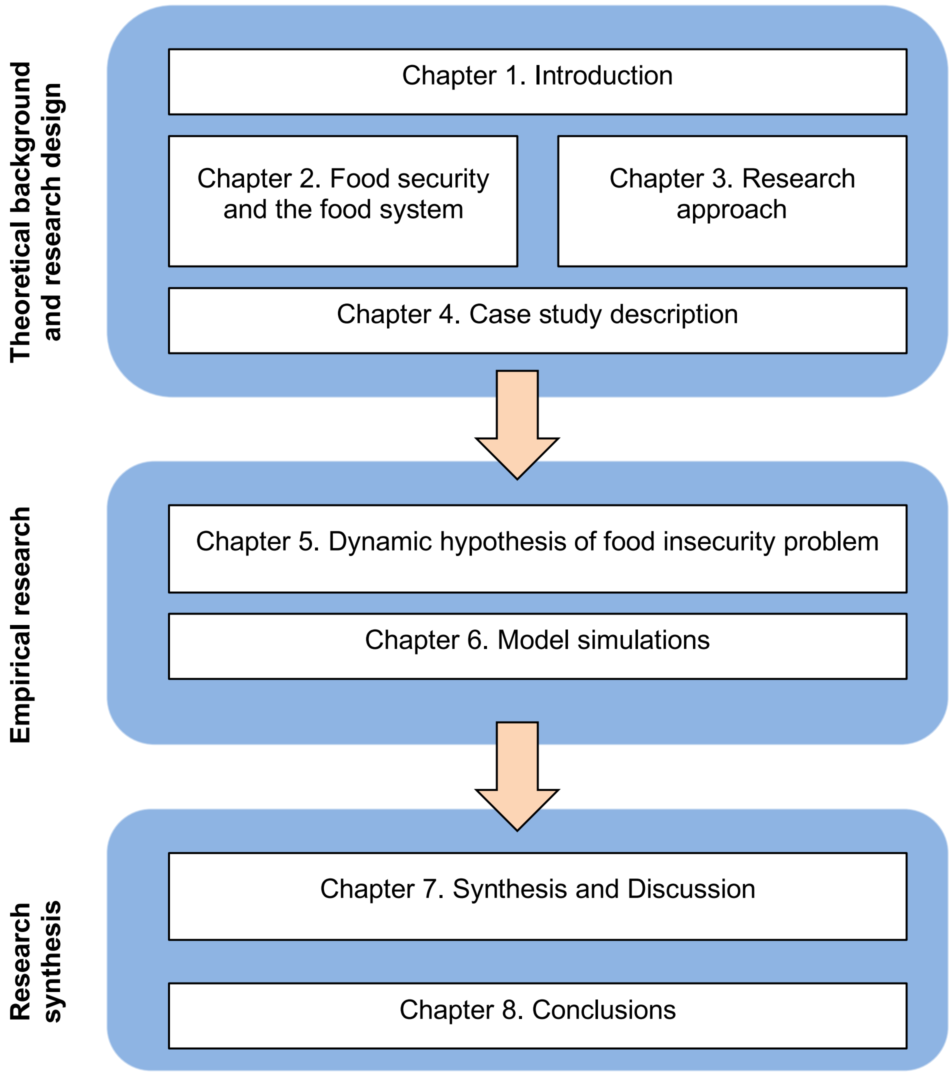

Figure 1-1. Dissertation structure

2 Food Security and the Food System

2.1 What is Food Security?

2.1.1 Food security definitions and pillars

Food security is a complex, multidimensional issue (ADB 2012; Botti Abbade and Dewes 2015), with multiple environmental, social, political and economic determinants (Ericksen 2008a; Ingram 2011) and is conceptualised as a dynamic outcome of a food system (Ericksen 2008a; Wu et al. 2011). The definition of food security itself is also a contested, evolving, multi-dimensional construct (Barrett and Lentz 2009; Foran et al. 2014) which includes dimensions of availability, access, utilisation and stability (Ericksen 2008a; Biggs et al 2014; Foran et al. 2014; Botti Abbade and Dewes 2015). It can be analysed through many viewpoints and from many geographical perspectives; global, regional, national (The Economist 2014) and local. Food security embodies a wide range of research challenges spanning the humanities and social and economic sciences, rather than just the biophysical sciences (Ingram 2011). As Martindale (2015) explains, it is often a difficult attribute to describe adequately because it is the sum of many aspects of people's lives.

Since the 1940s, the definition of food security has evolved from emphasising the supply side of food - a secure, adequate and suitable supply of food for everyone (Napoli 2011) - to one which recognises the importance of people gaining access to nutritional sources of food. It is commonly held throughout the food security literature (Webb et al. 2006) that Amartya Sen's 1981 essay on '*Poverty and Famines: An Essay on Entitlement and Depravation'*, was instrumental in shifting the paradigm away from availability or supply to that of access to food (Maxwell 1996; Webb et al. 2006), and in doing so, highlighted entitlement and achieving equitable livelihood security (Biggs et al. 2014). Sen's essay argued that people become food deprived due to a lack of access rather than supply (Webb et al 2006). Sen argued ''*starvation is the characteristic of some people not having enough food to eat. It is not the characteristic of there being not enough food to eat*" (Sen 1981, p.1; Mooney and Hunt 2009). Furthermore, Maxwell (1996) argues that this paradigm shift has also seen changes in the overall framing of the food security discussion shifting from; the global and the national levels to the household and the individual, from a food first perspective to a livelihood perspective, and from objective indicators to subjective perception.

Whilst this study is using the established definition of food security as, "*Food security exists when all people at all times have physical or economic access to sufficient, safe and nutritious food to meet all their dietary needs and food preferences for an active and healthy life*" (FAO 2006), the history of food security definitions highlights the evolving nature of the food security discussions and illustrates the importance of considering all pillars of food security. For example, this definition underlines the significance of not only the physical availability of food, but also the physical, social and economic access to food for those who are the most poor and malnourished (Moir and Morris 2011; Adephi Series 2013a; Nelson et al. 2016) – key elements for food security at the local level as highlighted by Sen (1981). It also encompasses hunger and nutritional status (McKay 2009; Adephi Series 2013a) and captures the concept of vulnerability to future disruptions in terms of people's access to adequate and appropriate food (Adelphi Series 2013a; Barrett and Lentz 2015).

Within the food security construct, there are four widely accepted indicators or pillars which are used to measure a populations', household or individual's level of food security - availability, access, utilisation and stability (FAO 2006; Barrett 2010; Moir and Morris 2011; ADB 2012; Barrett and Lentz 2015; Nelson et al. 2016). These concepts are inherently hierarchical, with availability necessary but not sufficient to ensure access, which is, in turn, necessary but not sufficient for effective utilisation (Hoddinott 1999; Barrett 2010). *Availability* links to the supply side of the food system (FAO 2006; ADB 2012) and refers to the availability of sufficient quantities of food of appropriate quality (Barron et al. 2013). This food can be sourced from local production or importation, although the latter can be very sensitive to disruptions (ADB 2012; Barron et al 2013; Cruz-Trinidad et al. 2014), thus linking it to the concept of vulnerability (see Section 2.4) and therefore stability.

Whilst availability of food reflects the supply side of the food security equation, *access* reflects the demand side (Barrett 2010), referring to the physical and economic access to food (Biggs et al. 2014), whereby people are able to produce food or have the ability to procure food (McKay 2009; Barron et al. 2013). In this way, it includes the distribution system for food, prices or may be driven by the pertinent local access arrangements of resources (Cruz-Trinidad et al. 2014). Access also accentuates problems in responding to adverse shocks such as unemployment, price spikes, or the loss of livelihood producing assets (Barrett 2010). It is through access to food that the linkages between food security, livelihoods and poverty (Barrett 2010) are also emphasised.

The third pillar of food security refers to *utilisation* which highlights the non-food resources and refers to the use of food for the body's nutrition and to the utility (i.e. pleasure) obtained from food (ADB 2012). This includes utilising food through appropriate diet, clean water, sanitation and health (Barron et al. 2013) to reach a state of nutritional wellbeing. Utilisation is important in recognising that food consumption needs to consider people consuming the right amounts of protein, fruits and vegetables and micronutrients to maintain physical and mental health (FAO 2006a; ADB 2012).

Lastly, the food security pillar of *stability* is beginning to receive more recognition within the literature, particularly given the focus on building resilient and sustainable food systems due to climate change issues (Wu et al. 2011). Stability refers to a population, household or individual having access to adequate food at all times (Barron et al. 2013) and reflects the vulnerability and exposure to shocks (Biggs et al. 2014) and the ability of the food system to continue to provide for the population it supports. This implies the need for stability in the availability, access and utilisation of food (ADB 2012; Barrett and Lentz 2015).

Whilst food security reflects the ability of people to have physical or economic access to sufficient, safe and nutritious food, food insecurity reflects people's *inability* to have physical or economic access to food. Food insecurity is the inability of populations, households or individuals to consistently access an adequate amount of food to live active and healthy lives, or to have the assured ability to acquire acceptable foods in socially acceptable ways (FAO 2006; ADB 2012). Food insecurity occurs primarily in those parts of the world where industrial agriculture, long-distance marketing chains and diversified non-agricultural livelihood opportunities are not economically significant (FAO 2009).

2.1.2 The relationship between food insecurity, poverty, malnutrition and hunger

In determining the current state of food security and how this translates at the local level (Research Question 1), the concept of food insecurity must also be viewed through the lens of poverty, hunger and malnutrition - all interconnected concepts and used throughout the food security literature. Food insecurity is closely related to poverty and vulnerability, especially among farming households in rural areas, where income and crop production overlap strongly (Devereux 2012). Despite there being more than enough food currently produced per capita to adequately feed the global population (FAO 2011; Godfray et al. 2010a; Alexandratos and Bruinsma 2012; Moomaw et al. 2012; Cuesta 2013) and even to satisfy the diversified demand of a demographically changing world (Godfray et al. 2010a), there still remains persistent or periodic food insecurity (Ericksen 2008b; Alexandratos and Bruinsma 2012). In the period from 2014 to 2016, the number of people who were undernourished and did not receive the minimum dietary energy needs was approximately 795 million people (FAO et al. 2015; Townsend et al. 2016), down from 842 million recorded in 2009 (FAO 2008; Southgate and Coxhead 2009), with the vast majority of them – 780 million people – living in developing countries (FAO et al. 2015). Asia is home to the majority with approximately 568 million people undernourished (Fan et al. 2013).

Food insecurity is caused by multiple factors ranging from the macro-level to the micro-level with most the result of failures in three types of entitlements - availability, access and utilisation (Ericksen 2008b; Barrett and Lentz 2015). For example, in terms of availability, food insecurity causes are linked to production failures and seasonal shortages impacting on availability (Devereux et al 2008) and impacts of climate change and resource constraints (Walqvist et al. 2009). Access is affected by food prices, conflict, poverty and a lack of income opportunities (FAO 2009), or inaccessible markets or local market failures (Devereux et al. 2008; Walqvist et al. 2009; Vermuelen et al. 2011; Adelphi Series 2013a; Barrett and Lentz 2015), influencing people's ability to secure food even when food is globally abundant (Vermuelen et al. 2011). The inability to utilise food is an outcome of poor health, poor sanitation, or lack of knowledge about food preparation or nutrition (Barrett and Lentz 2015).

These factors impact upon local food security in a number of ways. For example, in the Philippines where this thesis case study site is located, inflation and high food prices makes food items unaffordable and hinders the ability of poor households to meet their daily food and dietary needs (Focus on the Global South - Philippines 2014). People working in the agriculture sector meanwhile, are more prone to hunger due to low rural incomes, lack of access to productive resources (i.e. land and capital) and the vulnerability of the sector to various shocks i.e. climate change, extreme weather events, pests and diseases (Focus on the Global South – Philippines 2014).

Overall the literature agrees that the cause of food insecurity is significantly determined by poverty, whether chronic or seasonal (Barrett 2010; Mathur 2011; Moomaw et al. 2012; Barrett and Lentz 2015). The ADB (2012) acknowledges the lack of food security is both a cause and an effect of poverty, thus highlighting the complex and intertwined relationship between food insecurity, hunger, poverty and malnutrition (Southgate and Coxhead 2009; Yang and Hanson 2009; Adephi Series 2013a; Barrett and Lentz 2015). Poverty leads to people unable to access food because they do not have the land to cultivate or the income to purchase food (FAO 2009; Godfray et al. 2010a; Cuesto 2013; Guillou and Matherson 2014). This in turn, deprives them of access to adequate, good quality food, denying them the nutrition they need to be healthy, and is the main cause of systemic malnutrition (ABD 2012; Guillou and Matherson 2014). As part of the food insecurity cycle, malnutrition undermines productivity, keeps incomes low, and traps people in poverty (ADB 2012).

The relationship between food insecurity, poverty and malnutrition is particularly emphasised in rural areas of developing countries, whereby poverty rates are the highest with nearly 80 percent of those suffering hunger, being rural poor (Balisacan 2004; IFAD 2012; Guillou and Matheron 2014; FAO et al. 2015). Of the approximately 1.4 billion people living on less than US$1.25 per day (IFAD 2012), most are earning incomes from agriculture (Olinto et al. 2013). Poverty reduction across a wide range of countries and conditions has been associated with growth in the value of agricultural production, increased rural-urban migration and a shift away from economies highly dependent on agriculture to more diversified sources of income and employment (Timmer 2014). It is therefore argued that eliminating rural poverty is essential to eradicating hunger and poverty (Timmer 2014; FAO 2016).

2.1.3 The importance of agriculture and fisheries to food security and livelihoods

2.1.3.1 Smallholder agriculture, food security and livelihoods

With the vast majority of the world's food insecure people comprising rural farming households (Adephi Series 2013a; Townsend et al. 2015), agriculture plays a key role in economic development and poverty reduction (Rockstrom et al. 2010; FAO et al. 2015). In particular, agriculture remains the single most important source of food and nutrition (ESCAP 2009) being particularly effective in reducing hunger and malnutrition (FAO 2008). Furthermore, it contributes as a significant source of livelihoods for the poor and generates increases in food availability and incomes (Adelphi Series 2013a; FAO et al. 2015) and provides advantages such as low economies of scale and readily available household labour (Wiggins 2009). Smallholder farms for example, produce much of the world's food (Lipper et al. 2014), approximately 80 percent, in terms of value (FAO et al. 2015).

Agriculture is important for food security in two ways: (i) it produces the food people eat, and; (ii) it provides the primary source of livelihood for 36 percent of the world's total workforce (FAO 2008), of which around 43 percent of this is composed of rural women in developing countries (FAO 2016). For those who rely on subsistence agriculture, food security is strongly dependent on local food availability, and for the majority who exchange cash, other commodities or labour for food, the access component is of critical importance, especially in relation to dietary diversity and nutrition (Vermuelen et al. 2011).

Millions of people around the world depend on agriculture for base subsistence (Beddington et al. 2012), with 75 percent of the world's 1.2 billion poor living and working in rural areas, and dependent on agriculture as the main source of income and employment (Easterling et al. 2007; United Nations Global Compact 2012). Within Asia, people are much more dependent on agriculture than other developing regions, reflecting its historical structural dependence on smallholder farmers and the need to keep them profitably employed in agriculture even as the industrial sector is expanding rapidly (Timmer 2010). Nearly two thirds of the poor living in the region's rural areas are dependent on agriculture and agricultural-related industries for employment and income (Balisacan 2004; Dev 2011). The contrast between Asia and the rest of the world is significant with figures showing that in 1961 agriculture was 3.7 times as important to Asian economies as to the world as a whole, and in 2007 this had increased to 5.2 times more important (Timmer 2010). This contribution of agriculture to growth and poverty reduction[1] will continue to depend on smallholder farmers (Birner and Resnick 2010) as it increases returns to labour and generates employment for the poor (FAO 2012).

For many of these populations, economic ability and therefore economic growth, is determined by the ownership of agricultural related assets (land, labour and livestock), access to markets and access to secondary livelihoods other than agriculture (FAO et al. 2010; Cramb et al. 2010). However, even with access to key assets, there are a number of challenges facing smallholder farmers in achieving economic ability and growth. Many agricultural smallholders are characterised by limited access to land and water resources (Adelphi Series 2013a). For example, globally 84 percent of family farms are smaller than 2 hectares and manage only 12 percent of all agricultural land (FAO et al. 2015) whilst in Asia around 52 percent of farms are less than 1.0 hectare (Devendra and Thomas 2002).

[1] The World Bank estimates smallholder agriculture to be two to four times more effective at reducing poverty than growth originating from other sectors (Townsend et al. 2015).

Furthermore, low capital input, low levels of economic efficiency, diversified agriculture and resource use, conservative farmers who are illiterate and living on the threshold between subsistence and poverty, and who suffer from an inability to use new technology (Devendra and Thomas 2002), are all characteristics of smallholder farming. These characteristics all restrict the ability of farmers to not only produce substantial quantities of produce, but they also tend to be more exposed to shocks of different kinds including climatic, seismic and economic (FAO et al. 2015).

The adaptive capacity of smallholder farms to manage risk or shocks is low (IFAD 2007; FAO 2016) and is limited by barriers including lack of land tenure security, very limited access to information, extension advice and markets, a lack of safety nets to protect livelihoods against shocks, and gender-bias in all of those institutions (FAO 2016). To cope with shocks, during extreme events households tend to adopt precautionary strategies such as selling of assets that are difficult to rebuild, which may protect them against catastrophic losses but undermine long-term livelihood opportunities and can trap them in chronic poverty (IFAD 2007; Beddington et al. 2012; Godber and Wall 2014; FAO 2016). Thus, for low-income populations, food insecurity negatively affects future livelihoods through the forced sale of assets that are difficult to rebuild (Beddington et al. 2012).

The need to provide responses to assist in mitigating or adapting to systemic shocks is now imperative if rural poverty reduction is to occur. Given the lack of adaptive capacity of smallholder farmers, there are now calls to improve smallholder productivity and climate resilience through strengthening of links to markets, agribusiness growth, and increasing rural nonfarm incomes in order to raise household incomes (Townsend et al. 2015). In particular, linking smallholder farmers to markets, whether to local markets or regional supply chains, is seen as providing an avenue to reduce poverty and food insecurity, whilst increasing the global supply of food (United Nations Global Compact 2012). Others suggest that public policies recognising the diversity and complexity of the challenges facing smallholder farms throughout the value chain are necessary, for ensuring food security (FAO et al. 2015).

2.1.3.2 Fisheries, food security and livelihoods

Food from oceans, seas, rivers and lakes constitute an irreplaceable part of the dietary preferences in many cultures, including those of their poorest peoples (Kent 1997; ESCAP

2009; Garcia and Rosenberg 2010), with many relying on them for food security and livelihoods (Silvestre and Pauly 1997; FAO 2010a; Kittinger 2013). For example, in the Coral Triangle region of Asia, over one hundred million people living along the coastal zones use this biodiversity to support their livelihoods and incomes and provide food (Hoegh-Guldberg et al. 2009; Foale et al. 2013; Cruz-Trinidad et al. 2014). In addition to the provision of food and livelihoods, reef fisheries are also considered to be critical safety valves in times of economic or social hardship or disturbance (Sadovy 2005; Gill et al. 2017; Reef Resilience Network 2018).

Fisheries are critical to food security and poverty reduction including nutrition, supply (and its sustainability), demand, access, and the role of small-scale workers (Garcia and Rosenberg 2010; McClanahan et al. 2013; Bene et al. 2015; Bene et al. 2016). The importance of fish to diets is further highlighted when the World Bank (2013) noted that even in small quantities, provision of fish can be effective in addressing food and nutritional security among the poor and vulnerable populations. Fisheries therefore contribute to food security in two ways: (i) directly as a source of essential protein and nutrients, and; (ii) indirectly as a source of income, livelihoods and employment that enable fisher households to purchase food and other services (Garcia and Rosenberg 2010; Foale et al. 2013; Cruz-Trinidad et al. 2014).

Globally, in 2013, fish represented approximately 17 percent of animal protein supply and 6.5 percent of all protein for human consumption (World Bank 2013; FAO 2016b; Ferreira et al. 2016). However, in low-income countries these figures are higher, with fish consumption providing more than 3.1 billion people with almost 20 percent of their average per capita intake of animal protein (FAO 2009; FAO 2010a; Garcia and Rosenberg 2010; FAO 2016b; WWF 2016). Asia is the biggest consumer of fish accounting for two-thirds of total global consumption (Ferreira et al. 2016) with per capita consumption averaging around 27kg annually, compared to the world average of around 17-18kg (Dey et al. 2004; Dey et al. 2008; Garcia et al. 2008).

Whilst fisheries comprise an important element of food security, they also contribute as a source of income and livelihood for millions of people around the world (FAO 2010a; Ferreira et al. 2016). All up, the fisheries and aquaculture sectors contribute approximately US$100 billion annually to global trade (McClanahan et al. 2015), with the Asian region providing around 61 percent of the world's supply of fish (Dey et al. 2008). To accommodate this demand, employment in the fisheries sector has grown faster than the world's population and employment in traditional agriculture (FAO 2010a). In 2014, it was estimated that 56.6 million people were engaged in the primary sector of capture fisheries and aquaculture, of whom 36 percent were engaged full time, 23 percent part time, and the remainder were either occasional fishers or of unspecified status (FAO 2016b). Women accounted for 19 percent of all people directly engaged in the primary sector in 2014 (FAO 2016b) up from 12 percent in 2010, but when the secondary sector (e.g. processing, trading) is included women make up about half of the workforce (FAO 2016b). The majority of fishers and aquaculturists are in developing countries, mainly in Asia, which has experienced the largest increases in recent decades, reflecting, in particular, the rapid expansion of aquaculture activities (FAO 2010a).

Despite this reliance on fisheries as a food and livelihood source, it is now generally recognised that coral reef fisheries in particular, are unsustainable. Coral reefs account for only 0.1 percent of the world's oceans (Pauly et al. 2002), however, these ecosystems and the fisheries they support, are now under threat with estimates that 20 percent of targeted fishery resources are moderately exploited, 52 percent are fully exploited with no further increases anticipated, 19 percent are overexploited, 8 percent are depleted, and 1 percent are recovering from previous depletion (Garcia and Rosenberg 2010; Burke et al. 2011; Burke et al. 2012). Causes of this degradation include overfishing, destruction of habitats (e.g. coral reefs and mangrove forests), coastal eutrophication and nutrient enrichment, water pollution and climate change factors (Kent 1997; Rice and Garcia 2011; Burke et al. 2011; FAO 2012; ESCAP 2009; Foale et al. 2013; FAO 2016a). Where overall fish supplies diminish, and prices increase, the food security of people in general will be threatened (Kent 1997), thus leaving communities vulnerable. The social vulnerability of communities to these pressures has the potential to diminish the livelihoods, food security, well-being, and traditional lifestyles of coastal communities and cultures of the Asia-Pacific region and beyond (Kittinger 2013).

Given the threats to coastal fisheries, existing trends suggest that there is likely to be greater conflicts around food insecurity and fisheries due to issues such as declining fishery resources, a North-South divide in investment, changing consumption patterns, increasing reliance on fishery resources for coastal communities, and inescapable poverty traps (McClanahan et al. 2015). For poor people who are highly dependent on fish in their diets, insecurity with regard to fish food supplies caused by these threats, means that they are exposed to real harm (Kent 1997). Poverty and food security remain critical considerations in many coastal areas in the Asia-Pacific region, inextricably linking fisheries ecosystems to social vulnerability (Garcia and Rosenberg 2010; Kittinger 2013).

The improved management of fisheries, particularly coastal fisheries, is particularly important to coastal communities and their poorer populations as they rely so heavily on coastal fisheries for their income and food sources. In the context of variable and changing ecosystems, and despite some progress, the challenges of maintaining or restoring fisheries sustainability and stock sizes, reducing environmental impact and degradation, and improving local and global food security remain immense (Garcia and Rosenberg 2010).

2.1.4 The future of food security

There is increasing concern about the prospects for food security over the next forty years (Garnett and Godfray 2012; FAO 2016), as populations grow, demand increases and the environmental platforms the food system relies upon, continues to degrade (Foley et al 2011). Achieving sustainable food security, while not harming the social and biophysical environment, in a world of a growing human population and large-scale changes in economic development is a major challenge (U.S Grains Council 2011; van Wijk 2014). One dominant question arising in the literature is 'how will we feed the world of 9 billion people?' (Godfray et al 2010a; Msangi and Rosengrant 2011; Beddington et al 2012; World Bank 2013; Springer et al. 2014). This will need to be considered in light of increasingly affluent and urban populations, the shifting of diets towards higher consumption of calories, fats and animal products (Foley et al. 2010; Behnassi 2013; Barron et al. 2013), and given the recognition of environmental problems such as climate change, water and land scarcity and degradation, declining soil fertility, soil losses and habitat degradation (Beddington 2010; Godfrey, 2010a; Hanjra and Qureshi 2010; Foresight 2011; Moomaw et al. 2012).

In order to meet the growing demand for food from a population projected to reach 9.8 billion by 2050 (UN 2017), much of the literature focuses on the need to increase global agricultural production by 60 to 70 percent from 2006 levels (World Bank 2007; FAO 2009; Bruinsma 2009; Nachtergaele et al. 2011; ABARES 2011; Tilman et al. 2011; Foley et al. 2011; Foresight 2011; ADB 2012; Lineham et al. 2012; Garnett et al. 2013; Tomlinson 2013; Barron et al. 2013; Behnassi 2013; WRI 2014; Godber and Wall 2014; FAO 2016a). Bruinsma (2009) estimates that 66 percent of this increase will come from crop production and 76 percent from livestock production. To achieve the increases in crop production, it is estimated that 80 percent will need to come from higher yields and 10 percent from increases in the number of cropping seasons per year (Alexandratos and Bruinsma, 2012). Almost 97 percent of the required increase in agricultural production will occur in developing countries (Bruinsma 2009), with much of the projected rise expected to occur in Asia, accounting for 71 percent of the projected increase between 2007 and 2050 (Msangi and Rosegrant 2011), where agrifood demand is expected to double over the projection period, although China and India account for 43 percent and 13 percent (Msangi and Rosegrant 2011; Lineham et al. 2012) of the growth respectively. Whilst the production of food and other agricultural commodities may keep pace with aggregate demand, there are likely to be significant changes in local cropping patterns and farming practices (Easterling et al. 2007) to achieve this.

It is argued that these increases in agricultural production can be achieved through; producing food from the same or less land, through agricultural intensification (Evans 2009; Godfray et al. 2010b; Lambin and Meyfroidt 2011; Foresight 2011; Garnett and Godfray 2012; Garnett et al. 2013; FAO 2014), the application of new agricultural technologies (Sage 2013; Cuesta 2014) or improving crop genetics to enable them to better cope with new climates, and the new pests and diseases they will bring (Guarino and Lobell 2011).

However, whilst the promotion of a 60-70 percent increase in agricultural production to feed the population in 2050 is now widely used in the food policy arena and frames international policy debates about food security and the future direction of global agriculture (Tomlinson 2013), it remains a very narrow focus of the food system. Whilst the strategy of increasing agricultural production remains an important strategy to alleviate food insecurity (Ingram 2011), the focus remains only on the aggregated supply side of the food system of crops and livestock sectors (Tomlinson 2013; Garnett et al. 2013) and does not include fruit and vegetables which are important dietary requirements (FAO 2006; ADB 2012; Tomlinson 2013). Furthermore, it ignores the importance of fisheries as a key component for food security and livelihoods for many in developing countries (Foale et al. 2013; Cruz-Trinidad et al. 2014). Additionally, the focus on supply moves away from recognition of other food security outcomes such as access and utilisation of food such as dietary or nutritional requirements (Sage 2013; Feldman and Biggs 2012). Sage (2013) argues that any approach emphasising agricultural output increasingly regards food, feed and fuels as a set of interchangeable and tradable commodities for international markets rather than constituting the elements for national food security

The increased production argument does not take into account the associated ecological costs of production systems (Feldman and Biggs 2012). Food production is one of the primary causes of biodiversity loss through habitat degradation, overexploitation of species such as overfishing, pollution and soil loss (Rockström et al. 2009; Godfray et al. 2010a; WWF 2016) and is a major producer of greenhouse gases contributing to climate change (Beddington et al. 2012). In order to preserve the environment food systems are reliant upon, interventions are needed now (Garnett and Godfray 2012). It is argued that to achieve global food security and environmental sustainability, agricultural systems must be transformed to address both challenges (Foley et al. 2011). Any increases in food production whether across agricultural or fisheries systems, must be considered in light of global environmental change such as climate change, water and land scarcity and degradation, declining soil fertility and soil losses, and habitat degradation (Beddington 2010; Godfrey et al. 2010a; Hanjra and Qureshi 2010; Foresight 2011; Moomaw et al. 2012).

Future global food demand will lead to large land and water constraints of the poor, resulting in significant challenges for food security (Ibarrola Rivas and Nonhebel 2016). Whilst there is approximately 1.4 billion hectares of prime and good land that could be brought into crop cultivation, this would be at the expense of pastures require considerable investment (Alexandratos and Bruinsma 2012). Most of this available land is in sub-Saharan Africa and Latin America (Alexandratos and Bruinsma 2012) whilst in Asia, declining land trends are higher than in other developing regions. For example, the amount of arable land per person in Asia has been decreasing since 1960 almost halving to 0.25 hectares per person from 0.44 (Cuesta 2014) with the average farm size now less than 1.0 hectare (Devendra and Thomas 2002).

Competition will also be felt for water resources, with new constraints to be placed on water supplies available for irrigation as well as for rainfed agriculture (Ringler et al 2010), with competing demands from numerous sectors such as agriculture, energy, industry and drinking water (Biggs et al. 2014). Agriculture currently constitutes the largest user of freshwater supplies (Evans 2009; Rockstrom et al. 2010), accounting for between 70 and 80 percent of water use (Foresight 2011; Biggs et al. 2014). Access to water for livestock and particularly for the irrigation of crops, including food crops, is one of the ways poverty and food insecurity can be reduced in rural areas (Wenhold et al. 2007).

Along with constraints on land and water, is the growing issue of climate change posing a major and growing threat to global food security (IPCC 2007; Porter et al .2014; FAO 2016a; Nelson et al. 2016), and in particular to the agricultural sector (Dev 2011; Godber and Wall 2014). Climate change will bring about higher temperatures, more frequent extreme weather events, water shortages, rising sea levels, ocean acidification, land degradation, the disruption of ecosystems and the loss of biodiversity (Porter et al. 2014; FAO 2016a; Myers et al. 2017), adding to the global burden of hunger caused by poverty, weak governance, conflict and poor market access (Beddington et al. 2012). Climate change will compromise the agricultural and fisheries sectors' ability to feed the most vulnerable, impeding progress towards the eradication of hunger, malnutrition and poverty (FAO 2016a), as it alters agricultural production and food systems, and thus the approach to transforming agricultural systems to support global food security and poverty reduction (Lipper et al. 2014).

With widespread land degradation and increasing water scarcity limiting the potential for yield increases (Ringler et al. 2010; FAO 2016a), and without heightened efforts to reduce poverty, and to make the transition to food systems that are both productive and sustainable, many low-income countries will find it difficult to ensure access to adequate quantities of food for all of their populations (FAO 2016a). The literature places an emphasis on the crucial role that policies, investments and good governance can play in reducing risk and helping poor rural people to better manage them as a way of opening up opportunities (IFAD 2011; FAO et al. 2015). The FAO (2014) and OECD (2013) argue that countries will need to put in place policies such as targeted safety net programmes that ensure immediate access to adequate food for the most vulnerable, who have neither the capacity to produce their own nor the means to buy it.

2.1.5 From global to local food systems

Much of the debate on food security is focused at the global levels and does so under the '*presumption that the problems of hunger, starvation and malnutrition are a problem of global food security*' (Tomlinson 2013, p. 82). Food security or insecurity is very much a local problem in poor and agriculture-dependent societies (FAO 2006a) and is intrinsically linked to the issue of access to food at the local level, and in many cases is due to inadequate purchasing power (Yngve et al. 2009), rather than an issue of food availability through global production. As Sen (1981) noted, starvation is a characteristic of some people not having enough food to eat rather than there not being enough food to eat.

Furthermore, the debate focuses upon the supply side of the food security equation (Pinstrup-Anderson 2009), as the mechanism to provide a food secure future, rather than focusing on an integrated approach across all of the food security pillars. Alexandratos and Bruinsma (2012) argue that whilst there are no major constraints at the global level to increase agricultural production, this does not consider local level situations as some countries are already starting with adverse initial conditions of low national average food availability, high undernourishment, high population growth and poor land and water resource endowments. By focusing at the global level, the dynamics within the local[2] food system where the majority of food is grown for self-sufficiency and livelihood purposes, and where the impacts of the social-economic and environmental drivers will be felt the most (Tomlinson 2013), remain largely diminished.

2.2 Methods for measuring food security

With food security concerns growing worldwide, the focus is now on improving food security measurements (Barrett 2010), as food insecurity becomes a daily reality for hundreds of millions of people around the world, many of whom are also affected by government policy and aid decisions based on these measurements (Jones et al. 2013; Webb et al. 2006). Headey and Ecker (2012) note that whilst food security measurements have substantially expanded in recent decades, there persists significant dissatisfaction with existing measurement systems, especially in the wake of the 2008 global food and financial crisis.

There is an abundance of tools and measurement systems which are used by governments, organisations, aid and development agencies and non-governmental organisations, all of which are used to measure various aspects of the food security outcomes (i.e. availability, access, utilisation and stability) and across different levels (e.g. regional, national, household). The array of measurement tools and the complexity of many of the tools, has led to calls for the development of a universally applicable tool to capture all of the food security requirements (Melgar-Quinonez and Hackett 2008). Like

[2] 'Local' in this study refers to the Municipal level comprised of barangays (districts)

many of the current measurement systems, any universal tool will also have its limitations given the many complexities around food security, the various metrics required for each of the food security outcomes, different understandings as to how to measure these outcomes, the need to acquire information for different situations and circumstances, and current multiple methods used to obtain information at various levels for the metrics. As Webb et al (2006, p. 1405S) state, there is no ‘‘perfect single measure that captures all aspects of food insecurity’’. Whilst it is generally recognised that food security cannot be easily measured in monetary or energy-availability terms, it has not found a way to identify how, when, and where different facets of the concept are more important than others (Webb et al. 2006).

It is therefore generally agreed that measuring food security or food insecurity is complex, costly and complicated, and it remains an elusive concept due to the complexity and wide array of factors associated with food insecurity (Maxwell 2003; Cunningham 2005; Melgar-Quinonez and Hackett 2008; Barrett 2010; Carletto et al. 2013). Many researchers such as Cunningham (2005), Barrett (2010), Napoli (2011), National Research Council (2012), Headey and Ecker (2012) and Jones et al (2013), have all provided input into the discussion as to what an ideal food security measurement system should satisfy, and to benchmarking existing indicators and measurement systems. Whilst there is no agreement on a universal framework, there is however, agreement across the board as to why it is important to have an effective and reliable measuring tool which can monitor and evaluate food security or insecurity.

Much of the literature notes that effective measuring systems and their tools are critical to enable governments, aid agencies and development programs to be able to receive accurate and effective information on food insecurity issues including the identification of where and when there is a problem, and to diagnose the causes of food insecurity and malnutrition (Webb et al. 2006; Maxwell et al. 2008; Pinstrup-Andersen 2009; Ballard et al. 2013; Carletto et al. 2013). The information from these systems can be used to target policies and programs for food and economic aid, monitoring systems, and nutrition, health and development programs. Measurement systems can also be used as early warning systems as to potential food insecurity problems and enable the establishment of interventions and the effective mobilization of resources for problems. Furthermore, measurement systems enable an ongoing monitoring and evaluation of interventions and can be used to determine which interventions have a positive impact on the food security status of a country's population and when changes are required to improve the application of policies and programs (Webb et al. 2006; Maxwell et al. 2008; Melgar-Quinonez and Hackett 2008; Barrett 2010; Headey and Ecker 2012; Jones et al. 2013).

This study is not designed to evaluate the various systems and tools available, however, it does require an understanding of the enormous diversity of food insecurity measurement systems and tools and the range of metrics used in these measurements. This is particularly useful for the problem articulation in assessing and understanding the food insecurity problem in the study site outlined in Chapter 4. The following section provides a brief overview of the various measurement systems and tools highlighted in the literature and which are some of the major tools currently being used by governments, aid agencies and development programs to assess food security or insecurity across national or household levels.

2.2.1 Food Security Measurement Systems

There are multiple approaches and measurement systems designed to capture information across food insecurity metrics focusing on food availability, access, utilization or the stability of food security over time, and are designed to provide information at either the national level (which can then be aggregated for regional and global figures), household, and/or individual levels. The range of tools varies from simple indicators which can be used for a rapid-assessment by collecting data quickly and is easy to analyse, to all-inclusive measures that require detailed data collection and analysis (Napoli 2011; Jones et al. 2013) and which are time and resource intensive. As Jones et al (2013) notes, identifying the intended use of a tool and understanding the underlying constructs it measures are critically important for determining which metric should be used.

Whilst there are a large number of measurement systems and tools, there is a general agreement in the literature as to what the key measurement systems or tools are, and what they aim to measure. Many of the researchers who have reviewed these measurement systems have generated their own categorisation, although there are overlaps amongst some of these categories, and reviewers have broadly highlighted the same key tools in their reviews. For example, some of the categorisations of measurement tools includes Headey and Ecker's (2012) categories whereby they used a 'thought experiment' through placing the tools through the eyes of a policy maker with a mandate for ensuring both food and nutrition security and the requirement to empirically understand the spatial, temporal, and demographic dimensions of food insecurity in the country, and also how food insecurity contributes to malnutrition (Headey and Ecker 2012). Their results then group the tools into three categories; monetary poverty indicators, dietary diversity indicators or subjective / experimental indicators (Headey and Ecker 2012). Napoli (2011) uses the five categories measuring success against the Target 3 of the Millennium Development Goals (MDGs) on food insecurity at an FAO Symposium on Measurement and Assessment of Food Deprivation and Undernutrition in 2002 as a means for the categorisation of tools. The five groupings used include FAO Indicators for undernourishment, Household Income and Expenditure Surveys (HIES), Food Intake Surveys (FIS), Qualitative measures of food security, and Anthropometric indicators. The National Research Council (2012) demonstrates an overlap with Napoli and uses three categories: the FAO Indicator; food consumption surveys, and; anthropometric measures. Lastly, the approach taken by Jones et al. (2013) assigns the various measurement systems and tools to five types of categories which again overlap in varying degrees with those outlined above: (i) national level estimates of food security and global monitoring and early warning systems; (ii) measuring household food access; (iii) measures based on participatory adaptation; (iv) direct, experience-based measures, and; (v) measuring food utilisation e.g. anthropometry methods.

Table 2.1 provides an overview of the measurement systems and/or tools, and their categorisation based on what they are aiming to measure or achieve. The table uses a combination of both Jones's et al. (2013) and Headey and Ecker's (2012) categorisations and include: calorie-based indicators; dietary diversity-based indicators; subjective indicators i.e. qualitative measures; anthropometric indicators, and; global monitoring and early warning systems. These categories provide a simplified framework which is based on what the tool identifies and how it is used.

Table 2-1. Summary of key measurement systems and tools based on literature review

Category	Measurement System or Tool	Reference
Calorie Indicators Measured at the country level based on national food balance sheets	***FAO Indicators*** Estimates on a global scale the number of persons in a country whose daily food availability does not provide the minimum amount of energy (kilocalories)	FAO, 2015; FAO, 2013a and 2013b; Jones et al, 2013; Headey and Ecker, 2012; NRC, 2012; Napoli, 2011; Barrett, 2010; Cunningham 2005
	Global Hunger Index Assesses hunger globally, monitors the progress of the MDGs and interprets trends within causal models	Jones et al, 2013; Napoli, 2011
	Action Aid Hunger Index Measures hunger outcomes and a country's commitment to eradicating hunger in terms of a person's legal right to food, and the country's investment in agriculture and social protection	Napoli, 2011
Dietary Diversity Indicators Captures consumption of both macro and micro nutrients, and diversification into higher-value micronutrient-rich foods based on wealth and ability to purchase beyond staples.	*Household Income and Expenditure Surveys (HIES)* Assess consumption levels and welfare of a population. Surveys obtain information on specific conditions, experiences and behaviours indicating the severity of the condition	Napoli, 2011; Cunningham, 2005
	Food Intake Surveys (FIS) / Household Consumption and Expenditure Surveys Evaluates the amount of food consumed by individual members of a household over a period of time	Jones et al, 2013; Napoli, 2011; Cunningham, 2005
	Food Consumption Surveys Nationally representative surveys providing a direct assessment of food energy deficiency at the household level (e.g converts food expenditure information into consumption quantities and calories)	National Research Council, 2012
Subjective / Experimental Indicators (Qualitative Measures) Assesses food security through examining people' s perceptions about energy inadequacy and food deprivation. Respondents are asked to rate the depth or frequency of their food insecurity through surveys, questionnaires	***Gallup World Poll*** Asks respondents whether they have experienced problems affording food over the previous 12 months	Headey and Ecker, 2012
	Household Food Insecurity and Access Scale (HFIAS) Set of nine generic questions thought to represent universal domains of the access component of household food security	Jones et al, 2013; Headey and Ecker, 2012
	Coping Strategies Index Indicator of household food security behaviour that is based on the question "What do you do when you do not have enough food, and do not have enough money to buy food?"	Jones et al, 2013; Maxwell et al 2008; Maxwell et al, 2003; Maxwell, 1996
	Household Economy Approach (HEA) Participatory approach to understanding household food security used by Save the Children Fund. It is an analytical framework not a	Jones et al, 2013

Category	Measurement System or Tool	Reference
	measure of food security in and of itself. Prescribes a set of procedures for assessing livelihood vulnerabilities	
	United States Household Food Security Survey Module An 18-question survey module which asks families to report their subjective experiences of four domains of food insecurity: anxiety about household food supplies; perceptions that accessible food is not adequate; reduced adult food intake; reduced food intake by children	Jones et al, 2013; Melgar-Quinonez and Hackett, 2008
	Household Hunger Scale (HHS) New scale based on the HFIAS using the final 3 questions of that survey, all of which pertain to the consequences of severe food insecurity	Jones et al, 2013
	Latin American and Caribbean Household Food Security (ELCSA) A regional experience-based measure based on the Household Food Security Survey Module	Jones et al, 2013
	Food Security Supplement Measurement through questionnaire which asks respondents to report behaviours and experiences directly	Frongillo, 1999
Anthropometric Indicators	***Measuring food utilisation*** Use of human body measurements to obtain information about nutritional status. Indicators commonly used are wasting, underweight and stunting of children under the age of five	Jones et al, 2013; National Research Council, 2012; Napoli, 2011; Cunningham, 2005; Derrickson et al, 2000
Global monitoring and early warning systems Tools are predictive in nature and used to monitor food security in areas of high risk	***Famine Early Warning Systems Network*** Network of international and regional partners funded by USAID that produces monthly food security updates for 25 countries. Provides evidence-based analysis to support decision makers to mitigate against food insecurity	Jones et al, 2013
	IPC Set of protocols for broadly assessing the food security situation within a given region. Purpose is to identify the severity and magnitude of food insecurity in a given region, compare food security outcomes, and identify strategic action objectives across contexts	Jones et al, 2013
	Vulnerability analysis and mapping technology WFP employs several assessments to conduct food security analyses that are collectively known as vulnerability analysis and mapping. Analyses are undertaken in crisis-prone, food insecure countries to assess food security status and examine underlying causes of vulnerability	Jones et al, 2013

Category	Measurement System or Tool	Reference
	US Department of Agriculture Projects food consumption (food demand) and food gaps for 76 low-and-middle income countries through to 2028. Measures intensity of food insecurity by determining the gap between projected food consumption for those falling below the threshold and the caloric target.	Thorne et al, 2018

The most commonly used and cited metrics to measure food insecurity is that of the FAO Indicators which measure undernourishment and hunger. The FAO Indicators have long been used to gauge trends in global hunger, derived from national-level food balance sheets across 180 countries (Barrett 2010; Headey and Ecker 2012; Jones et al. 2013; FAO et al. 2015). The FAO's prevalence of undernourishment indicator measures the probability that a randomly selected individual from the reference population is found to consume less than his/her calorie requirement for an active and healthy life (FAO et al. 2015). In developing the indicators, the FAO draws on nationally aggregated data on food supply such as food produced and imported, and utilisation including the quantity of food exported, fed to livestock, used for seed and processed processed for food and non-food uses, and lost during storage and transportation (Headey and Ecker 2012; Jones et al. 2013).

There are a number of criticisms of the FAO Indicators, namely: there is a possibility of errors in the food balance sheets caused by uncertain data; it operates under strong assumptions about the distribution of food consumption in the population e.g. the mean of the distribution of calorie consumption in the population equals the average dietary energy supply, and it does not take into account food consumed outside of the home (Barrett 2010; Headey and Ecker 2012; National Research Council 2012; Jones et al. 2013). To ensure the system was more robust, the FAO introduced a suite of food security indicators in 2013, which measures separately the four dimensions of food security to allow for a more nuanced assessment of food insecurity. Added to the continued reliance on the food balance sheets, a parameter that captures food losses during distribution at the retail level was introduced in an attempt to obtain more accurate values of per capita consumption (FAO et al. 2015).

Whilst the FAO Indicators are seen as one of the leading measurements for food insecurity, particularly at the national and global levels, other indexes such as the Global Hunger Index developed by the International Food Policy Research Institute (IFPRI) is also utilised expansively as a national level metric, as it collates information from the FAO, WHO and UNICEF to measure hunger using three equally weighted indicators – undernourishment, child underweight and child mortality (Napoli 2011; Jones et al. 2013). However, despite the strength of the index being inclusive of three different aspects of hunger and the data being reliable, there remains some criticism of the index due to double-counting of figures, and that it fails to pick up changes to outcome distribution and cannot react to short-term food and health shocks (Napoli 2011).

Despite the recognised reliability of these national level measurement systems, they tend to measure the food availability aspects of food security, whereas food access is generally perceived to be one of the fundamental foundations to the problem of food insecurity (Sen 1981; Webb et al. 2006). Food insecurity is increasingly concentrated in particular regions or groups within countries and there is a need for sub-national information (Cunningham 2005), which these indicators are not able to capture or assess. In particular, national or regional level measurement tools do not emphasise household level behaviours and determinants of food access (Melgar-Quinonez and Hackett 2008; Jones et al. 2013) which is important to understanding the causes of food insecurity at a local level, and to developing interventions for these.

The measurement systems used to gauge household food insecurity range from quantitative surveys and data collection to more qualitative approaches whereby people's perceptions of the problem are sought. As seen in Table 2.1, the range of these metrics is wide reaching. A range of surveys undertaken at the household level such as the household consumption and expenditure surveys and dietary diversity indicators are aimed at capturing information on food consumption and acquisition, dietary diversity and food consumption frequency, whilst others take a more participatory approach. These approaches are informed by context specific information collected from stakeholders in the communities (Maxwell et al. 2008; Jones et al. 2013). They include: (i) Household Income and Expenditure surveys and Food Consumption surveys which look at consumption and calorie levels within the household to be aggregated at national levels;(ii) the Coping Strategies Index which looks at household food security behaviour through the question "What do you do when you do not have enough food, and do not have enough money to buy food?" (Maxwell et al. 2003; Maxwell et al. 2008), to surveys such as the Gallup World Poll (Headey and Ecker 2012) which asks respondents whether they have experienced problems affording food over the previous 12 months, and the Household Food Security

Survey Module which consists of a set of questions asking families to report on their experiences across anxiety about household food supplies; perceptions that accessible food is not adequate; reduced adult food intake; reduced food intake by children (Napoli 2011).

Whilst these tools are aimed at measuring food access, it is also recognised that due to its multidimensional concept, this is difficult to measure (Barrett 2010). Jones et al. (2013) notes that many of the tools measure food acquisition or food consumption and not necessarily economic access to food. Data on household food consumption and expenditures from household-level surveys are increasingly important for assessing household food acquisition, as the data on food expenditures usually reflects only the monetary value of foods (Jones et al. 2013). However, they are also met with some criticism relating to the way they operate under assumptions that household food acquisition equals household food consumption. The use of qualitative measures to capture people's perceptions of food insecurity, whilst it can lead to a more detailed measurement of food security, and a deeper understanding of the food insecurity problem, as with other indicators, they also have challenges in terms of viability and accuracy (National Research Council 2012). Household surveys can face problems with data accuracy, and the ability to use it to compare and measure across areas and contexts as coverage can be limited. The surveys also tend to be high cost and are time resource heavy. Most of all, questions over data accuracy arise due to memory lapses, observer bias, respondent fatigue and possibly short and unrepresentative recall periods (Maxwell 1996a; National Research Council 2012).

In summary, whilst there is currently available a wide range of measurement systems and tools designed to assess food insecurity across the fields of availability, access, utilisation and stability, there still remains no agreement on what a tool would look like which could measure across all dimensions. Much of this appears to be grounded in the complexities of the food security problem itself, as well as in people's various definitions of food security and what needs to be focused upon. However, despite the criticism of the systems and tools, there are many advantages to the use of these systems and how the results can be applied in a policy context and direct interventions for food insecurity problems at the national level. As also highlighted by Webb et al. (2006), the literature is highlighting a changing shift in approaches to measuring food insecurity including: (i) a shift from using measures of food availability and utilization to measuring ''inadequate access''; (ii) a shift from a focus on objective to subjective measures, and; and (iii) a growing emphasis on fundamental measurement as opposed to reliance on distal, proxy measures.

2.3 Understanding food security as part of the food system

As outlined in Section 2.1, food security is considered a complex, evolving and multidimensional issue, due to its environmental, social, political, ecological and economic determinants (Ericksen 2008a; Ericksen et al. 2010; Misselhorn et al. 2012; Sage 2013; Foran et al. 2014), and the interactions between these determinants. Food security is an intrinsic and essential element of the food system, underpinned by the system components linking the food chain activities of producing, processing, distributing and consuming food across a range of social and environmental contexts (Liverman and Kapadia 2010).

Schipanski et al. (2016) argue that systemic and transformative solutions are needed to address the intertwined global challenges of shifts towards resource-intensive diets, limited water resources, decreasing crop diversity, diet-related health problems and persistent undernutrition, all of which are present in the research setting under observation. Given the challenges this poses, Liu et al. (2015) argues that in order to address complex interconnected issues, and identify effective solutions, a holistic approach to integrating various components of coupled human and natural systems across all dimensions is necessary. The food system in this research setting frames the social-ecological problem of food insecurity.

The system dynamics methodology as outlined in Chapter 3 Research Methods, is the approach undertaken to assess a local food system as it incorporates temporal variability, adaptations, uncertainty and nonlinearity into its analysis whilst also opening up pathways to understand co-evolutionary processes and to identify dynamic patterns emerging across hierarchical levels and across different spatial, temporal and social scales (Rammel et al 2007). In this sense the theory, study design and methodology can all be aligned under a systems banner. The systems approach can capture the interconnectedness and interdependencies across components, scales, sectors and feedbacks (Liverman and Kapadia 2010; Ingram 2011; Misselhorn et al. 2012) present across both human and environmental spheres, all of which directly impact the food security outcomes of availability, access and utilisation.

2.3.1 Using a food system approach to understand food insecurity

Food systems are complex and integrate social, environmental and technological processes and attributes that span local to global scales (Ericksen 2008a; Godfray et al. 2010a; Eakin et al. 2016). In 2014 the High-Level Panel of Experts on Food Security and Nutrition (HLPE) of the UN Committee on World Food Security defined food systems as "*A food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food and the outputs of these activities, including socio-economic and environmental outcomes*" (HLPE 2014; Capone et al. 2016). Food systems also include sectoral policies and regulatory frameworks that shape the food system as they interact with one another (Capone et al. 2016).

The food system concept is not new and grew out of interest in the interactions between global environmental change and food security in the late 1990s (Liverman and Kapadia 2010; Ingram 2011) as the increasing complexity of the issues involved called for a new approach. Previously, few models broadly described the system and most focused on one disciplinary perspective or one segment of the system (Sobal et al. 1998; Ingram 2011; Tendall et al. 2015), such as food chains, food cycles, food webs and food contexts (Sobal et al. 1998). The revised food system approach enabled the analysis of the two-way interactions between the range of food systems activities and food security outcomes, and the full range of the global environmental change of parameters (Ericksen et al. 2010; Ingram 2011) to be brought together and analysed.

Food system approaches are increasingly seen as a way to improve food systems outcomes and sustainability, in order to deal with competing priorities, and address the complex relationships that exist between components of food systems (Ericksen et al. 2010; Ingram 2011; Garnett et al. 2013; Tendall et al. 2015). There are many conceptualisations of food systems approaches with many focusing on particular aspects or dimensions of the food system. For example: climate and non-climate drivers focused (Porter et al. 2014); cultural economy approach (Dixon 1999); exploring production sectors of the economy (Sundkvist et al. 2005); integrated models of the food and nutrition systems (Sobal et al. 1998; Rutten et al. 2011; Hammond and Dube 2012); food systems from policy, institutional and production (Babu and Blom 2014) or, from socio-communal, economic and environmental spaces and systems perspectives (Blay-Palmer 2010), and; vulnerability mapping of food security (FAO et al. 2015), building in endogenous and exogenous variables to model exposure, sensitivity, vulnerability and resilience (Allen and Prosperi 2016) into the system.

However, the food system is shaped by systems outside of the agrifood sector (Hammond and Dube 2012) and in particular, is strongly influenced by social-ecological systems. Given the importance of understanding how food systems interact between the social and environmental, and how these interactions are driven by global environmental change plus the consequences of these interactions for food security (Ericksen 2008a; Ericksen et al. 2010; Ingram 2011; Tendall et al. 2015; Prosperi et al. 2016), this study is adopting the framework developed by Ericksen (2008a) and Ingram (2011) illustrated in Figure 2.2, as the initial conceptual framework to explore the food system in the study site.

Ericksen and Ingram developed the concept of the food system further, incorporating global environmental change and social-economic drivers at the forefront of the system. The complexity of food systems arises from the interlinkage and interaction of these drivers and activities at various scales and levels (Gerber 2014). Given the food system drivers and activities lead to significant negative social and environmental impacts (Sundkvist et al. 2005) and the amplification of these impacts by global climate change (FAO 2008; Porter et al. 2014; Toth et al. 2016; Hammond and Dube 2012) to transform ecosystems that are essential to human well-being (O'Brien et al. 2013), the framework provides for a systemic approach to a complex issue. In addition, Ericksen and Ingram's framework enables analysis across the various scales and levels in food systems and provides a structure to help identify key vulnerabilities and interactions in the context of food security (Ericksen and Ingram 2009; Ingram 2011; Toth et al. 2016; Allen and Prosperi 2016). It enables a visualisation of the interactions between drivers and the effects on food system activities and outcomes generating feedbacks. Overall, the framework is synergistic and enables for a 'systematic analysis of synergies and trade-offs, balanced across a range of societal goals' (Ingram 2011).

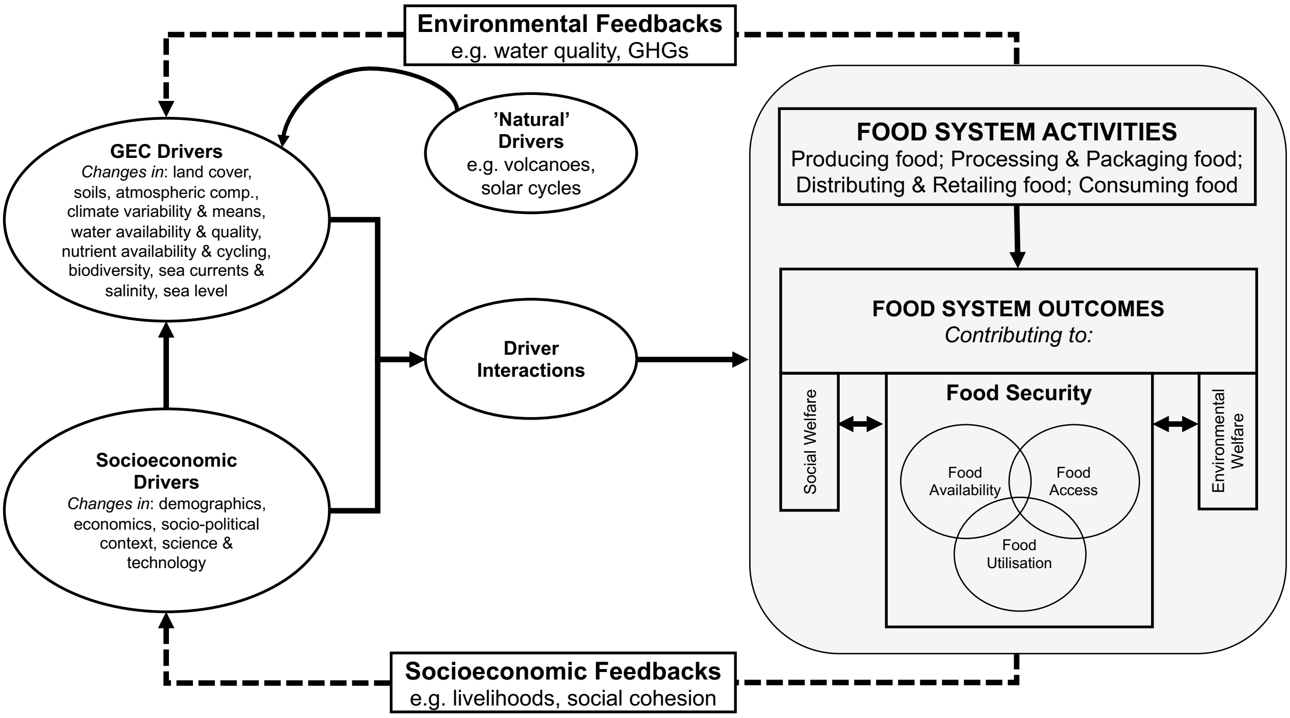

Figure 2-1. Food system framework highlighting food system drivers, activities, outcomes and feedbacks

(Source: Adapted from Ericksen 2008a; Ingram 2011)

The framework's central primary outcome is food security, and includes outcomes linking to the environment and social welfare, both of which are important either as platforms supporting the production of food or as livelihood sources and therefore accessibility to food. Linking to these outcomes are the major activities and actors involved in food systems, as well as the critical processes and factors influencing the social and environmental outcomes that are part of a food system. It links these so as to explain the nature of the outcomes at a point in time or space (Ericksen 2008a; Ingram 2011). This builds upon the idea that within complex systems it is possible to identify key processes and determinants that influence outcomes, although these outcomes may be contested (Ericksen 2008a).

Underpinning the food system is a set of activities comprising production (activities involved in the production of raw food materials), processing and packaging (the transformations that raw food material undergoes before it is sent to retail market), distributing and retail (activities involved in moving food from one place to another and marketing), and consuming (deciding what to select through to preparing and eating food) (Ericksen 2008a; Ingram 2011; Prosperi et al. 2016). These activities emanate in three outcomes – food security (i.e. availability, access, utilisation), social welfare and environmental welfare.

Food systems in turn have an impact on the environment as activities and outcomes are also drivers of global environmental change, engendering feedback loops and cross-scale interactions (Ericksen 2008a; Ericksen et al. 2010; Ingram 2011; Foran et al. 2014; Allen and Prosperi 2016). Both the activities and their outcomes relate to other socioeconomic issues and conditions, and to the environment, and all have feedbacks to the food system drivers (Ingram 2011). Furthermore, various elements of food systems are altered by, and actively impact, the socio-economic and environmental conditions of the system across local, regional and global levels (Prosperi et al. 2016; Toth et al. 2016). In generating feedbacks, they are influenced by the interacting GEC and socioeconomic 'drivers'; and the environmental, food security and other social outcomes of the activities feedback to the drivers (Ingram 2011; Ericksen 2008a). These activities in turn, are impacting on the environment or ecosystems which support them. For example, the act of producing both agricultural and fisheries products leads to impacts back onto the habitats or ecosystems which support them such as land through land clearing or soil degradation, water demand, or marine habitats through unsustainable fishing practices and overfishing.

2.3.2 Food systems as complex adaptive systems

Whilst this research did not apply complex adaptive systems methods in the food system analysis i.e. it applied systems dynamics (refer Chapter 3), it is important to recognize how the food system itself is a complex adaptive system. Complex adaptive systems evolve and are nonlinear (Holland 1992; Levin 1998; Rammel et al. 2007; Levin et al. 2012; O'Brien et al. 2013). They are evolutionary and do not return to states of equilibrium but continuously change in structure and behaviour over time (Hall and Clark 2010). Through interacting with and learning from its environment, a CAS modifies its behaviour to adapt to changes in its environment (Levin 1998; Lansing 2003; Holland 2005), and this ability of the parts to adapt or learn is the pivotal characteristic of CAS (Holland 1992; Mahon et al. 2008). Key to systems or complexity analysis is an emphasis on dynamics, interactions, feedbacks and delays, many of which occur at multiple levels and scales (Ericksen et al. 2010). In coupled human and natural systems, people and nature interact reciprocally and form complex feedback loops (Liu et al. 2007).

CAS are systems that have a large number of components (or agents), that interact and adapt to or learn from (Levin 1998; Holland 2005; Rammel et al. 2007; O'Brien et al. 2013; Holland 2014) changes in its environment (Mahon et al 2008; Lansing 2003; Holland 2005; Levin et al. 2012). In complex adaptive systems, nested hierarchies, multiplicity of cross-scale interactions and feedback loops between different hierarchical levels imply a high degree of complexity and non-linear behaviour (Rammel et al. 2007). As Holland (1992, p.19) notes, complex adaptive systems involve a *'great number of parts undergoing a kaleidoscopic array of simultaneous interactions*' and are at the heart of important contemporary problems.

Food systems themselves are complex adaptive systems (Clancy 2013) dealing with the challenge of how to provide access to food for the growing population without diminishing the environment upon which the system relies. The food system is comprised of systems nested within other systems and many systems are systems of smaller systems (Kaisler and Madey 2009). For example, food systems consist of complex social-ecological systems (Ericksen 2008a; Prosperi et al. 2016) which are themselves, composed of sub-systems involving multiple interactions between human and natural components (Allen and Prosperi 2016) linked through feedback mechanisms (Tendall et al. 2015). This coupling within the system evolves over time as a complex adaptive system with interactions, emergence, evolution and adaptation varying over spatial scales (Liu et al. 2015).

Figure 2.1 illustrates the food system as a nested hierarchy of adaptive systems and sub-systems or 'panarchy' (Holling 2001; Berkes and Ross 2016). Panarchy provides a framework that characterises complex systems involving people and the environment as dynamically organised and structured within and across scale of space and time (Berkes and Ross 2016) and can therefore be applied to social-ecological systems (Hollings 2001; Fraser et al. 2005; Berkes and Ross 2016). The diagram illustrates the food system embedded within the broader complex adaptive system structure, and like all complex and dynamic systems, the processes and components within food systems are highly interconnected and encompass social, economic and political issues as well as ecological (Ericksen et al. 2010). Within the food system itself, lies two sub-systems - sustainable food systems and resilient food systems which are discussed later in this chapter. Both of these concepts are complementary (Tendall et al. 2015) and display the overlaps of shared systems. Although they aim to achieve different outcomes, a desirable state for a food system would be achieved when these two sub-systems are paired. Residing within both sustainable and resilient food systems are the human-environment systems, which themselves consist of multiple sub-systems. Whilst social-ecological systems are considered complex adaptive systems (Levin 1998; Rammel et al. 2007; Levin et al. 2012), within the food system they are further embedded as key drivers either impacting or impacted upon by food system activities and ultimately leading to food security outcomes.

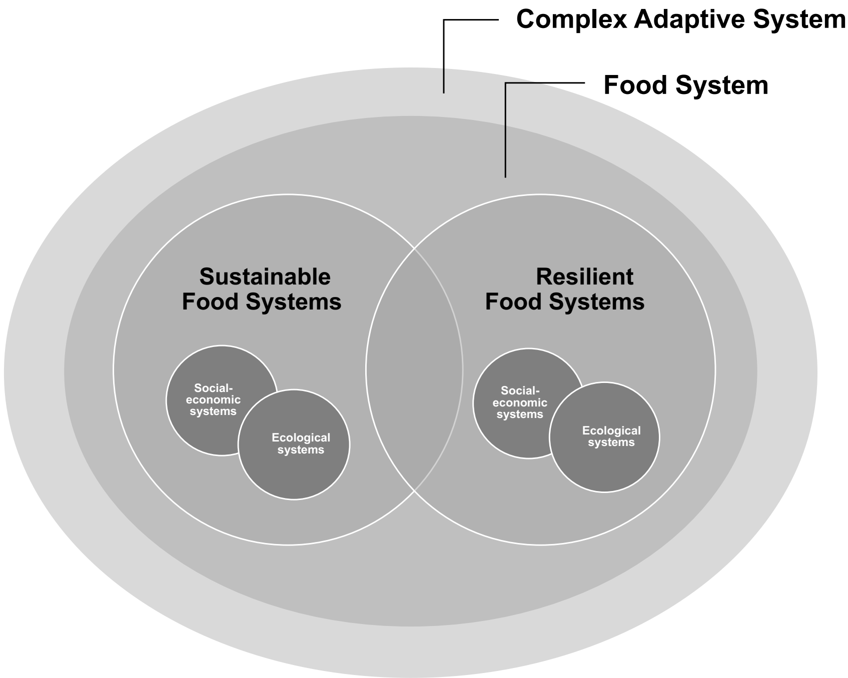

Figure 2-2. A nested hierarchy approach to the food system

The approach demonstrates embeddedness within the complex adaptive system framework, which is itself, composed of levels of sub-systems.

Food systems like all systems, are not static (Liu et al. 2007). They change over time and have to adapt to externally generated events and shocks, as well as responding to exogenous change. Each system or sub-system within the food system consists of individual agents able to learn from experience, adapt to changes from shocks and to exploit agendas (Levin et al. 2012). However, the ways these individuals act is not always predictable, especially as their actions can change the context for others (Clancy 2013). In this way, food systems demonstrate the three basic characteristics of complex adaptive systems – aggregation, evolution and anticipation (Holland 1992; Levin 1998).

Aggregation or self-organisation refers to the organisation of components or agents into groups or hierarchies which in turn influence system dynamics (Levin 1998; Miller and Page 2009; Kaisler and Madey 2009) across spatial or temporal scales (Kaisler and

Madey 2009). These components are usually grouped by homogeneity, that is, agents having similar regularities or consistencies (Levin 1998). For example, in the food system, aggregation can be seen at various levels such as through social or ecological systems themselves, or through a sub-system within the food system such as the supply chain, or food production systems. Levin (1998) notes that aggregation and hierarchical assembly are not imposed on complex adaptive systems but emerge from local interactions through endogenous patterns or behaviours from these interactions. All CAS have lever points, points where a small directed action causes large predictable changes in aggregate behaviour (Holland 2014). The actions of an agent are conditionally dependent upon what other agents are doing i.e. aggregate behaviour (Holland 2014) and emerge from local interactions through endogenous patterns or behaviours (Levin 1998).

Feedbacks can be described as an influence or message that conveys information about the outcome of a process or activity back to its source (Sundkvist et al. 2005). In the food system, this nonlinear behaviour and subsequent feedback loops can be seen in the interactions between these social-ecological systems (Miller and Page 2009). For example, an increased demand for crops will lead to communities converting forestlands into croplands and cultivating the land without supplying additional nutrients (e.g. fertilisers). This will lead to a loss of soil degradation with the result of decreases in crop yields and greater food insecurity, hastening conversion of further forestland to agriculture. Likewise, an increased demand for fish can lead to increased fishing pressure or destructive methods, which can damage the reef system supporting coastal fisheries. As the reef system declines, the productivity level of fish will also decline leading to food security and livelihood loss. The complexity of this nonlinearity is that components or agents often change in response to feedback from their own actions (Kaisler and Madey 2009).

Lastly, food systems anticipate. Learning from previous experience and seeking to adapt to changing circumstances, the components or agents can be thought of as developing rules that anticipate the consequences of certain responses (Holland 1992). Within the food system, this learning and adaptation process can be seen in the anticipation of food price increases, in which people will buy and hoard food at current prices, or in the anticipated dietary changes whereby production systems move away from traditional crops such as rice to be more grains orientated. This anticipation also leads to behaviours across agents, which also change how the system operates.

As with all complex adaptive systems, food systems are dynamic systems, composed of cross-scale interacting elements that change over time (Ericksen 2008b; Allen and Prosperi 2016). They incorporate processes and infrastructure involved in satisfying a population's food security (Rutten et al. 2011; Porter et al. 2014) and comprise a set of activities and outcomes ranging from production through to consumption (Ericksen 2008a; Ingram 2011; Rutten et al. 2011; Porter et al. 2014; Schipanski et al. 2016), involving both human and environmental dimensions interacting through feedback mechanisms (Tendall et al. 2015). These interactions compete for limited resources, leading to what Levin et al. (2012, p. 113) call "*behaviours of exploitation, competition, parasitism and cooperation*".

2.3.3 Resilient and sustainable food systems

Food systems are increasingly exposed to multiple internal and external drivers of change, ranging from sudden shocks to long-term stressors that in turn increase the systems' sensitivity to the disturbances and capacity to adapt (Wisner et al. 2003; Ericksen et al. 2010; Tendall et al. 2015; Toth et al. 2016). A food system is therefore considered vulnerable when it fails to deliver food security or has the potential to do so in the face of future stresses (Ericksen 2008b). However, food systems must continue to be able to fulfil their goals, even in the face of multiple, unpredictable drivers of change (Tendall et al. 2015). To do so, food systems must become resilient and sustainable. However, achieving this is one of the more pressing challenges of this century (Eakin et al. 2016) given the need for scale, commitment and involvement of multiple stakeholders (Ghosh 2014) necessary to bring about the changes needed.

Sustainable food systems and resilient food systems are complementary. Whilst sustainability involves preserving the capacity of the system to function in the future, resilience implies the capacity to continue providing a function over time despite disturbances, and thus forms an essential part of what enables sustainability (Tendall et al. 2015). In short, sustainability is the measure of system performance, whereas resilience can be seen as a means to achieve it (Anderies et al. 2013; Tendall et al. 2015) during times of disturbance. In both systems, the concepts of vulnerability, resilience and adaptive capacity are integrally linked to the ability of the food systems to continue to meet the outcomes of food availability, access, utilisation and stability.

Most approaches to vulnerability emphasise the importance of coupled human-environment systems (Turner et al. 2003). A common thread of vulnerability research, is the consideration that it is an 'intrinsic characteristic of a system' that is at risk (Birkmann et al. 2013; Allen and Prosperi 2016), and deals with features linked to the degree to which a system is susceptible to (Adger 2006; Cinner et al. 2013), and has the capacity to anticipate and cope with the impact of a change or hazard (Adger 2006; Eakin and Luers 2006; Ericksen 2008b; Cinner et al. 2013; Allen and Prosperi 2016). Vulnerability is conveyed therefore not by exposure to hazards alone, but also in the resilience of the system experiencing the hazard (Turner et al. 2003; Berkes 2007), and its ability to cope, adapt or recover from the effects of the exposure (Bruguglio 1995; Brooks et al. 2005; Smit and Wandel 2006; Adger 2006; Mumby et al. 2014).

Given the food system is a complex adaptive system coupling the human-environment system, this research focuses on vulnerability as both (i) biophysical – the potential for loss of a specific exposed population (Eakin and Luers 2006), that is, the ultimate impacts of a hazard event (Brooks 2003), and (ii) social - a measure of both the sensitivity of a population to natural hazards and its ability to respond to and recover from the impacts of hazards (Cutter et al. 2003; Adger 2006; Ericksen 2008b). Social vulnerability is driven by social inequity (Cutter et al. 2003; Phillips and Fordham 2009) and encompasses disruption to livelihoods and loss of security (Adger 2000a).

Vulnerability is interpreted in the literature through a variety of approaches or disciplines including socio-ecology (Turner et al. 2003; Adger 2006; Gallopin 2006; Turner 2010; Birkmann et al. 2013; Mumby et al. 2014), climate change science (IPCC 2007; O'Brien et al. 2007; Birkmann et al. 2013), disaster risk assessment (Cutter 1996; ECLA 2000; Dilley and Boudreau 2001; Pelling and Uitto 2001; Guillaumont 2007; TCARC 2012; Island Vulnerability 2013) and, political economy and political ecology (Adger 2000; Eakin and Luers 2012; Birkmann et al. 2013). Vogel et al. (2007) note that this range of approaches to understanding these concepts has enriched our understanding of the complex dynamics that produce vulnerability and adaptive capacity, but it also brings with it a variety of challenges, particularly in the application and use of these concepts in practice.

Given the focus on human-environment systems, this study utilises the social-ecological approach to vulnerability within the food system. This approach defines vulnerability as a condition encompassing characteristics of exposure, sensitivity, and adaptive capacity

(Adger 2006; Smit and Wandel 2006; Miller et al. 2010; Hughes et al. 2012; Mumby et al. 2014; Allen and Prosperi 2016). Exposure being the nature and degree to which a system is exposed to a given stressor, hazard or perturbation (Turner et al. 2003; Adger 2006; Gallopin 2006; Turner 2010; Mumby et al. 2014), such as environmental or socio-political including the magnitude, frequency, duration and areal extent of the hazard (Adger 2006; Cinner et al. 2013; Mumby et al. 2014). Sensitivity is the degree to which a system is modified or affected by perturbations, that is, the degree to which a stressor impacts the system (Adger 2006; Mumby et al. 2014). Adaptive capacity is the adjustments in a system's behaviour and characteristics that enhance its ability to cope with external stresses (Brooks 2003; Mumby et al. 2014). These components vary across space and time, regardless of the spatio-temporal scale of the stressor (Turner et al. 2003; Hughes et al. 2012).

Vulnerability of a food system, like that of the ecology and social-ecological approach, is the relationship between risks (exposure), resulting shocks (sensitivity), and resilience (adaptive capacity) (Dilley and Boudreau 2001; FAO 2004; Ericksen et al. 2010; Prosperi et al. 2014; Stave and Kopainsky 2015) to these. Food systems are increasingly exposed to multiple internal and external drivers of change, ranging from sudden shocks to long-term stressors that in turn increase the systems' vulnerability to shocks (Tendall et al. 2015). This in turn, affects population wellbeing and food security (Prosperi et al. 2014). When a food system fails to deliver food security or has the potential to do so in the face of a perturbation, the system can be considered as vulnerable (Ericksen 2008a; Allen and Prosperi 2016). However, food systems must also continue to deliver under increasing social-economic and global environmental change drivers, and to do so, it must therefore become resilient and adapt to changes as they occur.

Whilst vulnerability within the food system looks at the exposure to, and level of risk, resilience concerns the strategies implemented to mitigate the impact of the shocks (Prosperi et al 2015), that is, the capacity of the system to absorb and adapt to changes and adjust to shocks (Adger et al. 2005; Toth et al. 2016). The concept of resilience is increasingly used as an approach to understand and analyse the dynamics of human-environment interactions (Folke 2006; Berkes 2007; Cote and Nightingale 2012; Tendall et al. 2015). Resilience thinking relates to the functioning of a system and its capacity to absorb shocks or disruptions (Adger 2000a; Adger et al. 2005; Berkes 2007; Miller et al. 2010). In short, it reflects the degree to which a complex adaptive system is capable of self-organisation and the degree to which the system can build capacity for learning and adaptation (Adger et al. 2005). Figure 2.3 illustrates a systems approach to vulnerability, resilience and adaptive capacity (Cote and Nightingale 2012), highlighting the system's ability to absorb and react to the shock, restore and learn, and ultimately to adapt to the impacts of the shock and reorganise itself in such a manner as to become more resilient to the shock in the future. In this manner, the system incorporates adaptation, learning and self-organisation (Folke 2012; Mumby et al. 2014) – all of which fits well with attempts to predict or model social-ecological change (Cote and Nightingale 2012).

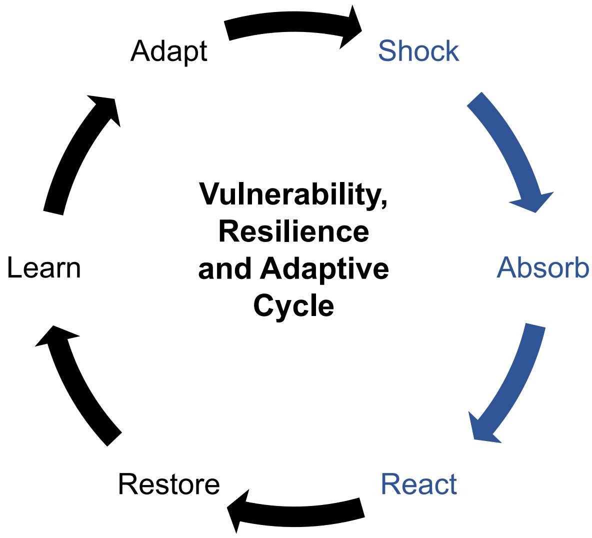

Figure 2-3. Vulnerability, resilience and the adaptive cycle

Resilience thinking relates to the capacity of the system to absorb shocks, react and adapt to these shocks. This overlays the food system framework to testing the resilience and adaptive capacity of the system, leading to long-term sustainability (Adapted from Tendall et al 2015). The steps highlighted in blue refer to the components simulated in the study's model.

Tendall et al. (2015, p. 19) defines food system resilience as the "capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances". This considers not only temporal and spatial scales, but also all of the aspects of food security i.e. availability, accessibility and utilisation. However, given the sustainability aspects of food systems, there is also a need to focus on the capacity of the system for renewal, reorganisation and development, which is essential for the sustainability discourse (Folke 2006), thus, the food system has to be able to adapt in the face of shocks or disturbances.

The last dimension in sustainable and resilient food systems – adaptation - usually refers to a process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity (Brooks 2003; Smit and Wandel 2006; Mumby et al. 2014). Given constant levels of hazards over time, adaptation will allow a system to reduce the risk associated with these hazards by reducing its social vulnerability. The direct effect of adaptation is to reduce vulnerability (Brooks 2003).

Each of these dimensions are key elements in both resilient and sustainable food systems. This study argues that a food system must be both with resilience embedded within the overall outcome-focus of sustainability of a food system. For example, vulnerability to shocks or disturbances is present across the food system and can be reflected in components and the feedback loops generated from interactions between these components. Resilience is the capacity of the system to mitigate the impact of the shocks and therefore to achieve sustainability through the adjustments or adaptations made in the system to mitigate against these impacts. A resilient food system is therefore considered to be one which enhances food security and is able to minimize, withstand and anticipate or adapt to, environmental and economic disturbances at different temporal and spatial levels (Misselhorn et al. 2012; Prosperi et al. 2016) and continuing to provide a function over time despite disturbances and change (Tendell et al. 2015; Schipanski et al. 2016; Toth et al. 2016). Schipanski et al. (2016, p. 601) defines these systems as "*the capacity of people to produce and access nutritious and culturally acceptable food over time and space in the face of disturbance and change"*.

A sustainable food system on the other hand needs to ensure it is both resilient to shocks in the system, and can adjust and evolve from these shocks, and in doing so, can continue to provide availability, access, utility and stability as outcomes within the system. Sustainable food systems are therefore defined as *"a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised"* (Ghosh 2014; Capone et al. 2016). Previous efforts to achieve sustainability within the food system have been framed in particular disciplinary discourses (Foran et al. 2014) such as agricultural sustainability studies (Prosperi et al. 2016) or focused selectively on only a few components of the food system (e.g., production, consumption, or distribution) (Foran et al. 2014; Schader et al. 2014; Eakin et al. 2016). This study is focusing on sustainability within food systems as more holistic and across the food system in its entirety.

In building in the concepts of vulnerability, resilience and adaptive capacity into these food systems, Ericksen and Ingram's food systems framework outlined in Section 2.3.2, provides a holistic approach in determining sustainability and resilience across all components and their interactions, and highlights the complexity and cross-level and scale interactions that must be considered for successful adaptation (Ericksen 2008b). Figure 2.4 illustrates the embeddedness of vulnerability, resilience and adaptive capacity within the food system framework to achieve the food system outcomes of food security, social welfare and environmental welfare.

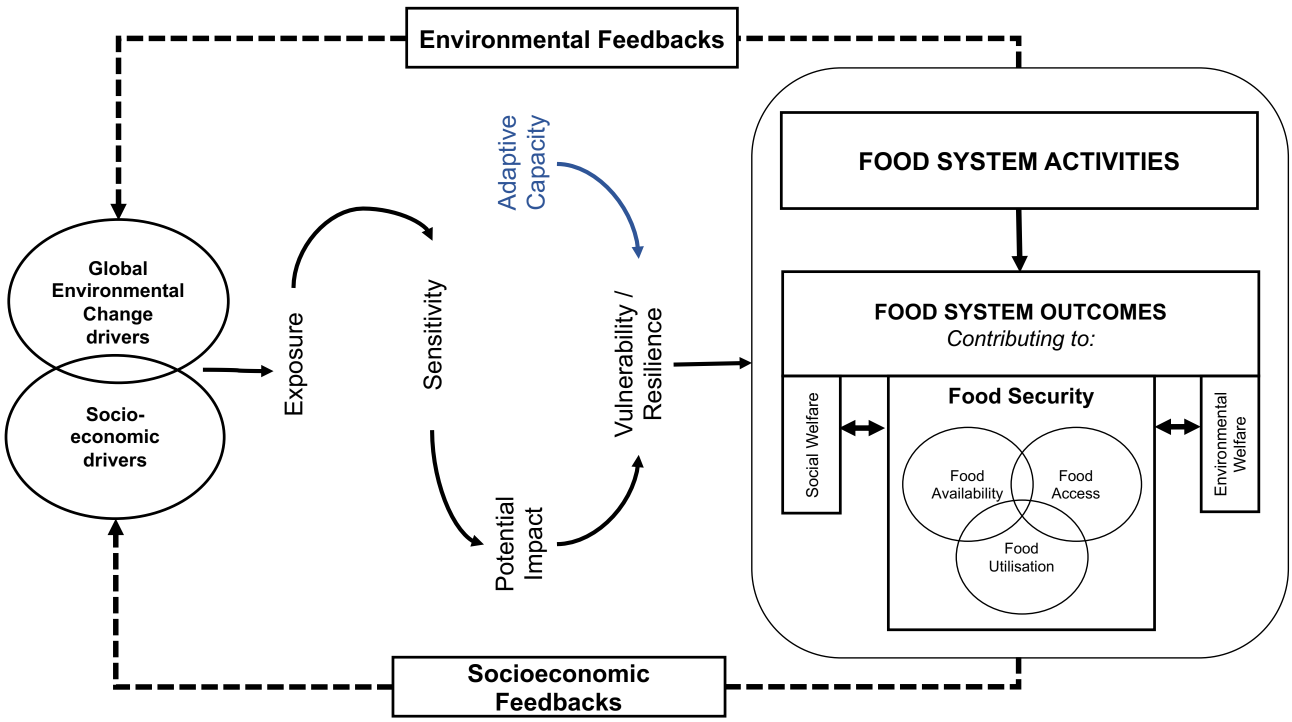

Figure 2-4. The food system framework illustrating the integration of vulnerability, resilience and adaptive capacity into the system

(Source: Adapted from Ericksen 2008; Ingram 2009; Mumby 2014; Allen & Prosperi 2016)

This framework forms the platform for developing a theoretical understanding of food systems as both sustainable and resilient, with many studies in the literature utilising this framework as the basis of further examination of the concepts of resilience and sustainability within the food systems (Eakin et al. 2016). The framework identifies the sustainability problems that affect food systems (Prosperi et al. 2016), and how feedbacks to both environmental and socio-economic conditions can affect food security and food systems in unexpected ways (Ericksen and Ingram 2009; Prosperi et al. 2016). This in turn, enables an assessment of the vulnerabilities in the system, thus hampering the ability of the system to be both resilient and sustainable if appropriate interventions are not implemented. The framework also enables an examination of the key food activities and consideration of how resilience can be increased in each (Toth et al. 2016). Lastly, the framework itself is underpinned by sustainability principles (Eakin et al. 2016), particularly the belief that the food system has to produce enough food and provide access to this food without further degrading the environmental platforms it relies upon.

In summary, the food system framework, as Gerber (2014) notes enables conceptualisation of the system for studying and understanding its complexity and behaviour including the impacts of shocks and the system's ability to adapt to these shocks; in building a framework where questions and studies can be placed in a structured way, and; contextualises the policy environment to understand and evaluate possible policy implications in an interlinked and broad frame.

2.4 Assessing vulnerability, resilience and adaptive capacity within a food system

Several indexes of vulnerability have been developed and are cited throughout the literature, however there is no strong consensus on the best methods to assess vulnerability, but most assessments entail considering one or more exposure to risks, susceptibility to damage, capacity to recover, and net outcomes (Barnett et al. 2008). For example, Turner et al. (2003) developed a vulnerability framework to link the human-environment coupled system's vulnerability to hazards. The framework includes exposure, sensitivity, resilience and adaptation dimensions, and consists of: (i) linkages to the broader human and biophysical (environmental) conditions and processes operating on the coupled system in question; (ii) perturbations and stressors stress that emerge from these conditions and processes; and (iii) the coupled human–environment system of concern in which vulnerability resides, including exposure and responses (i.e., coping, impacts, adjustments, and adaptations.

The fields of ecology, socio-ecology and climate change science also show examples of assessing exposure, sensitivity and adaptive capacity. Mumby et al. (2014) outlines a method of compiling a score for each of these dimensions at a particular site, which is then compiled into an overall vulnerability index that enables comparisons among sites

(Mumby et al. 2014). Both Hughes et al. (2012) and Cinner et al. (2013) have used these dimensions to assess vulnerability of regions and communities to impacts on coral reefs and associated fisheries, and therefore on food security and livelihoods. Hughes et al. (2012) calculated vulnerability as the degree to which a country is susceptible to a decline in coral reef fisheries as a food source and its ability to respond to the decline. Cinner et al. (2013) utilised the IPCC framework as the basis for exploring the vulnerability of fisheries to climate change in Kenya by considering both social and ecological dimensions of vulnerability.

Other vulnerability measurements have been used to assess the susceptibility of countries' economies to either climate change (Barnett et al. 2008) or household or individuals to a particular climate stress (Smith and Wandel 2006). Bruguglio (1995) constructed a composite index of vulnerability which intended to be a measurement of the lack of economic resilience arising from the relative inability of a small island state to shelter itself from forces outside of its control.

Within the food system, the notion of vulnerability has been focused more on food security outcomes or food production systems (Ericksen 2008b) rather than the system as a whole. However, some researchers are moving towards developing frameworks to view vulnerability, resilience and adaptive capacity as intrinsic elements of the system. Ericksen (2008b) developed a framework to assess the vulnerability of food systems to global environmental change. The framework builds on identifying food system vulnerability through responding to a set of questions to assess the vulnerability of food systems to global environmental change, identifying characteristics of food systems that may indicate vulnerability, and identifying components of food system vulnerability to specific global environment change factors.

Fraser et al. (2003) propose a framework based on the panarchy framework to identify vulnerabilities in the food system, and the capacity to adapt to change. He does this through looking at three generic characteristics: (i) the wealth available in the system; (ii) how connected the system is, and; (iii) how much diversity exists in the system. In this framework, differences between biophysical and social vulnerability are identified.

Lastly, Toth et al. (2016) and Tendall et al. (2015), both explore measuring resilience in food systems. Toth et al. (2016) developed a generic food system model comprised of nodes or activities and linkages representing flows of food and food system activities. From this, the resilience of each node by a constant and transferable measure which is then aggregated into an equation. Tendall et al. (2015) developed a conceptual framework for food system resilience, however, acknowledge that there still needs to be more research undertaken before more quantitative formulations of food system resilience with adequate metrics and measurements can be implemented (Tendall et al. 2015).

In summary, the method undertaken of measuring vulnerability depends on what is being measured and the research approach being undertaken. Whilst this study acknowledges the various techniques or approaches used to for measuring the exposure, sensitivity and adaptive capacity of a system, it will utilise a systems dynamics approach to assess the local food system and its vulnerability to system shocks (refer Section 3.3.1.1).

3 Research Methods

Drawing upon the previous chapter's review of theoretical understandings of food insecurity and the food system, this chapter describes the research approach developed to study the social-ecological problem of food insecurity within a local context. It firstly outlines the research approach and the analytical framework applied, and then describes the methodology of the research in detail, including the approaches used in each step of the methodology.

3.1 Developing the research approach

3.1.1 Ontological and epistemological issues

All research is underpinned by assumptions and obligations regarding ontology and epistemology, which are either implicit or explicit. Ontological and epistemological issues are important in shaping how problem situations are seen, framed, interpreted and investigated. The ontology and epistemology assumptions undertaken form the research paradigm (Figure 3.1). The assumptions and obligations underpinning this research are important due to the: cross-cutting nature of the social-ecological system studied; importance of the local context; spanning across multiple fields of knowledge and; linking of theory to practice in the study site. In developing the research constructs, there are multiple perspectives or paradigms which can be considered, and which guide social research including; post-positivism, interpretative / constructivist, critical, transformative, pragmatic, and arts based / aesthetic intersubjective (Leavy 2017). This section outlines the ontology and epistemology underpinning this research.

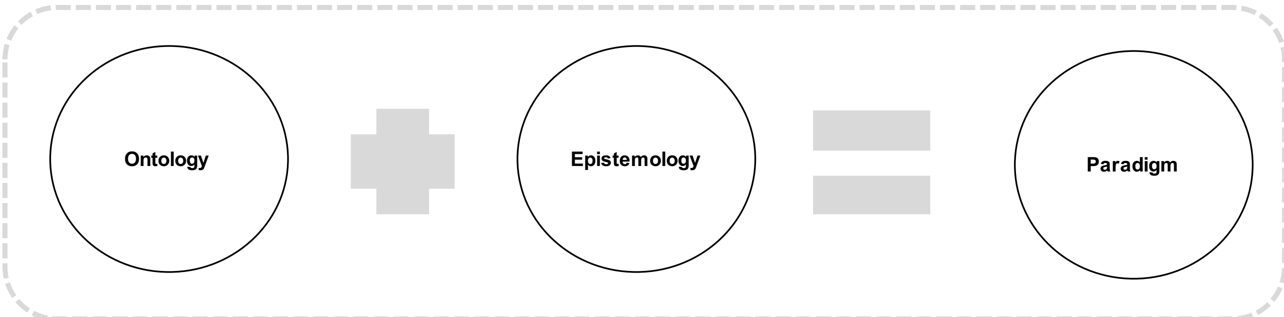

Figure 3-1. The components of a paradigm

(Source: Adapted from Leavy 2017)

An ontology is a philosophical belief system about how things really are (Scotland 2012; Klakegg 2015), that is, it represents phenomena in the empirical world as they actually exist or the nature of reality (Goertz and Mahoney 2012; Wahyuni 2012). The assumptions constitute reality and ask the '*what is'* (Scotland 2012) question. Ontological beliefs shape the nature of the social world and these belief systems inform our sense of the social world and, what we can learn about it and how we can do so (Leavy 2017). An epistemology on the otherhand, is concerned with how research proceeds and what counts as knowledge (Wahyuni 2012). Epistemological assumptions are concerned with how knowledge can be created, acquired and communicated, that is, '*what it means to know'* (Scotland 2012). It therefore informs how we enact the role of researcher and how we understand the relationship between the researcher and research participants (Leavy 2017).

In this research, I am adopting systems thinking as the research paradigm. Reynolds and Holwell (2010) argue that systems are constructs used for engaging with and improving situations of real-world complexity and provides for a holistic and interconnected 'world view' (Maani and Maharaj 2001). Therefore, systems thinking as a paradigm has a particular ontology (systems as representing real world entities) and epistemology (systems as learning devices to inquire into real world entities) (Reynolds and Holwell 2010).

Whilst this research uses the systems thinking approach as the overarching paradigm, it is recognized this also closely aligns with a constructivist approach. Systems thinking seeks to understand and explain relationships, including identifying causal relationships and seeking participant's perspectives (Scotland 2012). Utilising complex adaptive systems (CAS) theory this study seeks to explain the '*what is'* question to inform and understand the social world. As systems change and reorganize their component parts to adapt themselves to the problems posed by their surroundings (Holland 1992), and as these properties then feedback, influencing individuals' options and behaviours (Levin et al 2012), our concept of the social world and reality is therefore influenced by the constant realigning or feedbacks, caused by the interactions between these components. The evolution which therefore occurs is the lens in which we view the world.

Whilst the behaviours within complex adaptive systems are well laid out in the literature, how the researcher engages with CAS is not as well defined and can create particular epistemological and ontological challenges (Shipworth 2007). As systems are not static and they change over time and adapt to events or shocks (Liu 2007), particularly due to the actions or decisions of the actors involved, it is therefore important to involve the actors in the creation of the knowledge. In this sense, I underpin the systems approach with a constructivist epistemological paradigm to engage with the actors who influence and, whose actions determine the system behaviour.

Whilst the positivist paradigm seeks to understand and explain causal relationships, constructivists seek to understand how actors think, therefore the two paradigms are complementary. Constructivism asserts that social phenomena and their meanings are produced by social interactions and in a constant state of revision (Klakegg 2015). In the social sciences, Leavy (2017 p 13) argues that *we make and remake the social world through our patterns of interaction and interpretative process by which meaning to activities, situations, events and gestures are assigned*. People's subjective interpretation and understanding of their experiences is therefore important. Knowledge and meaning are therefore constructed from engagement with the realities in the world (Crotty 1998).

In this way, I am incorporating aspects of constructivism into the research methodology through the systems thinking approach of engaging with the stakeholders to understand how they think about the food insecurity problem, and how they engage with the food system. A constructivist approach enables a clearer understanding of the role people play within the system, and how their decisions and interactions impact on the system. For example, people use mental models constantly to interpret the world around them (Ford 2010). A mental model involves "*deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action*" (Ford 2010). In this research, I have engaged with the stakeholders at the barangay[3] level to capture their mental models which have then been interpreted through the development, firstly of the rich pictures, and then through the causal loop diagrams leading to the dynamic hypothesis to account for the problematic behaviour within the system.

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[3] A barangay refers to is the smallest administrative division in the Philippines and refers to a village, district or ward. In El Nido, the term is used to officially denote districts.

3.2 Methodology

This section describes the methodological design used to underpin the systems dynamics approach (i.e. case study and mixed methods approaches) and concludes with an overview of the case study site.

3.2.1 Methods

3.2.1.1 Case study approach

A case study approach was adopted for this research given the complexity and contextual nature of the research problem, and it enabled a focusing on understanding the dynamics present within the natural setting (Yin 1981; Eisenhardt 1989; Iacono et al 2009). Yin (2014) and Neuman (2006) state a case study approach should be considered when: the focus of the study is to answer '*how*' and '*why*' questions; you cannot manipulate the behaviour of those involved in the study; you want to cover contextual conditions because you believe they are relevant to the phenomenon under study, and; when the boundaries are not clear between the phenomenon and context.

These conditions are evident within the context of the research problem. For example, the research questions are examining how the problem of food insecurity has occurred and why it has occurred within the study site. Secondly, the study required stakeholder input into the study in order to ascertain their perception and understanding of the problem. Thirdly, the contextual conditions at the study site are important to understanding the problem and how these conditions impact on the system. Lastly, the boundaries were not clear between the problem of food insecurity and the environment.

Case studies can be either exploratory, descriptive or explanatory (David 2013; Yin 2014) and be either single or multiple case studies. This study adopted an exploratory, single case study (Yin 2014; Baxter and Jack 2008) approach with embedded units (Baxter and Jack 2008). This approach enables the exploration of the case whilst considering the differences between sub-units (Baxter and Jack 2008). In the case of this study, the single case study encompassed the El Nido Municipality consisting of the aggregated data collected from the embedded sub-units, or barangays (districts within the municipality) (Figure 3.2). Whilst this approach does have the distinct advantage of engaging in a rich analysis (Baxter and Jack 2008) which better illustrates the research problem, one of the disadvantages is there can be a failure to return to the higher-level issues the research is addressing and be too focused at the individual sub-unit level (Yin 2014; Baxter and Jack 2008).

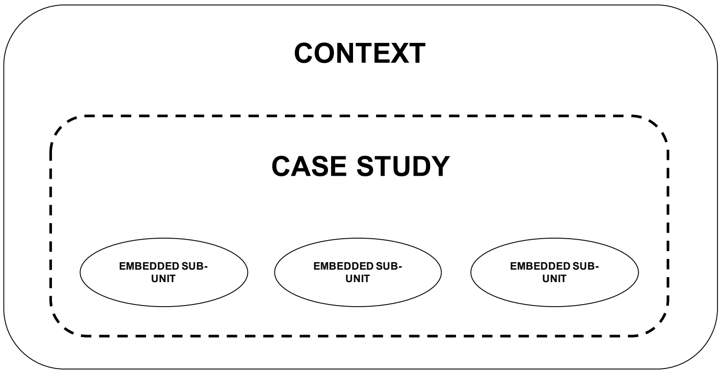

Figure 3-2. Conceptualisation of the embedded case study design chosen for the study

The design is a single case study indicated at the municipal level, with embedded sub-units of analysis undertaken at the barangay (district) level.

Data collection for case studies relies on multiple sources of evidence and data collection techniques (Iacono et al. 2009) such as archives, interviews, questionnaires, and observations, and can be either qualitative or quantitative (Yin 1981; Yin 1994; Eisenhardt 1989). The case study approach has incorporated a mixed methods approach and utilised both qualitative and quantitative approaches in the data gathering (refer Section 3.2.1.4). The combination of both qualitative and quantitative methods provides for a richer, contextual basis for interpreting and validating results, and increases the robustness of results as findings can be strengthened through triangulation (Kaplin and Duchon 1988).

3.2.1.2 Choosing the case study site

The case study approach has been applied to the Municipality of El Nido, Palawan Philippines (refer Chapter 4). Population growth and a steady decline in agricultural and fisheries productivity across the Philippines has contributed to the persistent hunger and food insecurity problems in the country, particularly for those people in the rural areas (Focus on the Global South 2015). In the Municipality of El Nido, these factors are reflected in declining household food security and the inability of the local food systems to provide for the demands of the local population and the growing tourism sector. Whilst the importance of the agriculture and fisheries sectors to self-sufficiency and employment in the Municipality remains, there has been no research undertaken on the impacts of drivers such as tourism and population on the food system within the Municipality. The choice of the Municipality for this study is therefore due to:

- The Municipality is historically reliant on both agriculture and fisheries to meet both food and livelihood needs. However, over the past 15 years, local agricultural production of both crops and livestock, and fisheries harvest rates has declined leading to an increase in the importation of important commodities including rice, fruit and vegetables, meat and fish products.
- The reliance on imported commodities has shifted the focus away from self-sufficiency and supply to one of reliance on livelihoods for income generation to be able to access foods.
- Increased growth in the tourism sector over the past fifteen years has brought about population increases through migration as people seek employment in the sector and related industries, thus increasing the demand for food and placing further pressures on the ecosystems underpinning the food system.
- The increase in the domestic and tourist populations has led to increased pressures on the terrestrial and marine ecosystems which support the agricultural and fisheries food systems and is leading to a decline in the natural resource base.
- The growth of the tourism sector has led to a shift in employment and livelihoods away from the traditional agricultural and fisheries sectors towards tourism and related industries, thus moving the Municipality into a singular economy heavily reliant on tourism. This is impacting on a move away from self-sufficiency and local production being able to provide for the local population.
- Despite the increase in wealth and employment to the Municipality overall brought about by the tourism sector, many people in the barangays are still suffering food shortages and livelihood challenges.

3.2.1.3 System dynamics approach

Dynamic complexity is challenging as it requires us to think in terms of complex causal interdependencies involving multiple sources of delay and nonlinearity, and evolving patterns of change over time (Kim and Senge 1994). System dynamics is a scientific framework for addressing complex, nonlinear feedback systems, drawing upon both qualitative (e.g., survey and interview methods) and quantitative techniques (e.g., computer programming and simulation) (Turner et al. 2016). Furthermore, it involves stakeholders (to define mental models within the system) and encourages researchers to adopt a nonlinear mental model to describe the feedback processes of a problem (Turner et al. 2016). The discipline of system dynamics has long been based on building specified models of strategic problems and is seen as the essential means by which the dynamics of a problem could be simulated and from which insights might be generated into policies to improve system behaviour (Coyle 2000).

3.2.1.4 Using system dynamics to assess food systems

Systems dynamics is a problem-oriented approach (Giraldo et al. 2008) for identifying, understanding and utilising the relationships between behaviour and structure in complex systems that change over time (Giraldo et al. 2008; Perrot et al. 2011; Stave and Kopainsky 2015). Using this approach enables an understanding of the critical factors that lead to particular outcomes or the interactions that determine the behaviour of the system (Sterman 2000; Ericksen 2008a), and how it responds to disturbances (Sterman 2000; Stave and Kopainsky 2015).

The use of systems dynamics to assess the performance of a local food system over time is prudent as it enables the complex dynamics and interactions within the food system to be examined with a greater understanding of: (i) how communities are organised economically, culturally, politically and technologically; (ii) how communities use and interact with ecosystems; (iii) how the interactions, along with exogenous and endogenous shocks, reinforce or undermine positive and negative social, environmental, and economic dynamics, and; (iv) establishes baseline expectations for interventions that will transform existing and/or establish new policies or government interventions (Sterman 2000; Hovmand 2014).

Given the dynamic complexity of the food system, Hammond and Dube (2012) argue that systems approaches are especially well suited for these requirements, whilst Walters et al. (2016) note that systems thinking is a better fit to holistically understand system complexity, especially given the consideration of both ecological and social drivers and impacts. A system dynamics approach enables a richer representation of the complex, dynamic and adaptive processes which occur within the food system (Hammond and Dube 2012). In particular, the causal loop diagrams can identify key feedback relationships that can convey internal or external shocks or disruptions throughout the system (Stave and Kopainsky 2015), and therefore, identify where the system is vulnerable. Viewing food system sustainability from a dynamic systems perspective makes it possible to examine non-linear, complex and reciprocally causal processes more explicitly (Allen and Prosperi 2016).

As food systems become more complex, it becomes increasingly difficult to see where the system might be vulnerable to disturbances that would disrupt food supply or how major disturbances would propagate through the system (Stave and Kopainsky 2015). Systems dynamics enables the answering of the key question 'vulnerable of what / to what' (Turner et al. 2003; Allen and Prosperi 2016). This can be answered through firstly, identifying the main drivers of change and understanding the relationships and feedback loops identified through the causal loop diagram process. The framework therefore enables improving the understanding of firstly, the vulnerabilities in the food system at the local level to endogenous (e.g. demographics, local economy) and exogenous (e.g. climate change, imports) shocks. Secondly, through simulation modelling, testing the system's response to different kinds and magnitudes of disturbance or shocks to the system (Stave and Kopainsky 2015). The system will be considered vulnerable if negative food system outcomes emerge (Allen and Prosperi 2016).

A key conceptual element of vulnerability and resilience models is the distinction between causal events and outcomes, noting that exposure, sensitivity, and resilience provide the concepts to identify the system's properties that shape pivotal pathways towards food system outcomes (Dilley and Boudreau 2001; Allen and Prosperi 2016). These causal pathways between variables in turn, form the feedback loops (Ericksen 2008a; Ingram 2011; Allen and Prosperi 2016) between connecting variables e.g. food system drivers and the food system outcomes. Given that complex systems are typically characterized by interconnected and interdependent elements and dynamic feedback processes (Walters et al. 2016), a systems dynamics approach can capture these changing patterns of interaction, inclusion of sufficient heterogeneity of individuals and modes of interaction; and capacity to include links to, and feedbacks with (Hammond and Dube 2012), other system outcomes, such as social welfare and environmental welfare.

As mentioned above, systems dynamics can be used to not only visually represent the causal structure of food systems, but also identify points of entry for disturbances external to the system, and map the pathways and mechanisms that transmit, and amplify or absorb the effects of those disturbances (Stave and Kopainsky 2015; Allen and Prosperi 2016). Undertaking a systems dynamics approach offers the potential to provide a deeper analytical understanding of the dynamics ultimately driving the food security of individuals and populations (Hammond and Dube 2012).

Within the literature the studying of food systems using systems dynamics is limited and focuses upon: (i) theoretical demonstrations using systems dynamics in conceptualising the relationships and pathways between food system components and how they can be affected by shocks or disturbances (Muetzelfeldt 2010; Stave and Kopainsky 2015); (ii) specific sectors within the food system e.g. agricultural production (Walters et al. 2016), cereal production and consumption levels (Tsolakis and Srai 2017), or water resources and food production (Atherton 2013).

3.2.1.5 The system dynamics approach

There are five main steps in the systems dynamics approach as identified by Sterman (2000) and Morecroft (2010) and outlined in Figure 3.4:

1. *Problem articulation*: identifies what the problem is and why it is a problem, as well as key variables to be considered including concepts, time horizons (both past and future), and the historical behaviour of the key concepts and variables.
2. *Formulation of a dynamic hypothesis*: explains the dynamics as endogenous circumstances of the feedback structure through the development of maps.
3. *Formulation of a simulation model*: specifies the structure and decision rules of the model as well as parameters, behavioural relationships and initial conditions.
4. *Model testing*: explores whether the model reproduces the problem behaviour adequately for the research purpose, and how sensitive the model behaves to shocks.
5. *Policy design and evaluation*: explores scenario specifications, policy design, ‘what if’ analyses, and sensitivity analysis to explore how robust policy recommendations under different scenarios may be.

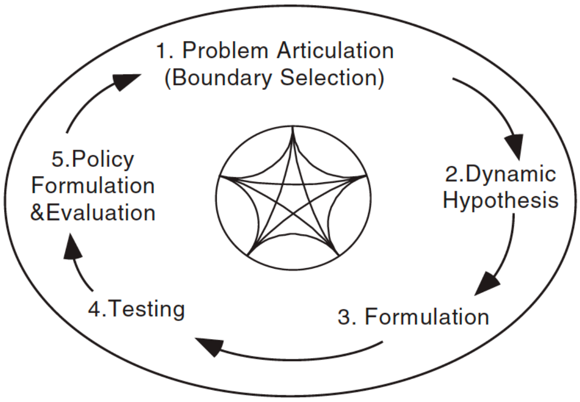

Figure 3-3. Iterative steps in the modelling process

Results of any step can yield insights that lead to revisions in any earlier step (indicated by the links in the centre of the diagram) (Source: Sterman 2000).

A mixed method approach was applied in order to achieve the required output (Table 3.2). Mixed methods are generally considered appropriate when the purpose of the research is to describe, explain or evaluate (Leavy 2017). Mixed methods have been described as '*empirical research that involves the collection and analysis of both quantitative and qualitative data'* into a single project (Almalki 2016; Leavy 2017). The sections below articulate both the qualitative and quantitative methods undertaken in each of these steps for this study (refer Table 3-2).

Table 3-1. Methods undertaken in each phase of the research

Systems dynamics step	Purpose	Methods
Problem Articulation	• Identify the problem, why it is a problem • Identify concepts, time horizons, and the historical behaviour	• Field observations • Stakeholder meetings • Document review • Expert elicitation
Formulation of the dynamic hypothesis	• Gather data to develop the rich pictures for the 18 barangays • Develop the system maps outlining the food insecurity problem for each barangay	• Community participatory workshops (Round 1 and 2) • SESAMME App
	• Develop the dynamic hypothesis of the food insecurity problem through causal loop diagrams	• Vensim Software • Document review • Expert elicitation • Semi-structured interviews • Informal interviews • Field observations

Formulation of the simulation model	• Develop the stock and flow models and simulation model showing parameters, behavioural relationships and initial conditions	• Stella Architect software • Data collection, collation and analysis
Model testing	• Test whether the model reproduces the problem behaviour, and how sensitive the model behaves to shocks	• Lab testing (Stella Architect software) • Community participatory workshops (Round 3)
Policy design and evaluation	• Develop scenario specifications, policy design, 'what if' analyses, and sensitivity analysis to explore what occurs under different scenarios and how robust different policy recommendations may be	• Scenarios tested in the model

3.2.1.6 Problem Articulation

A scoping phase was undertaken to assess the problem of food insecurity in the study site (i.e. seeking to understand the pattern of behaviour over time showing how the problem has arisen and how it might evolve in the future), establish the scale of the study (i.e. determine the number of barangays and stakeholders for the study), ascertain data availability, and to gain the support of the local government and local communities in undertaking the study.

Key to the scoping phase was the formulation and understanding of the food insecurity problem in the study site. Problem articulation involves understanding '*what is the problem*' and '*why is there a problem*' (Sterman 2000). Multiple methods including document reviews, engaging with local stakeholders and other actors, scoping interviews and field observations (Table 3.2), were used to establish and understand the problem. Each method had a particular purpose, and collectively these methods were used to build an understanding of the research problem and the study site prior to the fieldwork phase of the research. This was important as it built a repository of documents on the study site, built a knowledge as to the availability of data, and enabled an initial understanding of the site and how the research might be best undertaken at the site. Furthermore, it initiated the building of relationships with stakeholders across the site.

Document review involved critical interpretation of publicly available documents pertaining to the study site and the food system. This included 'grey literature' (e.g. government and non-governmental reports, government plans) and academic literature (e.g. journal papers, published research reports). There was a heavy reliance on grey literature as this was more commonly available, whilst the amount of academic and peer-reviewed literature on the study site is extremely limited, and what is available tends to focus upon coral reefs or forestry, rather than food security or the food system activities.

Stakeholder meetings were undertaken to gather information regarding the research problem, and to gain approval and support to undertake the research. These meetings were also important as it enabled relationship building and a broad understanding of the research by the key stakeholders in the site.

Following the information gathering process to define the research problem, a field team was established. Workshops were held to establish the local field team[4] or 'core modelling team' (CMT) who would undertake the community participatory workshops, and to develop the sampling framework and community participatory workshop scripts. The workshops also provided an opportunity to train the team in field techniques, including holding a test workshop with a community to refine both the script and the method of conducting the community participatory workshops. A fieldwork program was also developed during these workshops, deciding upon a number of boundaries for the research including:

- The timeframe bounding the problem was set at:
    - 2050 for the scenario development,
    - Trend data was set at 10 years ago for both the past and future trends
    - Data collection was to consider the past decade, and earlier if data was available to ascertain patterns and trends
- The geographical boundary was set to the Municipal level with the mapping exercises to be conducted at the barangay level, and data to be aggregated.

3.2.1.7 Formulating the Dynamic Hypothesis

In formulating the dynamic hypothesis, a systems thinking approach was undertaken incorporating community participatory workshops, document and literature reviews, expert elicitation, field observations and unstructured and semi-structured interviews were undertaken. These methods were considered the most appropriate due to:

[4] The establishment of a local field team was necessary due to language barriers and the need to have people operating as facilitators, iPad operators for the SESAMME tool, and note takers during the workshop process.

- The need to involve the stakeholders in understanding the problem and how it became to be a problem.
- To establish the stakeholders' perceptions or mental models of the problem.
- The need to triangulate information received from the workshops.
- To fill the information and data gaps.
- To view first-hand some of the issues relating to the problem.

This section outlines in more detail the methods used in developing the dynamic hypothesis.

a. Community Participatory Workshops

The involvement of stakeholders in the understanding of the problem of food insecurity and to inform the structure, parameters and testing of policies in the resulting simulation model (Hovmand 2014) was particularly important to the study. To achieve this, a group modelling approach or participatory systems approach was undertaken in order to enable buy-in from stakeholders and ultimately the likelihood that any recommendations generated from the research will be implemented (Hovmand 2014). Key advantages of this approach included: (i) it provided the stakeholders with a 'voice' about issues; (ii) it brought them together to exchange their perceptions of the problem and explore possible solutions to the situation; (iii) it enabled stakeholders to visualise their system and; (iv) enabled ownership of the process to occur during the development of the dynamic hypothesis.

Community participatory workshops (CPWs) were undertaken within the barangays to: identify the ecological, economic and social drivers on the food system, and; map the interactions (using feedback loops) that exist between socio-economic activity and ecosystems to develop social-ecological system maps of the food insecurity problem. The workshops were conducted in the local languages of Tagalog and Cuyonin and led by the field team comprising members of the El Nido Foundation, El Nido Local Government Unit and the PhD researcher.

Two rounds of workshops across all 18 barangays were undertaken over a 12-month period, totalling 54 workshops attended by 796 people (Table 3.3). In Round One the stakeholders were arranged into two groups in order to seek different viewpoints without influence of one group over the other. For example: (i) Group A: those affected by the problem such as fishers, farmers and community members, and; (ii) Group B: those able to affect the problem, for example, those community members who had power or influence in decision making such as community representatives, government and barangay officials. This group included community representatives, government and barangay officials. Two CPWs were conducted per barangay: one CPW was conducted in the morning with Group A participants to build the mental model of food insecurity in the barangay; and a second CPW with Group B participants was conducted in the afternoon to validate the information received from the CPW conducted in the morning. For Round Two, only one CPW per barangay was undertaken. The second round was to bring the groups together to validate the rich picture findings, and the draft causal loop diagrams (dynamic hypothesis), generated from the data collected in the first round of CPWs and further refinement based on literature reviews and other sources.

Table 3-2. Community Participatory Workshops held in El Nido, Palawan

Food Insecurity CPW	Number of Workshops	Number of participants		
		Male	Female	Total
Round 1	36	179	288	467
Round 2	18	134	195	329
TOTAL	**54**	**313**	**483**	**796**

The field team followed a script in conducting the community participatory workshops (CPWs). The script was developed by my PhD supervisors, Dr Carl Smith and Dr Russell Richards at The University of Queensland in consultation with the field team and provided a methodological roadmap for conducting CPWs in a consistent manner, which allowed for the results of the individual CPWs to be compared and aggregated up to the Municipal level.

Recordings, both visual and audio, were taken during the workshops. Of these, the transcripts for the three case study barangays were translated by Ms Noreen Follosco and students based at the Marine Science Institute, University of the Philippines. The transcripts capture the conversations held during the CPWs with the information aiding in the development of the causal loop diagrams and the formulation of the dynamic hypothesis (refer Chapter 5). The transcripts also add descriptive value to the rich pictures captured through the mapping exercises. However, due to the poor recording quality there are gaps in the information on the transcripts, and it was decided that not all the CPW recordings would be transcribed, with the dynamic hypothesis to rely heavily on the information collected through the 'rich picture' mapping exercises and other methods as outlined above.

b. Creating the rich pictures outlining the food insecurity problem in El Nido

The stakeholder groups were asked to construct a 'rich picture' for the food insecurity problem in El Nido. A rich picture is a free form diagrammatic representation and is especially useful as a tool to help groups arrive at a consensual analysis of a situation and to aid the thinking process and develop an understanding of how the system works (Bell and Morse 2013a; Bell and Morse 2013b; Salles and Bredeweg 2006). There are various methods to construct rich pictures including the common method of 'hand-drawn sketches of what each individual perceives to be going on in a situation' (Bell and Morse 2013a). This concept of hand-drawn sketches was taken a step further through the use of an iPad App '*Socio-Ecological Systems for App for Mental Model Elicitation*' (SESAMME)[5] to construct the rich pictures. SESAMME is a spatially explicit, 'drag and drop' icon-based mapping tool, with multiple features including:

- Apple map view that is comparable to Google maps
- Icon categories (Activity, Resource, Pressure, Decision) each with a library of icons
- Interconnections tool that enables icons to be linked and their causality highlighted
- Sub-library of qualitative trend icons that can be used to assign past, future and future desired trends to an icon
- Ability to assign a 'state' to an icon – this is a qualitative scale using a traffic light schedule (green = good, orange = moderate, red = poor)
- Edit mode feature where additions, deletions and modifications to the rich picture can be tracked
- Diagnostics where basis statistics can be compiled and presented for multiple maps

In constructing the rich pictures, the field team followed the prepared script and stakeholders were asked to:

[5] The '*Socio-Ecological Systems for App for Mental Model Elicitation*' (SESAMME) was developed by Dr Russell Richards, Dr Carl Smith and Dr Novie Setianto, The University of Queensland, Brisbane, Australia

- Identify and locate on the map the activities relating to the social-ecological problem
- Identify and locate on the map the resources that are directly affected by these activities
- Assign the current state of these resources using a traffic light scale (green = good, orange = moderate, red = poor)
- Identify and locate on the map the pressures influencing the resources and activities
- Assign past, expected future and desired future trends for each activity, resource, and pressure icon on the map
- Identify the interactions and their polarities that exist between the activity, resource and pressure icons on the map, and
- Identify and add the decisions that could be taken to address problematic trends in these activities, resources or pressures
- Identify the interactions and their polarities that exist between the decisions and the existing icons on the map.

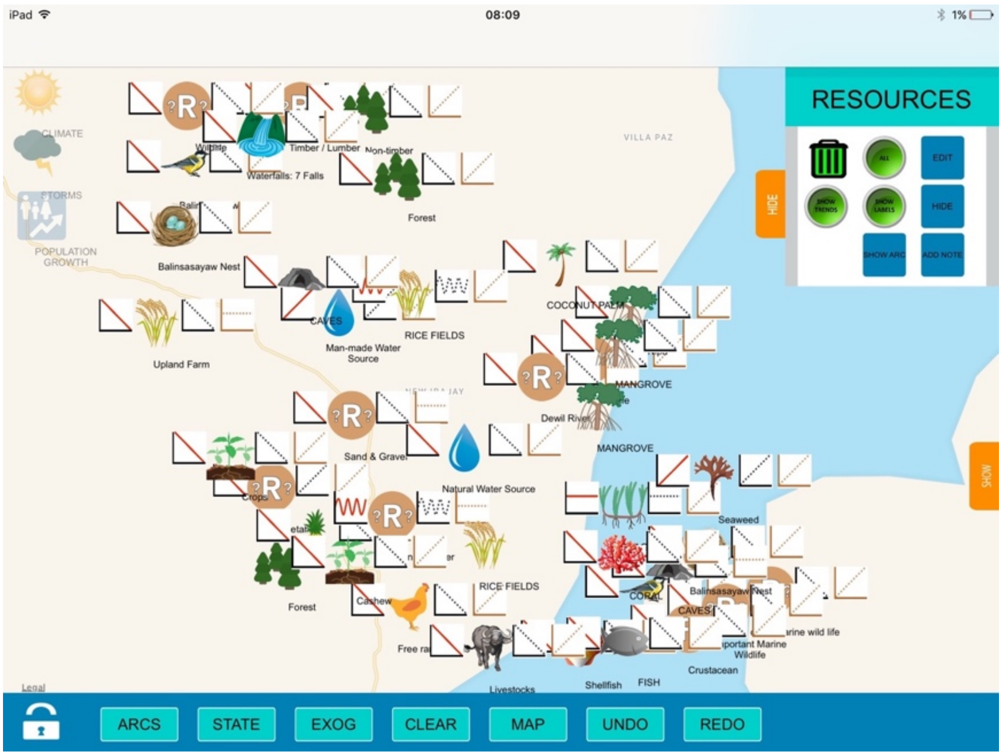

Figure 3-4. Rich picture mapped for the food insecurity problem in Round Two of the Community Participatory Workshops, New Ibajay barangay, El Nido

This particular rich picture only shows identified resources and trends.

This information was directly recorded into the SESAMME App to produce the stakeholder's perception of the system against these elements (Figure 3.5). A series of rich pictures were produced outlining resources, activities, pressures and decisions considered by stakeholders to be part of the food insecurity problem within their respective barangays, and the trends (past, present and desired future) of these variables. Each barangay produced two maps in the first round – one for each session, and in the second round, the maps were validated and/or updated. These steps encouraged the stakeholders to look at their analysis and focus on what they felt were the most important elements (Bell and Morse 2013a). Following the second round of CPWs, the rich pictures were updated at each location, data collated and analysed, and common groupings were made, and duplicates removed.

c. Post processing of rich pictures

The rich pictures from round one and two were uploaded into an iCloud database, and a collation and analysis of the data was undertaken. The information from the rich pictures was transcribed into a series of spreadsheets to provide the initial information for the development of the conceptual model and of the preliminary dynamic hypothesis. An analysis was undertaken to compare the information across all the rich pictures developed for round one and two, looking for common groupings and themes, and patterns and trends.

A number of data issues arose when analysing these rich pictures resulting in the omission of unreliable data. These highlight the risks of utilising field teams to capture data. For example, reviewing the community participatory transcripts showed there was a deviation from the developed script by the CMT, which was difficult to ascertain at the time of observing a round of the workshops due to language barriers. Rather than establishing boundaries around the research problem of food insecurity, the CMT developed maps indicating resources covering a range of issues across food, environment, policy, business and decision-making. Similarly, a lack of understanding on mapping the causal relationships between resources, activities and pressures, reflects a mix of identifying both causal relationships and 'association' within the rich pictures. To remedy these data issues, all data was collated into spreadsheets and an analysis undertaken on the relevancy of each individually identified resource, activity and pressure and the links to the food insecurity problem. Causal relationships between variables were undertaken based on literature reviews and expert elicitation. The combined data sources provided the basis of the draft causal loop diagrams describing the social-ecological problem of food insecurity.

d. Gathering additional information through semi-structured interviews

In addition to the community participatory workshops, field observations, expert elicitation, literature reviews and semi-structured interviews were also conducted over the course of the study to obtain an understanding and knowledge of the system, and to validate data and the hypothesis of the food insecurity problem. These methods enabled a more in-depth examination of the system, clarifying areas of interest which arose during the construction of the rich pictures during the CPWs and filling in any information gaps not captured during the CPWs or through the literature reviews. Ultimately, the information collected was also incorporated into the development of the final causal loop diagrams or dynamic hypothesis outlined in Chapter 5.

Scoping interviews involved semi-structured and unstructured approaches depending on the stakeholder and the situation. The initial list of interviewees was provided on advice of colleagues familiar with the study site, and from these interviews a snowball effect took place and additional interviews were conducted from recommendations. These interviews provided more in-depth information on the study site and activities impacting on the research problem and enabled the dynamic hypothesis to be refined and validated.

Stakeholders participating in the semi-structured interviews consisted of barangay captains, members of the barangay council and members of the barangay with in-depth knowledge of the food system in the barangay. The semi-structured interviews were designed to assist in clarifying the system structure and filling in any knowledge gaps which arose during the development of the dynamic hypothesis. The interviews consisted of a number of lead questions and depending on the participant’s responses, a further sub-set of questions was asked. The set of leading questions for these interviews can be viewed in Table 3-4.

Table 3-3. Set of questions asked during the semi-structured interviews

Is food insecurity a problem in your barangay?
Do you have access to enough food to feed households?
Have people in the barangay experienced periods of hunger over the past 12 months? If so, would this be moderate or severe?
What is the main source of food in the barangay i.e. what do people eat the most of?
What do you see as the biggest threats to food production or buying food (i.e. food security) in their barangay? Why?
What do you think people in the barangay will be eating over the next 5-10 years? Where is the possible source of food?

e. Developing the dynamic hypothesis

Utilising the information generated from the rich pictures, and information gathered from literature reviews, expert elicitation and the interview processes, the dynamic hypothesis was formulated. A dynamic hypothesis is a working theory of how the problem arose and guides the modelling effort by focusing on certain structures (Sterman 2000). As the process is iterative, various versions were created and refined based on the feedback from stakeholders and from additional information obtained during the semi-structured and informal interviews.

Several tools can be used for the system mapping including model boundary charts, subsystem diagrams, causal loop diagrams (CLD) and stock and flow diagrams (Sterman 2000). In this study, causal loop diagrams were used as CLDs use feedback loops to visualise the relationships amongst a set of variables or factors operating within a system (Maani and Cavana 2007), with the variable being a condition, situation, action or decision that can influence or be influenced by other variables (Maani and Cavana 2007), thus creating the cause and effect influence within the relationship. Much of the art of system dynamics modelling is discovering and representing the feedback processes, which, along with stock and flow structures, time delays, and nonlinearities, determine the dynamics of a system (Sterman 2000). Furthermore, the use of CLDs as the mapping tool allowed for a simple visualisation of the feedback loops within the system that controls system behaviour. Utilising this approach also enabled a mechanism to be developed for review and feedback through the community participatory workshops.

The CLDs developed identified the interactions or the polarities (positive “+” / negative “-“) between variables and demonstrate how the dependent variable changes when the independent variable changes. A positive polarity means that cause and effect move in the same direction whilst a negative polarity means that cause and effect move in opposite directions (Maani and Cavana 2007; Sterman 2000). Developing these relationships leads to development of the feedback loops. The feedback loops may occur either in a reinforcing (R) or balancing (B) loop type, with reinforcing loops representing growing or declining actions in the systems, and balancing loops representing self-correcting mechanisms which counteract and oppose change (Sterman 2000; Maani & Cavana 2007). These feedback loops dictate the behaviour of the system over time, and Chapter 5 discusses the system behaviour in relation to the feedback loops identified in the causal loop diagram developed for the food insecurity problem in El Nido.

3.2.1.8 Formulating the Simulation Model

Whilst causal loop diagrams are extremely useful for capturing mental models of the problem, and for identifying interactions and feedback processes, they do have their limitations, not least, is their inability to capture the stock and flow structure of systems (Sterman 2000). Furthermore, to be able to understand the complexity of systems, testing of these systems must be conducted in a virtual world. As Sterman (2000, pp 103) notes, to do so, requires a move away from the 'conceptual realm of diagrams to a fully specified formal model, complete with equations, parameters and initial conditions'.

Stocks and flow models are therefore used to create subsystem models (Figure 3.6) which formulate the simulation model. In developing these models, stocks represent the accumulations of certain entities or state variables (Sterman 2000; Fowler 2003) and the flows that create or deplete them (Fowler 2003) and are measured over an interval of time.

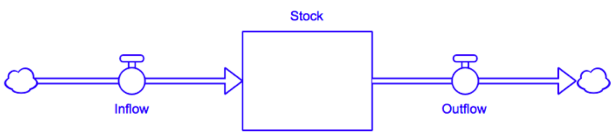

Figure 3-5. Stock and flow example

The causal loop diagram developed from the processes outlined above, was used as the platform for translating the dynamic hypothesis into the stock and flow model. Formularizing a conceptual model often generates important insight even before it is ready to be simulated and helps to recognize concepts and resolve contradictions that went unnoticed or undiscussed during the conceptual phase (Sterman 2000; Ford 2010).

The development of the stock and flow subsystem modules, and the simulation model was undertaken by Drs Carl Smith and Russell Richards, from The University of Queensland using Stella Architect software, and was developed as part of a broader project. It was decided this model would be the most appropriate to provide the platform for answering the research questions due to: the complexity of the research problem; the custom-made functionality of the model to explore the food insecurity problem; the functionality of the model linking to other related components in the system which impact on food insecurity through feedback loops; the ability of the model to capture the feedback loops and interactions between the components identified during the development of the dynamic hypothesis, and; the ability of the model to test various policy scenarios.

The stock and flow model captured all elements of the food system outlined in the dynamic hypothesis including modules covering:

- Population
- Tourism
- Urban development (hotels, housing)
- Land use
- Livestock production
- Crop production
- Fisheries (i.e. catch, population dynamics, fishing effort, boats)
- Marine habitats (i.e. reefs, mangroves, seagrass
- Water quality
- Runoff
- Water Resources
- Livelihoods (i.e, jobs, income)
- Food pricing
- Imports

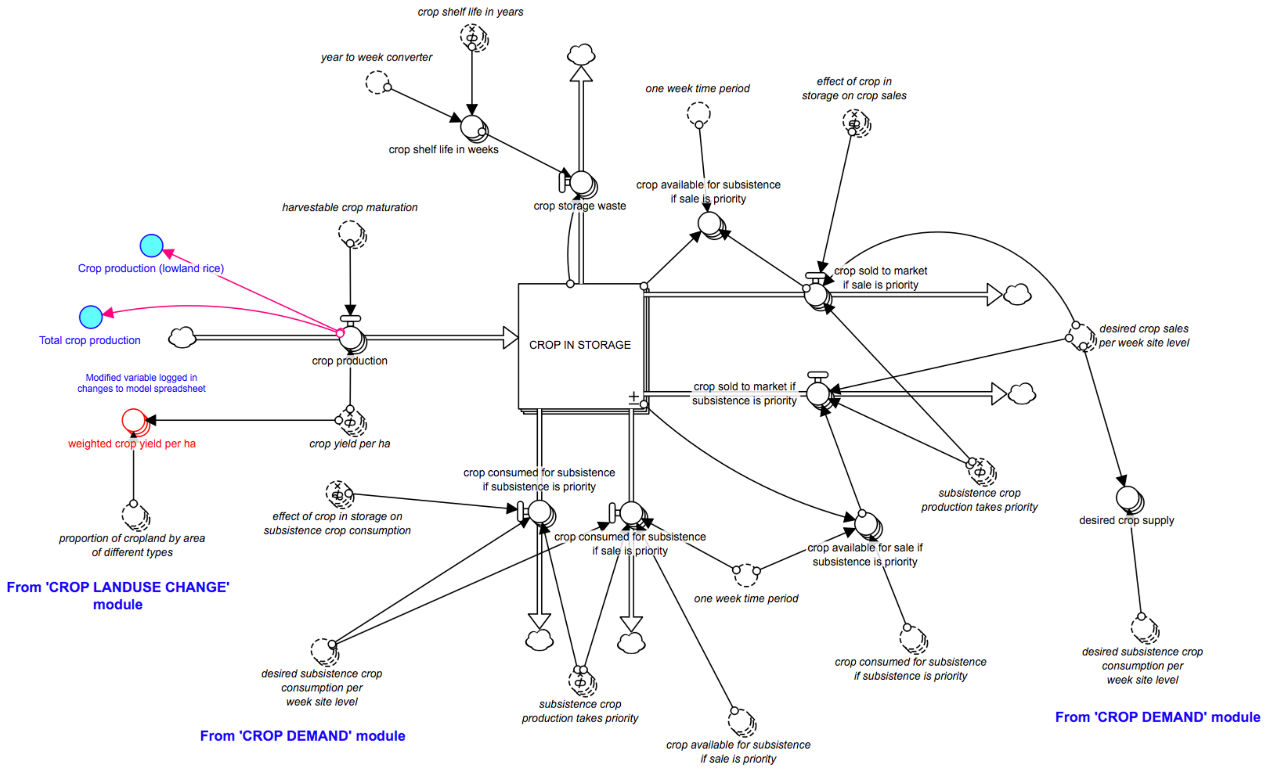

Figure 3-6. Screen shot of the stock and flow model of a component of the crop production module as a component of the food insecurity simulation model

Data incorporated into the stock and flow models was collected from primary and secondary data sources. When the data was not available, given the scale of the study site, proxies were used to maintain the system integrity. The stock and flow subsystems were developed to integrate into the broader food system showcasing the food insecurity problem, which once completed, was then moved into the next step of model testing.

3.2.1.9 Model testing

Policy design involves the amendment of current strategies or the establishment of new strategies, structures or rules. Since the feedback structure of a system determines its dynamics, most of the time high leverage policies will involve changing the dominant feedback loops by redesigning the stock and flow structure, eliminating time delays, changing the flow and quality of information available at key decision points, or fundamentally reinventing the decision processes of the actors in the system (Sterman 2000; Maani and Cavana 2007). As Sterman (2000) notes, the robustness of policies and their sensitivity to uncertainties in model parameters and structure must be assessed, including their performance under a wide range of alternative scenarios.

Testing of policy evaluation within the model took place through a third round of Community Participatory Workshops attended by 109 participants across eight barangays in the study site by the field team led by the PhD researcher and involving members of the Palawan State University. The testing was aimed at testing the sensitivity of the model behaviour to policy recommendations and addressed the assumptions undertaken in the model development. The eight barangays chosen for the model testing had the potential to be most affected by shocks to the food system due to their reliability to agriculture or fisheries, or both for food and livelihoods. The participants included those people affected by the problem and decision-makers or influencers within the community.

Following the policy evaluation testing, final scenarios for the study were developed and modelled. The main purpose of developing the scenarios is to stimulate thinking about possible occurrences, assumptions relating these occurrences, possible opportunities and risks, and courses of action (Jarke et al 1999). These four scenarios include:

1. **Baseline or 'business as usual'**: this scenario assesses the current situation of high environmental cost and unsustainable food production.
2. **Policy implementation**: this scenario outlines a possible future based on policy implementation co-existing with high resource-intensive consumption and low prioritisation of agriculture.
3. **Resource-efficient consumption**: this scenario tests potential policy interventions aimed at prioritising agriculture, fisheries and preserving the ecosystems which underpin the food system. It assesses a resource-efficient consumption whilst still maintaining economic growth through the tourism sector.
4. **Systemic shocks**: This scenario provides a 'what if' framework if particular endogenous or exogenous shocks occur within the system.

Further detail on the scenarios and results are in Chapter 6.

To showcase the behaviour occurring under these scenarios, a user-friendly interface was developed as part of the Stella Architect food insecurity model outlined in the above section. The interface demonstrates the likely effects of the changes in model parameters against various performance measures. Figure 3.8 provides an example of the interface outputs, demonstrating the scenarios tested with the eight barangays in the study site as part of the overall model testing and showcasing the effect of decisions on the trajectory of specific problems associated with food insecurity. These test scenarios were also used to determine the stakeholder preferences for various interventions or policy parameters within the system. The results from the refined model and scenarios, are outlined in Chapter 6.

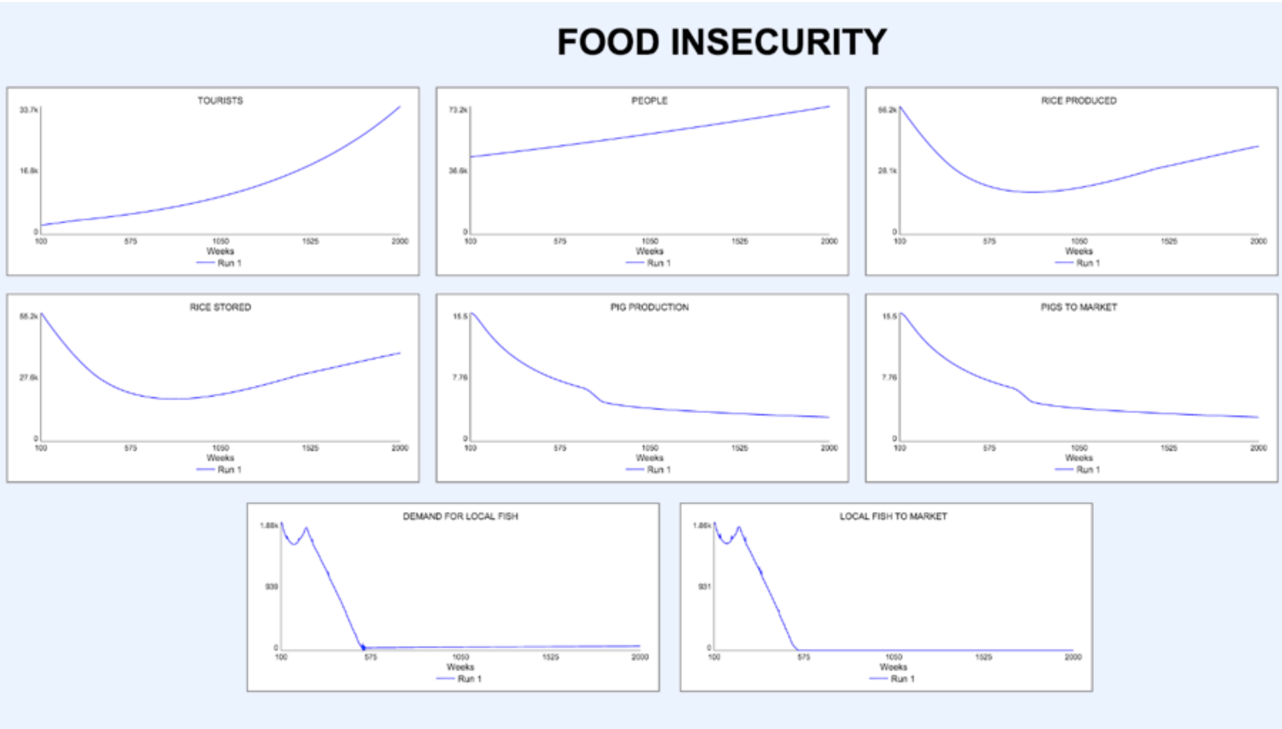

Figure 3-7. Example of the user-friendly interface showing the effect of decisions on various components of the food system

The example shows the base case pre-determined scenario modelling parameters against food insecurity performance indicators, during testing of the model behaviour in eight barangays in El Nido, Palawan.

4 Food security in Southeast Asia at the local level: A case study on El Nido Municipality, Palawan (Philippines)

This chapter describes the case study area of the Municipality of El Nido in the province of Palawan, Philippines. It outlines the significance of the food insecurity problem through an analysis of known biophysical and socio-economic factors impacting on the food system in the Municipality, thus responding to Research Question 2 – what are the dynamics affecting food security in a southeast Asian country? The chapter outlines how geographical setting, population growth, the rise of tourism, declining agricultural and fisheries production, and increasing competition for resources are impacting upon the food systems ability to continue to provide enough food for the local population.

4.1 Geographical setting and the limitations for the food system

The Municipality lies in the northernmost part of the province of Palawan (Figure 4.1) and is composed of 45 islands and islets totalling a land area of 92 326 hectares, or around 6 percent of the total area of the Palawan province (El Nido LGU 2012). In addition to the terrestrial area, El Nido's coastlines have a jurisdictional boundary out to 15 kilometres out to sea and comprise a total area of 160 square kilometres (PCSDS 2006). Institutionally, the Municipality is classified as a first-class municipality governed by a local government, and is politically subdivided into 18 barangays or districts, four of which are classified as urban and 14 as rural (PCSDS 2006). The Poblacion barangays of Buena Suerte, Corong-corong, Maligaya and Masagana comprise the town proper and serve as the centre of commerce, education and governance of the Municipality.

The Municipality of El Nido provides a unique environment both terrestrial and marine. In addition to the terrestrial area, under the Philippine Fisheries Code 1998 (Republic Act No 8550), the local government unit has jurisdiction 15 kilometres out to sea from the coastline, comprising an overall total area of 160 square kilometres (PCSDS 2006). In 2000, the Philippines Department of Environment and Natural Resources (DENR) classified 49 percent of the Municipality's land area as protected areas, thereby coming under the auspices of the El Nido-Taytay Managed Resource Protected Area (ENTMRPA) (PCSDS 2006). Under the Comprehensive Land Use Plan (CLUP) 2003-2012[6], all the Municipal barangays (except Pasadena) have at least one hundred hectares of

[6] The CLUP 2003-2012 is the current Land Use Plan. Whilst the Local Government Unit has developed a draft CLUP 2013-2022, this has not been approved by the Government and is unavailable to the public.

environmentally vulnerable ecosystems that need protection from destructive human activities (PCSDS 2006), much of which is livelihood orientated.

The geography or biophysical aspects of the area play a major role in restricting the expansion of the Municipality's development area for economic growth (UP 2015). The Municipality consists of mostly mountainous terrain interspersed with small areas of lowlands which occur on the coastal plains and alluvial valleys (Pontillas 2013). A large portion of the land area of El Nido is steeply sloping[7], close to 70 percent, with only approximately 19 percent of the land flat to gentle slopes and suitable for agriculture or urban development (Figure 4.2) (PCSDS 2003; PCI 2006). Given the small percentage of land deemed suitable for agricultural or urban use, it can be extrapolated that there consist some discrepancies within the zoning plan with the amount of land zoned under the CLUP for both agriculture and urban development set at 46,905 hectares (PCSDS 2003) or half of the total land area in the Municipality. Ultimately, the amount of land suitable for agriculture will be more critical in analysing prospects for agricultural production than the amount of land zoned. Furthermore, the small percentage of useable land for either agriculture or urban development, highlights the potential for competition between the two sectors for this resource (refer Section 4.5).

In addition to the restrictions brought about by the steep terrain, agricultural development is further impeded by poor soils and a reliance on seasonal rainfall. The soils in the Municipality are generally considered to be inadequate for producing high yields without the application of fertilisers, with clay and / or sandy loam types dominating with the more fertile soils residing in the stream valleys (PCI 2006). Along with low soil fertility, the dependence upon rainfall for cropping also hinders production. Climate in the Municipality has two distinct seasons – the dry season from December to May and the wet season from June to November, with the driest month being April and the wettest August (Pontillas 2013), with the average annual precipitation around 2 200 mm (PCI 2006). Extreme weather events such as El Niño also lead to a reduction in water resources for farming. The El Niño phenomenon results in droughts, causing water levels in watersheds to recede, thus reducing the availability of both surface and groundwater (Uy et al. 2016).

[7] The El Nido CLUP 2002-2012 classifies the Municipal's topography as: 0-3% level or nearly level; 3-8% gently sloping undulating; 8-18% undulating to rolling, moderately steep; 18-30% rolling to hilly, steeply sloping in many directions, and; above 30% very steeply sloping. They note land from the 18-30% classification and above is difficult to utilise and causes erosion problems if cultivated.

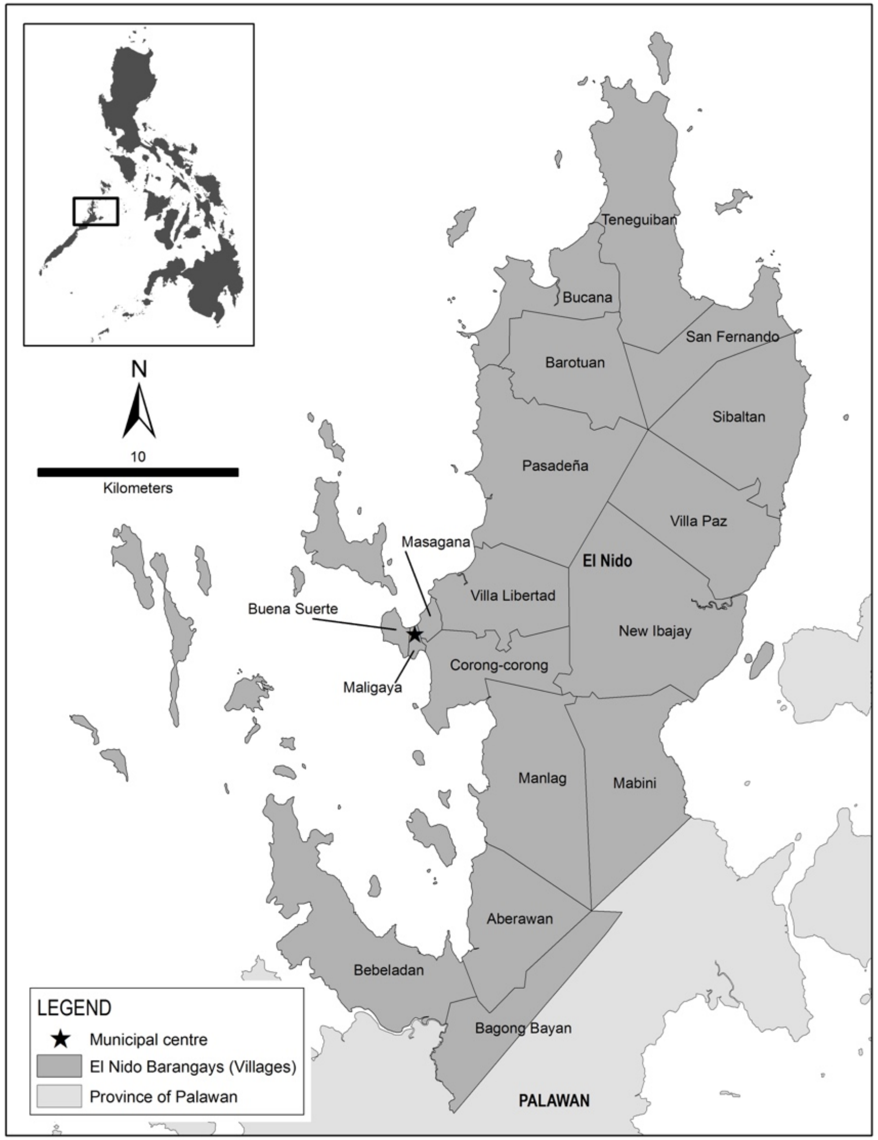

Figure 4-1. Location map of El Nido Municipality

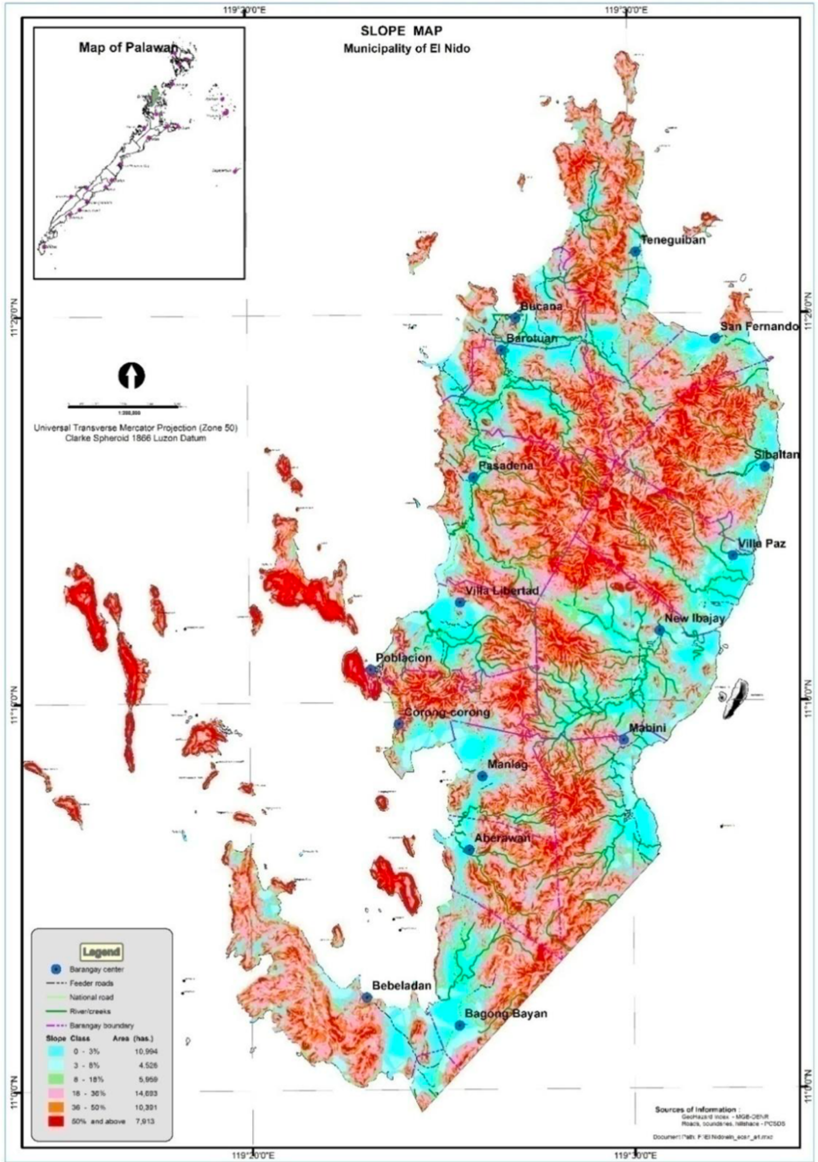

Figure 4-2. Slope map of El Nido Municipality

4.2 Population and tourism growth driving food demand

Globally it is predicted population and consumption growth will drive food demand increases for at least another 40 years (Godfray et al. 2010). This situation is reflected in the El Nido Municipality, as exponential growth in the local population over the past 20 years drives a growing demand for food (Research Question 2). This has been further exacerbated by the expansion in the tourism sector, causing not only an increase in food demand, but also in the consumption of food, as the tourism sector demands different types of food from that of the local population.

The Municipality has seen its population increasing from 17 985 in 2002 to 41 606 people in 2015 (Figure 4.3) (Philippines Statistical Authority 2016), and projections show the future population is expected to continue to grow reaching just over 54 000 people by 2025 (Philippines Statistical Authority 2016). This equates to an annual growth rate of approximately 7 percent. To date, much of the recent growth in the population is attributable to migration (Hodgson and Dixon 2000), with approximately 96 percent of the population in 2000 coming from outside the municipality (PCSDS 2003). Fabinyi (2012) notes that migration to the whole Palawan province has been a key driver of environmental and social change since the beginning of the twentieth century. This trend is continuing, with the Mayor of El Nido reporting during informal discussions, that the local population growth rate in 2016 reflected a higher percentage of migration at 4.5 percent, compared to the birth rate of 2.5 percent.

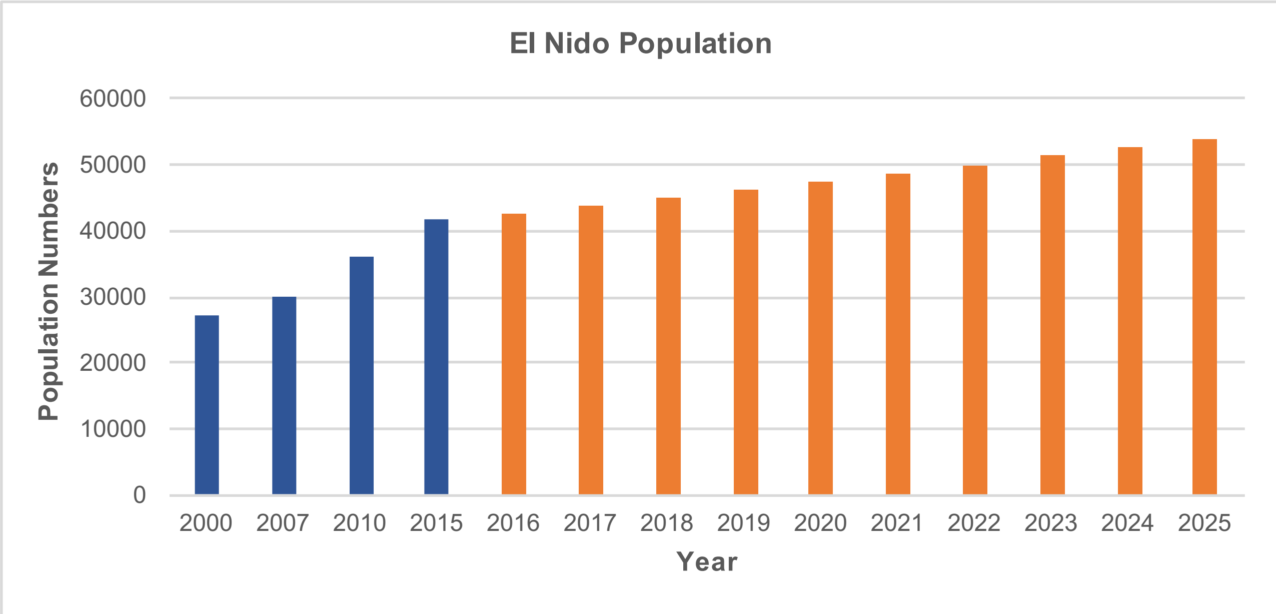

Figure 4-3. El Nido population figures and future projections

The blue columns represent the PSA population figures for those years, whilst the orange columns represent PSA population projections for future years. Population data for the period 2001-2006 and 2011-2014 is not available. (Source: Philippines Statistics Authority 2017)

Driving this trend in migration, is the growth over the past 20 years of the local tourism sector, brought about by the increasing popularity of the area for both domestic and international tourists. In the early 1980s, El Nido was considered to be a high-end diving tourism destination marketing clear water and beautiful coral reefs (Hodgson and Dixon 2000; Arquiza and Yabes 2017). However, since the late 1990s, the area has undergone a changing tourism demographic, brought about by a change in ownership of the resorts now targeting a mixed clientele, and the growth of budget-oriented accommodation in the Población town area attracting budget tourists and backpackers. In addition, accessibility to the Municipality through regular flights from Manila into El Nido and the paving of the main road between Puerto Princesa, the capital of Palawan and El Nido, has also brought with it increasing numbers of tourists (Business World 2010). Tourist numbers have escalated in the past 20 years from approximately 12 000 tourists in 1998 to estimates of 124 000 tourists in 2016 (Figure 4.4) (Fabro 2017; McAvoy 2016). Recent newspaper reports state that in 2017 the number of tourists had reached 200 000, with arrivals in the Municipality increasing by more than 30 percent annually in the past three years (Business Mirror 2018).

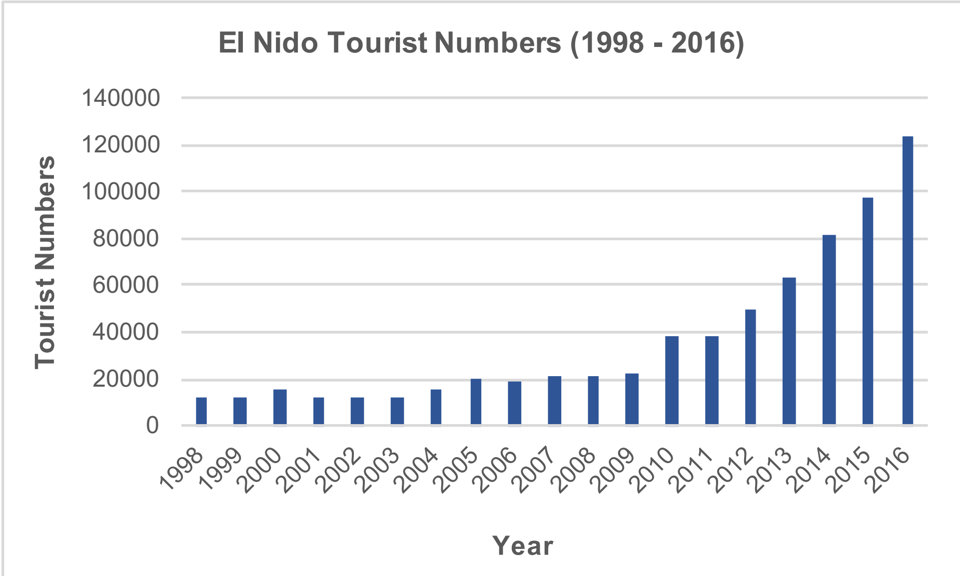

Figure 4-4. Tourist numbers in the Municipality of El Nido for the period 1998-2016

(Source: El Nido Municipal Tourist Office 2014; McAvoy 2016; Fabro 2017)

As the local and tourist population grow, demand for food increases (Schneider et al. 2011; Kastner et al 2012), and in turn, this requires a higher production of food, therefore placing higher demand on agricultural land. It is estimated that to meet the global increases in food demand, cereal production will need to reach three billion tonnes by 2050 whilst livestock production will need to reach 470 million tonnes to feed the projected world population (FAO 2009). At the Philippines level, meeting food demand through local production may prove to be challenging. Historically in the Philippines there has always been a food-population imbalance with Tablante (1965), arguing the population would outstrip the ability of the country's domestic food production to produce enough food to feed it. He further noted that agricultural production would not be able to meet the demand due to a range of issues including: small farm size; reliance on mono-culture; one-crop system of farming dependent on rainfall; inefficiently organised farms, and; a lack of capital to acquire the necessary agricultural inputs limiting the employment of improved technology and modern farm practices (Tablante 1965). Tablante's arguments are reflective of the situation in El Nido, with these issues influencing agricultural production at the local level (Uy et al. 2016; King 2016a) and impacting heavily on the ability of the agricultural system to produce the crops or livestock required to meet current demand. Continued population and tourism growth over the future years will mean the quantity of food will need to continue to increase annually (Umberger 2015), however, given the current pressures on the local production systems, much of the demand will need to be met by imports.

The flourishing tourism industry is not only driving increases in food demand but is also leading to a certain level of affluence from tourists, and also from locals who have either established successful tourism-related businesses in the Municipality, or who are employed in the tourism sector and earning higher incomes than in other sectors. This level of affluence increases purchasing power (Gerbens-Leenes et al. 2010), causing not only a demand for more food, but also leads to changing consumer preferences for food products (Gerbens-Leenes et al. 2010; Baldos and Hertel 2014; Umberger 2015), adding considerable additional claims on agricultural-related resources (Kastner et al 2012). As income rises, people tend to consume more calories in total, and the share of animal calories increases (Lotze-Campen et al. 2008). It is recognised that with socioeconomic development, diets change with the consumption of animal protein, vegetable oils, and fruits and vegetables increase, while starchy staples become less important (Kastner et al. 2012). In El Nido, like many in the Philippines, locals still rely heavily on traditional diets of rice, vegetables, and fish with little reliance on western-style diets at this time (Indrawaty Lipoeto et al. 2012). However, the tourist population demands more western-style diets with high quality diets of beef, certain types of fish (in particular grouper), vegetables and fruits, much of which cannot be met by local production.

4.3 Tourism sector driving economic development

Tourism is one of the most important economic sectors worldwide (Baggio 2008; Scott et al. 2009; Moreno and Amelung 2009), with tourism development increasingly viewed as an important tool in promoting economic growth, alleviating poverty, and advancing food security (Kiss 2004; Richardson 2010; Holzner 2011; Mai and Smith 2015) through improving local economies and employment prospects, increasing income levels and standards of living, improving tax revenues and larger investment in infrastructure (Tkalec and Vizek 2016), as well as providing alternative livelihoods to natural resource users (Kiss 2004). It is further argued that the economic impact of tourism can be maximised through enhancing linkages with other economic sectors, creating greater demand for local goods and services, the creation of more jobs and the development of more opportunities for local businesses (Richardson 2010). In the Philippines, sustainable tourism is now considered by many local governments as part of their initiatives for economic transformation and one of the major sources of income (Manalo 2017). It is considered as a key livelihood for coastal regions (Fabinyi 2010), with the government heavily promoting tourism as an alternative livelihood to fishing in order to combat overfishing in artisanal fisheries (Fabinyi 2010; Gilliland et al 2016). The hope is that by creating opportunities in the tourism sector, fishermen will shift to new livelihood activities while maintaining or even increasing local incomes (Gilliland et al. 2016).

Reflecting this trend, tourism is now the key driver of economic development in the Municipality and is considered as one of the major sources of income for local residents in El Nido (El Nido LGU 2012; Pontillas 2013). It is now driving changes to livelihoods (refer Section 4.6), employment and business growth within the local economy. Whilst figures are not available as to how many people are employed in the tourism sector, a 2013 survey of 182 respondents across seven barangays by the Palawan State University, registered that the rise in the tourism industry and its related sectors saw 7.3 percent directly involved in tourism-related occupations, whilst 22.4 percent were engaged in related entrepreneurial and trading activities (Pontillas 2013). It is also evident from field observations that the rise in tourist numbers has seen a substantial increase in businesses such as booking offices for tours, pumpboats for island hopping, dive and souvenir shops, motor and pedal bike rentals, massage parlours, internet cafes, restaurants and water refilling stations (Pontillas 2013; King 2016a).

Tourism is also driving interconnected industries such as wholesale / retail, manufacturing, construction and forestry as the demand for the services these industries provide increases with the growth in the local population and tourism developments. One of the largest growth areas has been in the forestry industry which rose from 6 percent of people employed in the industry in 2002 (CBMS 2002) to 52 percent in 2014 (CBMS 2014). Much of this growth is attributed to the growing demand for timber for the construction of resorts and hotels (Business Mirror 2018). The growth in extractive resource alternative livelihoods such as charcoal making (*uling*) and non-timber resource extraction for household construction or furniture has also been highlighted during the field component of this study.

Whilst tourism is improving business and employment prospects of some in the Municipality, there are suggestions tourism activity and its benefits are not reaching all of the barangays in the Municipality. Whilst the four urban barangays in the Población are receiving the economic benefits of tourism, many barangay community members in the rural barangays reported during field site discussions, that they are yet to see the flow-on effects from the tourism industry into their areas either through business or employment opportunities. Livelihoods remain an issue with many people in these barangays unable to generate enough income to provide for their daily needs. People working in the agricultural sector are more prone to hunger, because of low rural incomes (whether as farmers or farm workers), lack of access to productive resources such as land and capital, and the vulnerability of the sector to various shocks such as climate change, extreme weather events, pests, and disease (Focus on the Global South 2015). This is particularly problematic for those people who do not own land as they are unable to produce their own food to see them through periods of hardship. Without an income, the ability to procure and access food becomes difficult.

Furthermore, tourism is now being attributed to increases in the overall price level in the economy (Tkalec and Vizek 2016). In El Nido, there has been perceived an increase in food prices linked to the growth in the tourism sector, with high retail food prices making food items unaffordable and hindering the ability of poor households to meet their daily food and dietary needs (Focus on the Global South 2015). Hodgson and Dixon (2000) reported that over a ten-year period, market prices of seafood had increased dramatically with two of the most desirable fish species – grouper (*lapu lapu*) and skip jack (*tanguige*) increasing from P5 to P65 per kilo. As illustrated in Table 4.3, fish prices now range from between P100 to P430 per kilo depending on the type of fish, with many of the preferred fish now only available in restaurants. Similarly, the price of rice in the marketplace at P110 per *ganta* (2.2 kilograms), is also seen as expensive to the locals.

The growing reliance on tourism to underpin the economy has challenges as it can be a very volatile sector and particularly sensitive to disturbances caused by factors such as political instability, global economic shocks, and negative portrayals (Espiner and Becken 2014; Comelissen 2016). There are currently no safety nets built into the tourist sector in El Nido to mitigate against any future shocks which may cause a sudden decline in tourist trade. As one of the participants in the semi-structured interviews at Bebeladen barangay noted "*when tourism declines and the resorts close, and people lose their livelihoods, then people here will get hungry*" as they no longer own farms or fish to be able to be self-sufficient.

4.4 Declining agricultural and fisheries production and the rise of imports

Agriculture and fisheries play a key role in providing for the Municipality's population. However, these sectors have come increasingly under pressure over the past 20 years from competition for resources (i.e. land and water), poor soil fertility, pests and diseases, overfishing, and habitat degradation (King 2016a) impacting on the ability of these sectors to produce enough food for the growing population and the tourist sector. As these systems decline, the ability to continue to produce enough food to meet the growing demand from the local and tourist populations is leading to a supply and demand imbalance, which is now being met by food imports into the Municipality.

4.4.1 Declining agricultural production

Globally and at the national level, agricultural production has always been an essential component of food provision (Baldos and Hertel 2014; Godfray and Garnett 2014) with cropping and livestock production important contributors to sustainable food security for many nations, particularly in low-income areas (Gerbens-Leenes et al. 2010; Godber and Wall 2014; Lipper et al. 2014). However, the agricultural sector in El Nido is now facing a number of pressures (i.e. land and water competition, low soil fertility, pests and diseases, poor market linkages) and its ability to continue to produce enough crops and livestock to meet the demand from a growing population is declining (King 2016a). Assessing the trends or patterns of agricultural production in the Municipality is difficult due to a lack of data availability, however, an analysis of available data and information collected from interviews, particularly that relating to land under production and imports, does enable some insights into the local production system to be reached.

The one key element driving cropping and livestock production is that of the land – that is, the amount of land available and the amount of land used for agriculture. Within the Local Government's *Comprehensive Land Use Plan 2003-2012* (CLUP), 31 139 hectares or approximately 34 percent of the total municipal land area has been zoned for agricultural purposes (PCSDS 2003). Whilst this is an increase from the previous zoning allocation of 11 872 hectares (PCSDS 2003), agricultural land only makes up approximately 5.5 percent of the 78 square kilometre drainage basin (Hodgson and Dixon 2000) and is located on relatively flat ground.

Despite the area zoned for agriculture, there is a discrepancy between that zoned and the amount of land actually used for agricultural purposes. Overall, the actual amount of land under agricultural production has declined. For example, land for rice cultivation has declined from 2 308 hectares in 1999 (PCSDS 2003) to 1 800 hectares in 2017, despite the Local Government Unit's intentions to cultivate an additional 500-800 hectares for rice production to work towards meeting the national goal of not importing rice at the national level (El Nido Municipal Agricultural Office 2017). Whilst production has declined, the volume of locally grown rice to reach the market is also low. The majority of the rice grown in El Nido (Figure 4.5 and Figure 4.6) is primarily for the household's own consumption as rice is considered expensive to buy (Uy et al. 2016). Those who sell their produce do so only if they have a surplus or if they require money for other household expenses (Uy et al. 2016), thus limiting the volume of locally produced rice at the market.

Figure 4-5. Preparation of rice fields, Barotuan barangay, El Nido

Farming in El Nido is labour-intensive and still uses traditional methods (Photo: Melanie King)

Figure 4-6. Local and imported rice sold at the Corong-corong market, El Nido

(Photo: Melanie King)

Likewise, cashew production (one of the important cash crops in the Municipality) declined from 3 300 hectares under production in 1999 (PCSDS 2003) to 2 340 hectares in 2017 (El Nido Municipal Agricultural Office 2017). Given the estimates from the El Nido Agricultural Technician that there are 60 kilograms produced per hectare, this is a potential decline in production of 57 600 kilograms. A further cash crop, corn, also shows that despite the Local Government targeting 297 hectares for production, only 30 hectares has been planted (El Nido Municipal Agricultural Office 2017).

Declining agricultural production can be linked to a number of reasons including: small farm size; one-crop system of farming dependent on rainfall; inefficiently organised farms and; a lack of capital to acquire the necessary agricultural inputs (Tablante 1965). Additionally, a lack of land suitable for farming and land tenure issues (Uy et al. 2016) have also led to a reduction in farming activity (Uy et al. 2016).

Due to declines in local agricultural production, the Municipality is now relying on imports to meet the food demand. Key import commodities include rice, fruit and vegetables with 107 500 tonnes of rice (Figure 4.7) and 312 843 and 231 639 tonnes of assorted vegetables and fruits respectively, imported during the twelve-month period 15 December 2015-15 January 2016 to 15 December 2016-15 January 2017 (Table 4.1) (El Nido

Municipal Agricultural Office 2017). In particular, the food insecure[8] months of May to August saw 47 200 tonnes of rice imported into the Municipality, some 44 percent of the total imported for the year.

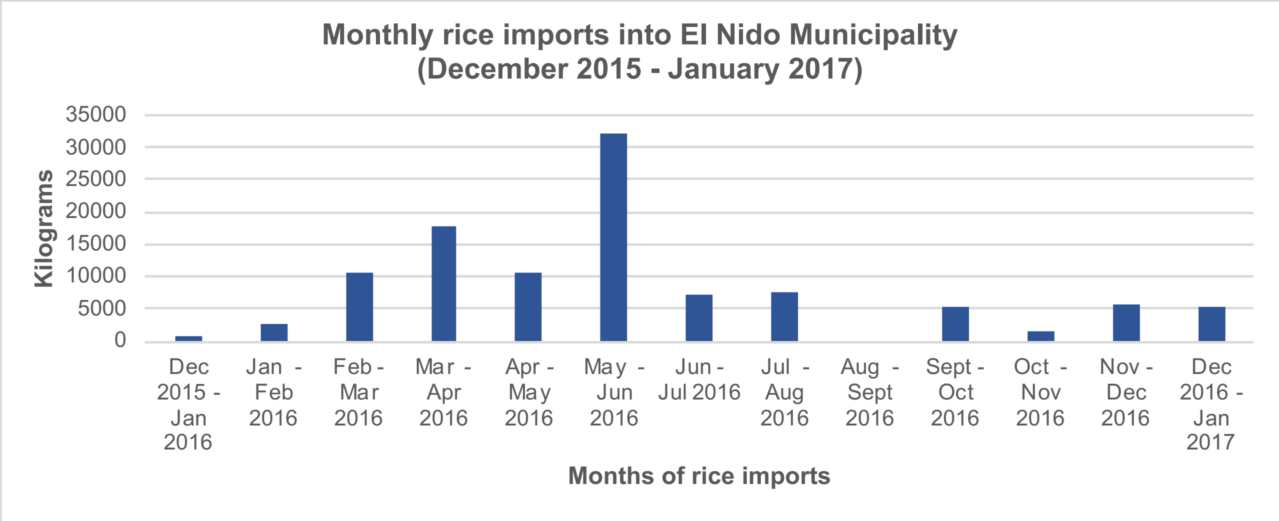

Figure 4-7. Monthly rice imports into the El Nido Municipality

(Source: El Nido Municipal Agricultural Office 2017)

[8] The term 'food insecure' relates to the period when a household's food stocks, in this case rice, have been depleted and crops are awaiting harvest.

Table 4-1. Imported produce by tonnes in El Nido Municipality (December 2015 - January 2017)

Product	Dec 2015 - Jan 2016	Jan - Feb 2016	Feb - Mar 2016	Mar - Apr 2016	Apr - May 2016	May - Jun 2016	Jun - Jul 2016	Jul - Aug 2016	Aug - Sept 2016	Sept - Oct 2016	Oct - Nov 2016	Nov - Dec 2016	Dec 2016 - Jan 2017	Total
Assorted vegetables	41,520	33,763	16,791	27,816	30,783	36,763	21,665	15,523	22,225	9,080	16,929	23,693	16,293	**312,843**
Assorted fruit	36,925	24,675	13,359	19,152	24,098	22,580	9,590	7,733	12,390	11,130	13,948	17,843	18,218	**231,639**
Mango	15,930	10,320	3,270	6,930	12,705	6,178	3,290	5,168	10,185	6,580	10,745	6,020	10,680	**108,001**
Pineapple	2,250	1,125	1,345	1,530	2,972	2,345	90	765	900	1,485	540	336	720	**16,403**
Squash	660	240	940	490	720	840	110		1,080	0	0	432	540	**6,052**
Onion	8,550	6,650	2,852	3,268	10,640	11,520	7,720	3,760	8,080	4,960	3,340	3,694	2,520	**77,554**
Garlic	2,000	1,160	1,607	980	1,755	3,984	2,480	1,320	2,560	920	1,215	814	880	**21,675**
Ginger	400	80	260	855	1,440	520	605	1,104	640	765	400	675	765	**8,509**
Melon / Watermelon	1,740	0	0	0	0	4,060	2,210	1,860	3,420	1,500	600	195	0	**15,585**
Calamansi	2,030	1,015	1,020	560	2,205	2,974	0	0	0	0	455	840	910	**12,009**
Tomato	3,192	5,915	4,265	5,810	8,820	8,350	9,170	4,655	6,510	2,240	2,590	1,750	3,710	**66,977**
Rice	850	2,750	10,500	17,900	10,550	32,050	7,400	7,750	0	5,250	1,500	5,750	5,250	**107,500**
Sugar	6,000	0	0	950	5,300	700	3,200	5,050	5,350	5,500	950	2,500	5,500	**41,000**
Peanuts	450	0	0	0	950	350	0	720	400	150	0	0	0	**3,020**
Wheat	13,800	11,400	11,200	24,400	27,550	26,300	5,950	4,240	12,150	20,350	8,320	20,400	8,320	**194,380**
Mungbean	600	450	1,126	0	800	700	400	0	450	40	80	700	40	**5,386**
Corn							900				1,440	1,440	1,440	**5,220**

(Source: El Nido Government Municipal Agricultural Office, 16 May 2017)

Reflecting the decline in local crop production, livestock production has also declined within the Municipality, with the shortfall between local supply and demand again met by imports. The El Nido Municipal Agricultural Office reported in an informal interview, that the local livestock production can no longer meet the demand brought about by both the local population and tourists, with breeding stock for cattle declining from 2 086 heads in 2000 (PCSDS 2003) to 1 200 – 1 500 in 2017 (El Nido MAO 2017). To meet demand, imports of livestock from Puerto Princesa and Taytay are increasing to approximately 10-15 heads of cattle and 35 heads of pigs per month (El Nido MAO 2017).

4.4.2 Fisheries Production

Fisheries are culturally, economically, socially and ecologically important to Filipinos as they contribute significantly to income, employment, foreign exchange earnings, nutrition and thus to the stability of the Philippines (Green et al. 2003; Muallil et al. 2014a). In many cases households use the income from fisheries to purchase other important foods such as rice which forms the basis of food security for many households in coastal Philippines (Fabinyi et al. 2017). However, Philippines fisheries resources are rapidly being depleted as evidenced by the decline of fish catch around the country (Green et al. 2003; Yang and Pomeroy 2017) and fish for food is considered to be increasingly becoming out of reach of those who need it most (Green et al. 2003). This national trend is being reflected across the Municipality whereby small-scale fisheries are coming under increasing pressure from open access regimes, overfishing, an expanding fishing population, small and large-scale fisheries conflicts, unregulated extraction, improved fishing technologies, climate change, pollution, inadequate management, poverty and a lack of alternative livelihood options (Muallil et al. 2014a; Yang and Pomeroy 2017).

Figure 4-8. Fish catch at the Corong-corong markets, El Nido Municipality

(Photo: Melanie King)

Fish catch from El Nido waters has declined over the eight-year period from 2007 to 2014 from 701 metric tonnes to 261 metric tonnes (Table 4.2) (MAO 2014; Pontillas et al. 2015). Whilst data on the volume of imports is not available[9], observations at the local market in Corong-corong reveal the majority of fish are imported from either Taytay or Manila (Table 4.3) with local catch accounting for the smaller size of particular seasonal species.

Table 4-2. Fisheries production profile of El Nido Municipality

Year	Volume in metric tonnes (MT)	Percentage of decrease over past year
2007	701.11	-
2008	670.20	-4.41
2009	646.64	-3.58
2010	625.24	-3.31
2011	541.07	-13.46
2012	418.19	-22.71
2013	432.30	3.37
2014	261.40	-39.53

(Source: El Nido Municipal Agricultural Office, 2014; Pontillas et al 2015)

[9] Discussions with the Coastal Management Office under the Municipal Agricultural Office indicate the office does not keep records as to the importation of fish.

Table 4-3. Fish price and origin, El Nido Municipal Market

Fish Produce	Price	Origin
Squid (small)	100 pesos / kg	Unknown
Squid (medium)	180 pesos / kg	Bucana
Milk fish	100 pesos / kg	Dagupan via Manila*
Tilapia (large)	170 pesos / kg	Manila*
Tilapia (small)	100 pesos / kg	Aberawan
Unicorn fish	180 pesos / kg	Taytay*
Snapper	180 pesos / kg	Taytay*
Shrimp	430 pesos / kg	Taytay*

*Note: * denotes areas external to the El Nido Municipality*

(Source: Corong-corong market, 17 May 2017)

To mitigate against declining fish stock, the establishment of marine protected areas (MPAs) has been implemented in some areas in El Nido such as in the San Fernando barangay. Fabinyi et al. (2017) argue it is commonly asserted that food security will improve as an outcome of improving the supply of fish through interventions such as MPAs. However, the linkages between increased availability of fish and improved food security are not always straightforward (Foale et al. 2013; Fabinyi et al. 2017) and it remains unclear as to whether this has led to any significant increases in fish stocks in El Nido. Whilst in some barangays the MPAs are not seen as conducive for fishing, in other barangays such as San Fernando and Mabini, there is support for the closure of fishing grounds as they are deemed a successful mechanism to increase fish stocks (King 2016a). However, even in those barangays which support MPAs, it is noted they do not have the funds or equipment to enforce them properly and illegal fishing still occurs within the boundaries.

4.5 Competition for land and water resources

Land and water are essential resources for the production of food and thus constitute two of the most fundamental resources for mankind (Godfray et al. 2010b; Schneider et al. 2011; Bryan et al. 2015). However, they are continually under pressure from population growth, economic development, and environmental change, with ‘tomorrow’s farmers needing to produce more food with fewer resources’ (Scheider et al. 2011, pp. 204). Competition for land is increasing as demand for multiple land uses and ecosystem services grows (Garnett et al. 2013; Bryan et al. 2015), and land is becoming a scarce resource (Godfray et al. 2010b; Lambin and Meyfroidt 2011), asserting the need for more efficient land use allocation and innovation in agriculture (Lambin and Meyfroidt 2011).

Within El Nido, competition for land exacerbated by the rapid urban development to accommodate the demand for accommodations and other tourist-related infrastructure, is reflecting the global scarcity of suitable land for agricultural purposes, and different land uses are now competing for the available land (Lambin and Meyfroidt 2011). With only 19 percent of land in the Municipality suitable for agricultural and urban development (PCSDS 2003; PCI 2006), competition is mounting between these two sectors. Under the current CLUP, agricultural land is zoned at 31 139 hectares and land zoned for urban development at 15 766 hectares (Table 4.4). However, as tourism continues to dominate the economy and drive growth, more agricultural land is being either zoned or sold to developers for tourism developments. In a growing number of incidences, for those farmers whose land is no longer productive, is unsuitable for farming, or whose land is situated in a potential tourism site, they are turning towards selling to foreigners or to developers (Smith et al. 2014; King 2016a). As Schneider et al. (2011) note, 'rationally acting agents' use the economically most suitable resource first and additional agricultural land is likely to be less profitable. As the tourism sector grows and improves the local economy, agriculture will continue to compete as tourism and population growth increases predominantly urban land areas (United Nations 2015; Schneider et al. 2011), thus reducing the amount of land available and suitable for agricultural areas.

Table 4-4. Proposed General Land Use(s), 2003 - 2012, Municipality of El Nido

Land Use	**Area (hectares)**	**Percentage of total land area**
Agriculture	31,139.05	33.73
Built-Up	15,766.29	17.1
Forest	29,352.51	31.79
Mangrove	1,740.50	1.9
Tourism	330.60	0.32
Other (Roads, idle lands, vacant lands)	13,997.02	15.16
Total	**92,326**	**100**

(Source: PCSDS 2003)

In the face of the growing competition for land, particularly agricultural land for those still reliant on agriculture as a livelihood, various practices to increase farmland are now becoming more prominent. For example, farmers in the uplands of El Nido, are relying more heavily on the practice of *kaingin* or slash and burn methods to clear forested land for cropping (Figure 4.9), despite interventions seeking to modernise upland farmers by stabilising, sedentarizing or replacing swidden cultivation (Dressler and Pulhim 2010). Field studies over the past four years have observed an increase in this practice in El Nido. It is claimed the absence of an effective land redistribution program spells doom for Filipinos relying on agriculture for livelihood and undermines their capacity to feed the nation (Focus on the Global South 2015).

Figure 4-9. The practice of *kaingin* agriculture (slash and burn)

Despite being illegal, kaingin is increasing in the rural barangays of El Nido. (Photo: Melanie King)

As with land, the competition for water is also increasing between the agricultural sector and urban development. The Municipality remains heavily reliant on rainfall to fill rivers, creeks, streams, wells, and groundwater supplies. Whilst there are thirteen major river systems which drain several watersheds in the municipality (PCI 2006), the demand for the water from these rivers remains high with it increasing with the growing population and tourism. The agricultural sector suffers the most with a lack of water for farming purposes and is dependent upon rainfall limiting most planting to once a year (Uy et al. 2016). Some farms have installed irrigation systems (Figure 4.10), all for rice production, however, even these systems remain small with the Municipal Agricultural Office reporting only 460 hectares of the 1 800 hectares under rice cultivation is irrigated whereas 1 340 hectares of agricultural land relies on rainfall. The lack of irrigation for agriculture is exacerbated by high cost of installing irrigation systems but is also reliant on water from rivers or creeks for the irrigation system to fully function.

Figure 4-10. Irrigation system for rice growing, Barotuan barangay, El Nido

(Photo: Precious Latras)

With the urban sector increasing due to growth in the tourism sector and local population, demand for water is also increasing. Currently, only the Población barangays (Buene Suerte, Masagana, Maligaya, Corong-corong) have access to a municipal water system whilst the other barangays are dependent on deep wells and springs for their main water supply (El Nido LGU 2012). Without any infrastructure in place to store water for urban or agricultural use, the Municipality will remain reliant on rainfall and competition for the limited resource will continue.

4.6 Shifting from agriculture and fisheries sectors to tourism

Food security is seen as a major outcome of livelihood generation by households. The livelihood system is a fundamental element in the El Nido Municipality's food system, as it ensures access to food through the generation of income and therefore the ability to economically procure food and non-food basics such as services, education and other requirements for household well-being. Approximately 96 percent of the workforce in El Nido is employed (CBMS 2014), with approximately 25 percent of the households relying on primary income sources alone, with the remainder having secondary income sources (Pontillas 2013). This brings with it challenges to maintain incomes sources in the face of change or system shocks such as economic downturns, extreme weather events or the loss of resources.

Within the Philippines, agriculture and fisheries have been the mainstays of food security (Fabinyi et al. 2017) and particularly for areas such as El Nido, income generation, rendering the livelihood platform quite fragile at times (Pontillas 2013) as these systems are increasingly pressured from various shocks including extreme weather events, lack of technologies and techniques and market forces. Like many traditional livelihoods throughout Southeast Asia, these sectors are now in a state of transition (Dressler and Pulhin 2010), with communities shifting from predominantly rural, farming livelihoods to livelihood strategies marked by intensification, diversification into “off-farm” activities, and increasing levels of engagement with globalisation, new markets and urbanisation (Fabinyi 2010). Much of this transition is moving towards the tourism sector.

There is a lack of complete data on the livelihood situation in the Municipality, thus making it difficult to ascertain any trends or patterns to confirm anecdotal evidence which states there is a decline in the number of people undertaking agriculture or fishing as a primary or secondary occupation. Data which is available demonstrates that for 2002, 2008 and 2014 – 43.69 percent, 53.98 percent and 36.13 percent of households respectively were engaged in agricultural activities (Table 4.5) (CBMS 2002, 2005, 2008, 2011, 2014). A 2013 survey by the Palawan State University of 7 barangays in the Municipality, indicated that of the surveyed participants[10], 17.8 percent were involved in agricultural activities such as rice, crop, fruit and vegetable farming, and livestock raising (Pontillas 2013).

[10] The survey consisted of 473 residents across the 7 barangays over 15 years old and not in school

Table 4-5. Number of households in El Nido engaged in agricultural and fisheries activities (2002 – 2014)

Barangay	2002			2005			2008			2011			2014		
	Nbr of households surveyed	Nbr of households engaged in agriculture	Nbr of households engaged in fisheries	Nbr of households surveyed	Nbr of households engaged in agriculture	Nbr of households engaged in fisheries	Nbr of households surveyed	Nbr of households engaged in agriculture	Nbr of households engaged in fisheries	Nbr of households surveyed	Nbr of households engaged in agriculture	Nbr of households engaged in fisheries	Nbr of households surveyed	Nbr of people engaged in agriculture	Nbr of households engaged in fisheries
Aberawan	153	114	26	176	n/a	n/a	244	142	24	246	n/a	n/a	250	102	38
Bagong Bayan	191	18	7	160	n/a	n/a	236	125	55	251	n/a	n/a	277	108	41
Barotuan	244	156	98	320	n/a	n/a	408	318	6	462	n/a	n/a	n/a	n/a	n/a
Bebeladen	130	44	0	338	n/a	n/a	389	61	137	446	n/a	n/a	337	59	209
Bucana	169	126	1	700	n/a	n/a	850	295	590	866	n/a	n/a	712	146	365
Buena Suerte Pob	109	155	27	357	n/a	n/a	446	3	174	452	n/a	n/a	456	9	104
Corong-corong Pob	102	66	5	143	n/a	n/a	258	39	65	389	n/a	n/a	n/a	n/a	n/a
Mabini	289	153	13	177	n/a	n/a	247	207	25	290	n/a	n/a	268	195	118
Maligaya Pob	2002	170	0	172	n/a	n/a	197	11	4	201	n/a	n/a	n/a	n/a	n/a
Manlag	239	216	3	236	n/a	n/a	329	213	55	358	n/a	n/a	345	126	38
Masagana Pob	126	69	15	174	n/a	n/a	297	18	21	355	n/a	n/a	n/a	n/a	n/a
New Ibajay	220	266	8	395	n/a	n/a	585	535	62	571	n/a	n/a	496	232	42
Pasadena	507	322	9	299	n/a	n/a	347	360	11	393	n/a	n/a	195	86	38
San Fernando	159	25	96	281	n/a	n/a	355	266	77	354	n/a	n/a	406	260	73
Sibaltan	172	98	24	230	n/a	n/a	294	237	46	301	n/a	n/a	n/a	n/a	n/a
Teneguiban	217	222	4	560	n/a	n/a	780	495	338	829	n/a	n/a	800	313	306
Villa Libertad	208	49	61	253	n/a	n/a	333	120	14	424	n/a	n/a	n/a	n/a	n/a
Villa Paz	174	95	61	153	n/a	n/a	217	232	36	238	n/a	n/a	199	77	43
Total	**5,411**	**2,364**	**458**	**5,124**	**-**	**-**	**6,812**	**3,677**	**1,740**	**7,426**	**-**	**-**	**4,741**	**1,713**	**1,415**

(Note: Data for 2005 did not include the number of households engaged in agriculture or fisheries. Source: CBMS Census 2002 – 2014)

Anecdotal evidence from community participatory workshops and interviews (refer Chapter 5) indicates there is a decline in the number of farmers in the Municipality as farmers move away from this sector due to pressures such as weather events, lack of water resources for farming, pests and diseases, and a lack of sustainable income (Uy et al. 2016; King 2016a). For the latter, the Focus on the Global South (2015) notes that in 2013 the rural income of those employed in agriculture is way below the required food threshold or the required minimum income/expenditure to meet the basic food needs and nutritional requirements for socio-economic and physical activities for a family of five. A recent survey undertaken by Uy et al. (2016) used the data supplied by the respondents to estimate their potential annual income from the sale of their produce. Estimated annual income of farmers (multiple crops) ranged from a maximum of P490 000 to an average of P85 000 depending on the land they use, among other factors. To supplement incomes, farming families engage in alternative livelihood activities such as carpentry, small convenience stores (sari-sari), hired labourers for other farms, tour guides, bus or tricycle drivers, laundry, and weaving bags (Uy et al. 2016).

As with the agricultural livelihoods, fisheries data is also difficult to ascertain to analyse trends or patterns. The CBMS census data illustrates that in 2002 of the 5 411 households surveyed, 458 households were engaged in fisheries activities. In 2008 this was 1 740 households (6 812 households surveyed) and in 2014 the figure was 1 415 households engaged in fisheries activities from 4 396 households surveyed (Table 4.5) (CBMS 2002, 2005, 2008, 2011, 2014). The 2013 Palawan State University survey indicated 15.7 percent of the respondents were engaged in fisheries as a primary or secondary occupation, whilst another 16 or 4.7 percent were engaged in fisheries-related occupations such as fish vending and processing. The growth in fisher numbers may be due to an increase in migrants to the Municipality, of which many are fishers by occupation (Figure 4.11) and who have migrated due to a lack of livelihood opportunities in the area they originated from (Uy et al. 2016). For those fishers who own their own boat, there is evidence that they are moving into the tourism boat services (Figure 4.12), particularly during the off-fishing seasons, due to the higher income to be earnt (King 2016a).

Figure 4-11. Local fishermen posing with nets, Villa Libertad barangay, El Nido

(Photo: Mark Paterson)

Figure 4-12. Former fishing boats converted into tourist boats in Poblacion, Bacuit Bay, El Nido

The boats are now used for taking tourists out to the various marine sites within the Municipality.

(Photo: Melanie King)

Monthly incomes for fishers range significantly depending on the season, the particular fishery they are involved in and variability in fish catch (Fabinyi 2010). A 2016 survey by De La Salle University (Uy et al. 2016) found the most common mode of compensation for fishermen is “*partehan*”, a system by which the catch is divided amongst the fishers, with the owner of the boat receiving two parts of the catch and the other fishermen divide the remaining one share of the catch. Approximately a third of the fishermen surveyed earnt less than P4 000 per week, about one-fifth earnt more than P4 000 per week, whilst almost a half were not able to determine how much they earnt (Uy et al. 2016).

However, whilst the numbers of fishers are increasing, the catch levels are decreasing in the Municipality. A survey from Muallil et al. (2014b) across 20 fishing municipalities (including El Nido) in the Philippines noted that only three percent of the respondents considered fishing as financially rewarding whilst 53 percent said that the catch was barely enough to provide for the daily needs of their households. The rest of the respondents reported that income from fishing is no longer enough even for the daily needs of their households, and supplemental income from other sources was needed.

With shifting of people from agriculture or fisheries into other sectors e.g. tourism, this can shift the demographics from being rural poor to urban poor and becoming more vulnerable to food insecurity e.g. whilst not necessarily shifting into urban environments, the impact is the same. These populations primarily purchase their food and while food may be readily available at local markets, food expenses can account for a large percentage of their total income, leaving them vulnerable to price fluctuations (Poulsen et al. 2015). The access to food safety nets like agriculture, and the high costs of shelter, transport and other services further undermine the affordability of sufficient food (Poulsen et al. 2015).

4.7 Household poverty

Despite the economic growth brought about by the tourism sector, there still remains a number of households under the poverty and food threshold. Access to food is closely related to poverty and income growth with poor people usually not having the adequate means to grow and / or purchase the food they need to lead healthy and productive lives (Pinstrup-Andersen and Pandya-Lorch 1998; ADB 2012a). Access to food is therefore, the biggest challenge in El Nido due to low incomes and poverty leading to many households suffering food shortages and unable to meet their daily food and nutritional requirements (Pontillas 2013).

Poverty incidence is particularly high among landless agricultural workers and farmers cultivating small plots of lands and in areas where the concentration of land ownership remains with only a few (Focus on the Global South 2015). Using the CBMS Census data, there are indications that there are a large proportion of households with incomes still remaining below the poverty and food threshold. In 2005 the number of households below the poverty threshold was approximately 59 percent of those surveyed, whilst in 2014 this remains at over the 50 percent mark (Table 4.6) (CMBS 2005, 2014). Likewise, the number of households with income below the food threshold has only fallen slightly from approximately 45 percent in 2005 to 35 percent in 2014 (CBMS 2005, 2014).

Table 4-6. Number of households below the poverty threshold, food threshold and experiencing food shortages in El Nido Municipality (2002 - 2014)[11]

Year	Total Surveyed HH	HH Food Shortage*	Average %	HH Income below Poverty Threshold		HH Income below Food Threshold*	
				Magnitude**	Proportion***	Magnitude+	Proportion ++
2002	3,609	n/a	n/a	n/a	n/a	4	2.61
2005	5,124	n/a	n/a	3,058	59.51	2,351	45.53
2008	6,812	288	4.23	4,548	66.76	3,556	52.20
2011	7,426	264	3.34	5,014	65.45	4,109	53.53
2014	4,741	78*	1.65	2,496	52.65	1,681	35.46

(Source: CBMS Census 2002 – 2014)

From these figures, it can be induced that there still remain a large percentage of households who do not earn enough income to be able to meet their daily needs. As more agricultural land is lost to urban development or becomes unproductive, the Municipality is becoming more increasingly reliant on imports to satisfy the food demand. Given it is now moving towards a controlled market, and as prices for food increase, this places increasing pressure on the ability of households to access affordable and nutritional food either through procurement or growing their own.

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[11] *Households that experienced food shortages in the last three months prior to the census

**Households with income below poverty threshold. Current thresholds are estimated, when the official is not applicable to the reference period, by projecting the official NSCB thresholds using prevailing prices. The currently used poverty thresholds are: 11,932 (Rural) and 12,506 (Urban).

***Number of households with income below poverty threshold over total number of households as a percentage

+Households with income below food threshold. Current thresholds are estimated, when the official is not applicable to the reference period, by projecting the official NSCB thresholds using prevailing prices. The currently used food thresholds are: 17,084 (Rural) and 17,905 (Urban).

++Number of households with income below food threshold over total number of households as a percentage

4.8 Summary

As the continued growth in the local and tourist population drives the demands for food and changing consumption patterns, the decline in the agricultural and fisheries sectors is leading to an inability of the local food system to meet these demands. Given the pressures facing these production systems - competition for land and water, overfishing, and a shift away from these sectors – it is highly probable that these food systems will continue to decline into the future. Supplementing the shortfall between demand and supply, with food imports can also be uncertain, particularly given the reliance on an income to procure the food, rather than strengthening the safety net of them producing enough food for household consumption. Of particular concern to the El Nido Local Government, is the inability of the local food system to continue to be able to produce enough food even for its local population, with the Municipal Tourism Officer commenting in a recent media article that, "*the food production in our town cannot sustain its growing population*" (Fabro 2017). With the dominance of the tourism sector driving economic development in the Municipality, and many in the area reliant on this sector for income-generation, this also leads to a greater level of vulnerability particularly if there is a downturn in the tourism industry. Overall, the drivers and the repercussions ensure the Municipality of El Nido is vulnerable to system shocks which impact upon their food system. The ability to be resilient to these shocks and for food to remain available and accessible to all of the population is examined in Chapter 6.

5 Mapping the food insecurity problem in El Nido

Chapter 4 has provided an overview of the case study site articulating the food insecurity problem in the El Nido Municipality. This Chapter will expand on the food insecurity problem and define the dynamic hypothesis through a systems thinking approach including: descriptions of the processes of structuring the problematic situations of food insecurity; identifying the causal loop diagrams, and; investigating the system behaviours and archetypes.

5.1 The Food System in El Nido

The Municipality of El Nido is heavily reliant on two production systems – agriculture and fisheries – to ensure availability and access to food for its population, and to ensure households can economically procure food through income generation from employment and livelihood opportunities. The community participatory workshops identified agriculture as practiced in 18 barangays and fisheries undertaken in 16 barangays, thus highlighting their continued importance as a provider of food and livelihoods for many of the population. Furthermore, a third production system - wild foods - emerged from the discussions, illustrating alternative food and income sources to the agricultural and fisheries systems. The gathering or capture of wildlife to provide both meat and incomes for poorer people in the rural barangays who do not have sufficient access to agricultural or fisheries produce for food or to earn income, was highlighted as an important alternative in a number of rural barangays.

In turn, the production of food within these systems, is entirely dependent upon well-functioning ecosystems in the form of healthy arable land, healthy soils, plentiful water and resilient fisheries (Moomaw et al. 2012). Terrestrial and aquatic ecosystems provide food not only for people, both as ecosystems in their natural state, but it also acts as a source of income and, buffers against biophysical, social or economic shocks (Barron et al. 2013; Ericksen 2008). However, these ecosystems are under threat from the increasing demands brought about by growing populations, which is placing further pressure on the ecosystems to produce enough food to feed the population, as well as provide the resources used in the provision of employment and livelihoods. This relationship, highlighted throughout the field program and captured in the dynamic hypothesis through the development of the causal loop diagrams, illustrates how this environmental degradation is generating multiple feedbacks on food production systems, and on the livelihoods and human well-being they support (Barron et al. 2013).

The causal loop diagrams to support the development of the dynamic hypothesis has been created from the initial information received during the community participatory workshops. As outlined in Chapter 3, the results from these workshops consisted of a series of rich pictures outlining resources, activities, pressures and decisions (Table 5.1) considered by stakeholders to be part of the food insecurity problem within their respective barangays, and the trends (past, present and desired future) of these variables. Additional information expanding the dynamic hypothesis was gathered from the field program consisting of informal and semi-informal interviews and field observations, and from expert elicitation and literature reviews.

Table 5-1. Resources, activities and pressures identified during the community participatory workshops

Resources	Activities	Pressures
Domestic animals: Poultry, pigs, livestock (e.g. cattle) Crops: crops, rice, fruit, vegetables, coconut, cashews	• Farming • *Kaingin* (slash and burn) • Copra processing • Coco vinegar	• Pests and diseases • Increased demand for farm produce • Low production • Overharvesting • No irrigation and/or insufficient water supply • Unsustainable farming practices • High farm input commodities e.g. feeds, fertilisers • Overuse of fertilisers and pesticides • Lack of post-harvest facilities • Lack of capital for agricultural use of land • Lack of knowledge in agricultural farming • *Kaingin* • Shifting from farming to tourism activities • Lack of farm to market linkages e.g. road access • Inappropriate variety of crops • Poor or declining soil quality • Thieves (livestock) • Insufficient grazing area • Conversion of agri-area to commercial zoning
Forage and gathering: honey bees, birds nest (*balinsasayaw*), guano	• Gathering of resources • Nest harvesting	• Decreasing *balinsasayaw* population • Fogging of insects at resorts • Displacement of *balinsasayaw* nesting sites due to resort development • Overharvesting of birds' nest
Fish Molluscs: shellfish, abalone, squid, giant clam (*manlet*), tamilok Crustaceans: crabs, prawns / shrimp Echinoderms: sea cucumber, sea urchin Seaweed: *lato*	• Fishing • Gleaning • Fish cages / aquaculture • Fish processing	• Illegal fishing • Overfishing • Increasing number of fishers • Weak enforcement • No access or easement to beach and coastal areas • Shifting from fishing to tourism activities • Expensive fishing gear and fuel • Habitat loss e.g. decreasing beach area due to dikes • Limited access in fishing area with private tourism sites • Use of unsustainable fishing gear • Beach anchoring and designated safe harbours for boats • Use of chemicals for shrimp fishing
Land Habitat: forest, planted trees (rubber, magium, palapata), caves	• Logging and cutting • Reforestation	• Demand for timber • Habitat loss • Encroachment on timberland and salvage zone • Illegal and/or rampant cutting and logging • Lack of alternative livelihoods
Marine Habitat: coral, mangroves, seagrass, beach	• Charcoal making (*uling*)	• Habitat loss • Siltation

	• Cutting of mangroves • Sand quarrying from beaches	• Pollution e.g. garbage, sewage • High demand for charcoal for household use • Conversion of mangrove areas • Charcoal making (*uling*) • Residues from pearl farms
Water Resources: natural water sources, river, streams, wells	• Irrigation	• Pollution e.g. garbage, sewage • Siltation • Management of water system • Improper waste management • Poor Water quality • Poor drainage system
Land materials: sand, gravel	• Sand and gravel quarrying	• Siltation • Unregulated quarrying
Non-timber Materials: rattan, buho, yantok, coconut palms, nipa, pawid, pandan	• Cutting of non-timber products e.g pawid production, sawali • Alternative Livelihoods: bed matting (banig), weaving, handicraft making	• Habitat loss • Siltation • Illegal or rampant logging and cutting • High demand for non-timber resources • High demand for charcoal for household use • Demand for coconut lumber • Increasing demand for pandan • Lack of alternative livelihoods
Wildlife	• Poaching and Hunting	• Demand for wildlife • Wildlife trading • Demand for wild meat (household) • Illegal hunting
Other: Tourism	• Tourism activities • Tourism development	• Growing tourism industry • Unfair transactions on tourism services • Insufficient tourist support services • Congestion e.g boats, bikes, vehicles • Real estate development • Unsustainable tourism practices • Poor implementation of boat docking • Unregulated collection of user entrance fee
Other: Business	• Business e.g. trading / selling	• Low market price value • Unregulated prices • Unfair trading practices • Price competition • *Palakasan* system • Poor market management • High market stall fees • Price competition • Concessions

(Source: King 2016a & 2016b generated from the Community Participatory Workshops 2015)

The rich pictures showed many commonalities across the barangays for the identified resources, activities and pressures. For example, in terms of resources, poultry was reported in all 18 barangays and was the highest recorded food related resource. This was followed by shellfish, livestock, wildlife and coconuts which were reported in 17 barangays. Other food resources including fish, crustaceans, vegetables, fruit, and crops were reported in 16 barangays. Natural resources supporting the food and livelihood systems in the Municipality were also considered important and included forests, mangroves, water resources, and non-timber resources (i.e. rattan, nipa, buho, bamboo), all of which were all reported across 17 barangays (Figure 5.1).

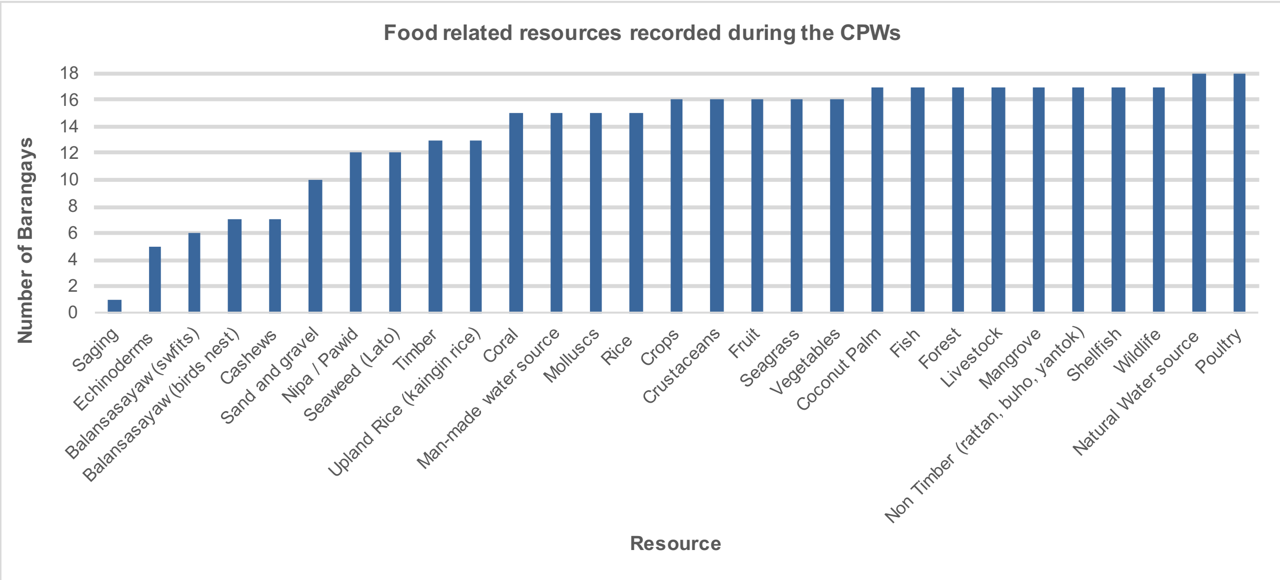

Figure 5-1. Resources recorded in five or more barangays in El Nido during the Community Participatory Workshops

Numerous activities relating to food systems were also commonly identified across the barangays with farming the highest recorded food system activity with it identified in all 18 barangays. The term farming includes a range of sub-activities such as cropping, rice growing, vegetable gardening and livestock raising. Fishing and gleaning were also highlighted as major food and livelihood related activities, identified in 16 and 17 of the barangays respectively. Other livelihood related activities including logging and cutting, tourism activities, charcoal making (*uling*), poaching, and tourism development were also commonly recorded across the barangays (Figure 5.2).

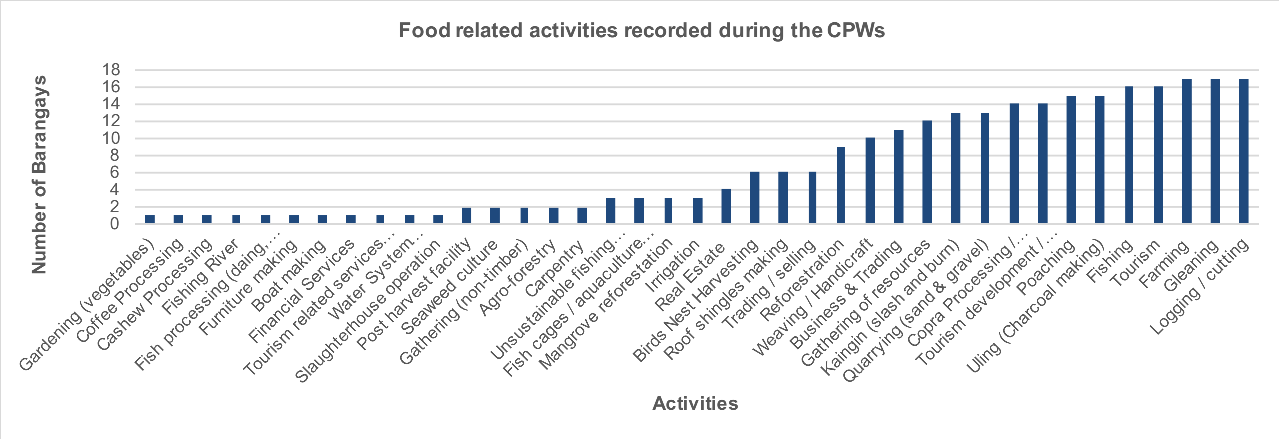

Figure 5-2. Activities recorded in five or more barangays in El Nido during the Community Participatory Workshops

Lastly, during the mapping exercises, a total of 84 pressures impacting on food insecurity in the Municipality were recorded. Of these, pests and diseases of crops and livestock was reported across 84 percent or 15 barangays, followed by illegal activities linked to both marine and terrestrial ecosystems (14 barangays), no irrigation or insufficient water supply for agricultural purposes (12 barangays), habitat loss (10 barangays), siltation and weak enforcement (7 barangays), and unfair trading practices, overfishing, low market price and unregulated prices, and *kaingin* (6 barangays) (Figure 5.3).

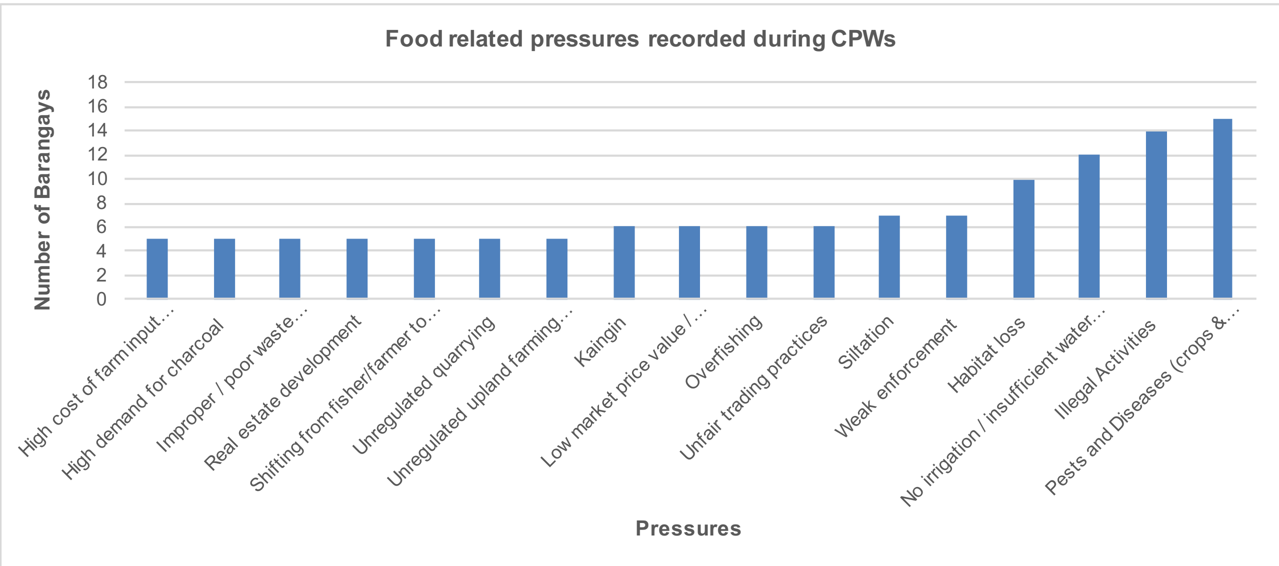

Figure 5-3. Pressures recorded in five or more barangays in El Nido during the Community Participatory Workshops

As outlined in Chapter 3, these rich pictures were used to develop the dynamic hypothesis of the food system in El Nido, outlined in this chapter.

5.2 Drivers impacting on the food systems in El Nido

The food system in El Nido is impacted upon, or being driven by, two socio-economic, endogenous drivers – population growth and tourism growth. The situation in El Nido is reflective of the global situation whereby population growth is not only leading to increasing consumption, which in turn is driving the increasing demand for food (Godfray et al. 2010; Harvey and Pilgrim 2011; ADB 2012a), but it is also leading to an intensification in competition for land, water and other resources which are threatening the supply of food (Godfray et al. 2010). In El Nido, this is exacerbated by the growth in the tourism sector over the past 20 years. This section outlines these drivers and their impact on the food system through increased competition for food, land, water and natural resources.

5.2.1 Population Growth

Population growth in the El Nido Municipality has been exacerbated by a substantial increase in tourist numbers which is directly contributing to the population through migration as people enter the Municipality seeking employment opportunities. As outlined in Chapter 4, the local population has more than doubling from 17 985 in 2002 to 41 606 people in 2015 (Figure 4.2) (PSA 2016). Based on current growth, the Philippines Statistics Authority projects the population of El Nido will reach over 50 000 people in 2025. Recently, the Local Government Unit has expressed concern regarding the growth in population and the impacts on the ability of the Municipality to provide for a food secure future, with the Municipal Tourism Officer commenting in a recent media article that, "*the food production in our town cannot sustain its growing population*" (Fabro 2017).

Population growth within the Municipality is influenced by four factors - births, deaths, immigration and emigration. The relationship between births and domestic population - illustrated through reinforcing loop (R1) (Figure 5.4), with the arrow from births to population indicating that births add to the size of the population, and the corresponding arrow from population to births indicating that a larger population will tend to have more births in the future, thus demonstrating the growing action of the system (Sterman 2000; Maani and Cavana 2007). Balancing loop (B1) demonstrates the system self-correcting this action, through the relationship between population and deaths. As the population increases, there will be more deaths, denoted by the arrow from population to deaths, and as deaths increase, particularly if there are more deaths than births, the population will decline, illustrated by the arrow from deaths to population. Both births and deaths will be impacted by the *rate of births* and *rate of deaths* respectively. These two 'dangles' are variables included in the diagram but lying outside of the loop (Sterman 2000) and denote the annual birth and death rate which will impact on the local population's annual growth rate.

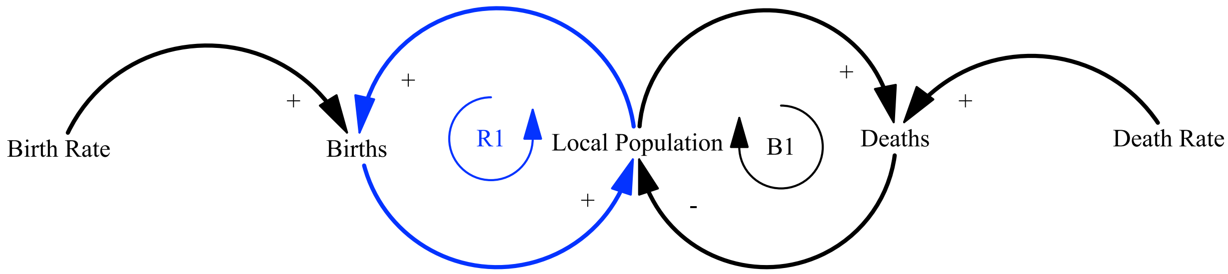

Figure 5-4. Causal loop diagram illustrating the relationship between local population, births and deaths

The Local Government Unit of El Nido views migration as the dominant influencer on population growth and in discussions reported the current immigration rate was 4.5 percent per annum compared to the birth rate of 2.5 percent per annum. Socio-economic circumstances are the key determinants driving migration, with human migration one of the traditional and adaptive responses to environmental stress, often undertaken in an attempt to diversify sources of income (Zezza et al. 2011; Barron et al. 2013). This is highlighted in El Nido, with many migrants entering the municipality seeking employment opportunities created from the tourism sector or related industries such as forestry, construction, wholesale and retail, or for alternative livelihood opportunities generated by the increasing demand for materials for the tourism sector or local households.

As people migrate to the Municipality seeking employment and alternative livelihood opportunities, this increases the population i.e. increases in the *immigration rate* leads to an increase in the *local population.* As the *local population* increases, this can lead to an increase in *immigration* due to the attractiveness of opportunities (employment), thus generating a reinforcing loop (R2) (Figure 5.5). If the *immigration rate* decreases, this in turn, will decrease the level of *immigration* and in turn, the *local population*. The balancing loop (B2) illustrates the role emigration also plays in local population growth. If the population is larger the *emigration* outflow will also be larger which reduces the *local population*, creating a balancing loop. Emigration will also be driven by employment or alternative livelihood opportunities, however, unlike immigration, emigration occurs when those opportunities are no longer existing or viable. The positive polarity arrow from *population* to *emigration* denotes the larger the population, the more movement of people out of the area. Likewise, the higher the emigration flow, the more the population is reduced, particularly if the emigration feedback loop becomes more dominant than the immigration feedback. The migration causal loop also has two 'dangles', denoting the rate of migration and emigration, that is, the flows into the system. The *immigration rate* dangle denotes the impact of migration rates on the population. The *emigration rate* 'dangle' also shows the impact of emigration rates on the population.

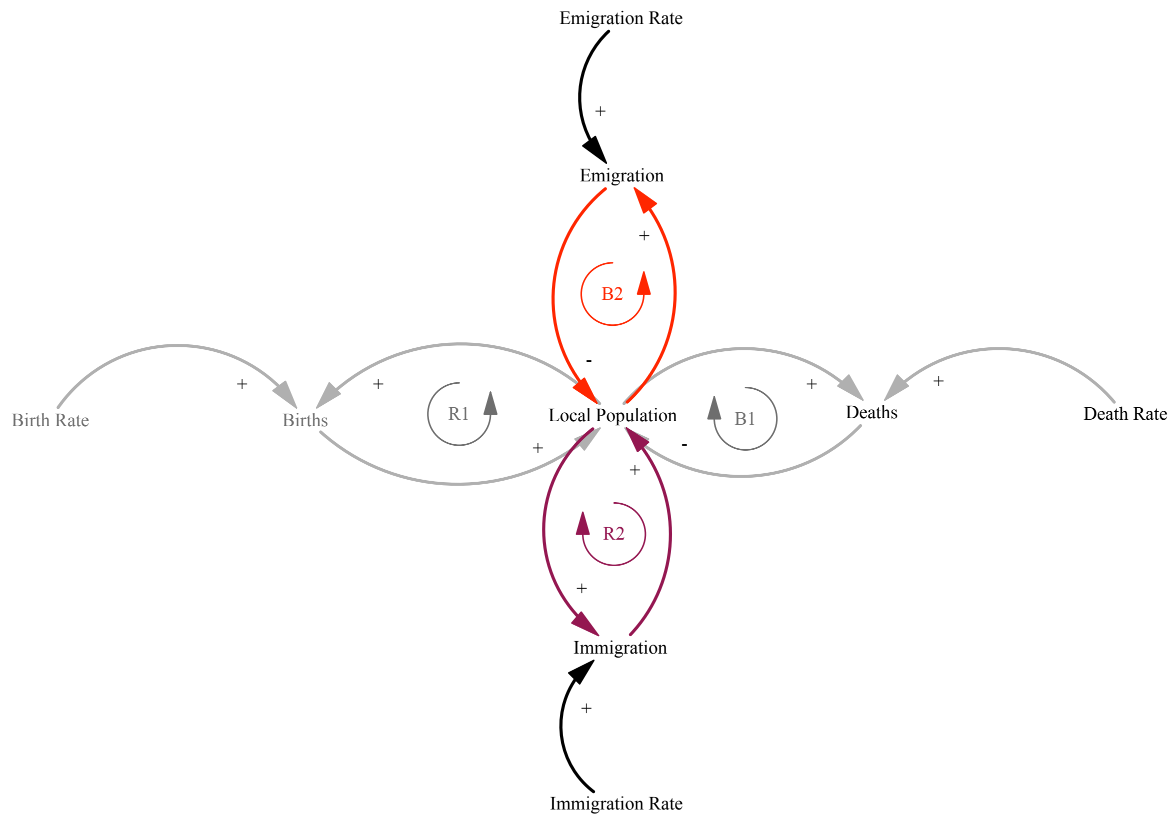

Figure 5-5. Effects of migration on local population growth

5.2.1.1 Tourism sector influence on population growth

As the tourism sector continues to grow by approximately 10 percent per year since 1998, with numbers rising from approximately 12 000 tourists in that year to estimates of 124 000 tourists in 2016 (Figure 4.3) (El Nido MTO 2014; McAvoy 2016; Fabro 2017), this has led to increased employment opportunities in the tourist sector or supporting industries. The arrow from *tourist population* to *jobs* denotes the positive relationship generated. As jobs increase, the *labour / job ratio* shows more jobs than labour, which in turn will lead to an increase in *immigration* as people enter the Municipality seeking employment (Figure 5.6). As more people enter the Municipality this increases the *local population* which in turn, leads to an increase in the amount of *labour* available, as denoted by the positive polarity from population to labour. However, as more immigration leads to an increase in the labour market, this in turn has the effect of an increasing the supply of labour, and over time, labour availability may outstrip the number of jobs available, thus leading to an increase in the *labour / job ratio* (balancing loop (B5)). Conversely, if the amount of labour is higher than the number of jobs available, people will seek opportunities elsewhere and depart the area. This relationship is demonstrated in the balancing loop (B6), which illustrates a *higher labour / job ratio* will lead to an increase in *emigration*, which in turn will lead to a drop in the population numbers, particularly, if emigration is higher than immigration.

Therefore, whilst reinforcing loops R1 and R2 represent a growth in the system through increases in tourism and population, this is counteracted through the balancing loops B1, B2, B5 and B6 which provides for the self-correcting mechanism within the system. As the current migration is driven by the growing tourist sector, any changes in the sector will also impact on the migration flow. Therefore, as the system starts to reach its' carrying capacity and / or tourists venture to other locations, tourism will either slow down or decline, and these loops will become more dominant as people emigrate from the Municipality to follow livelihood opportunities elsewhere.

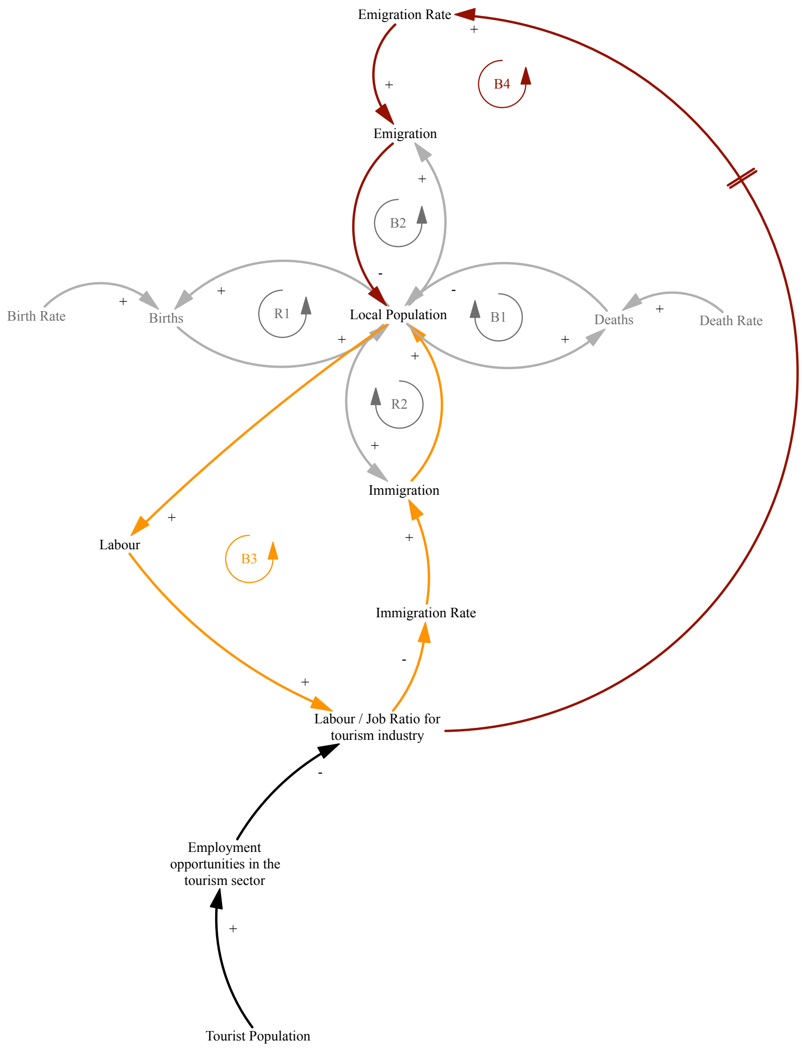

Figure 5-6. Impacts of the tourism sector on the local population

The causal loop diagram illustrate the effects through the generation of employment opportunities leading to an increase or decrease in migration.

5.2.2 Tourism Sector

As referred to in the above section, the growth in local population is being driven by migration caused by the burgeoning tourist sector and the opportunities this provides. Tourist destinations are influenced by various environmental factors, such as socio-cultural, economic, technological, physical, political and legal (Mai and Smith 2015), and any changes to these can lead to changes in the sector and numbers of tourists visiting. A survey of tourists undertaken in April 2015 by T. Gilliland of the University of California (Davis) and the Palawan State University recorded the attractiveness of the physical and socio-cultural environment as the key driver for tourist numbers. In addition to this, the area is also politically stable, adding to its attractiveness. Up until the late 1990s, El Nido was considered a luxury travel destination focusing on dive tourism with high-end island resorts offering the majority of accommodation options. As El Nido has become more well-known due to it being used as a location for international television programs and movies, and along with increasing budget accommodation options, this has made the area more accessible to budget travellers.

As the attractions of El Nido spread, the *attractiveness of the area* continues to draw in more tourists, thus increasing the *tourist population*. As the number of tourists to El Nido increases, field observations over the last four years show this is driving the demand for and subsequent supply of, accommodation such as resorts and hotels, and other infrastructure including better roads, support services, restaurants and shops, representing an increase in *tourism development*. Improved services through tourism development also increases the *attractiveness of the area to tourists*, thus creating a reinforcing loop (R3) (Figure 5.7), illustrating exponential growth which arises from a positive (self-reinforcing) feedback (Sterman 2000). The larger the number of tourists entering the Municipality, tourism development will compound, thus leading to ever-faster growth.

However, whilst the reinforcing loop (R3) illustrates exponential growth in the system, this is balanced by the limitations of land availability (Figure 5.7). Increases in tourism development drives a significant increase in the *demand for land for development*. As the demand for land grows, over time, the *land available for development* will decline as demand outweighs supply, particularly given that available land is a finite resource. As the amount of land available declines, this in turn, will lead to a decrease in new tourist developments, thus creating a balancing feedback loop (B5).

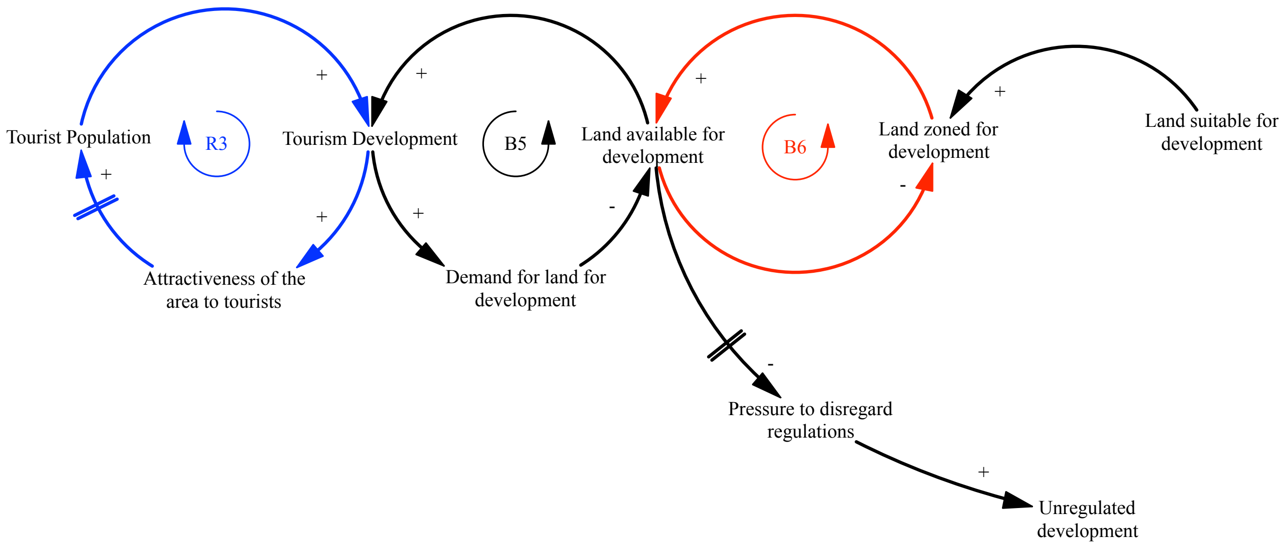

Figure 5-7. Tourism and development loops for El Nido

The interaction between the variables demonstrates a limits to growth archetype. The number of tourists visiting the area is limited by the amount of supporting infrastructure such as accommodation, and by the attractions of the area (R3). However, the amount of tourism development is limited by the amount of land available regardless of demand (B5), which itself, is limited by the amount of land zoned for development (B6) and the overall amount of land suitable for development purposes.

Whilst El Nido was established in the early 1980's as a high-end diving destination, this has changed over the past 20 years and it now caters to a wider tourism market, particularly budget and backpacker tourism. Tourists are now attracted to the area for its limestone formations, lagoons and beaches for swimming rather than for diving. Discussions with local government officials, at community participatory workshops and field observations demonstrate marine tourist sites have gone beyond their carrying capacity with sites now becoming degraded from too many tourists visiting and poor boating practices (e.g. anchoring) which damage the coral reefs. A lack of a tourism master plan, poor tourism management and unenforced regulations exacerbate this problem.

This situation is highlighted in Figure 5.8, illustrating that as the *tourist population* increases leading to an increase in *tourist activities*, this causes more tourist boats to visit the marine sites, leading to the destruction of the sites' habitats caused by poor *boat anchoring practices and trampling on corals* by tourists (Smith et al. 2014; King 2016a) or damage from too many tourists visiting the site. A balancing loop (B7) is generated from these actions, as the coral reefs and the general site areas degrade, this will lead to a reduction in the *attractiveness of the area to tourists* which over time, will then lead to declining tourist numbers as tourist seek attractions elsewhere.

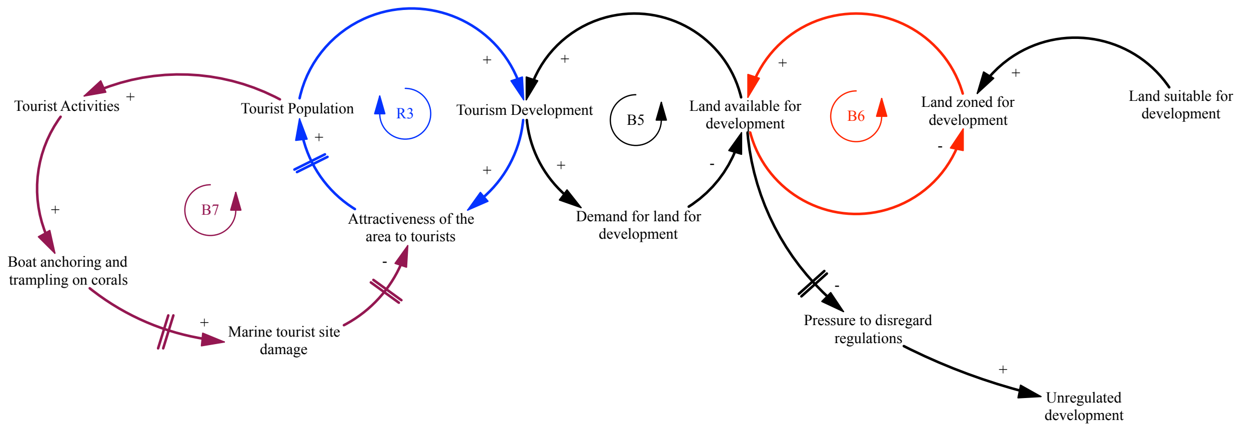

Figure 5-8. Tourism loops illustrating the impacts of tourism on the marine sites in El Nido

5.3 The agricultural food system in El Nido

The agricultural sector in El Nido has historically provided food and income for many in the Municipality, however, over the past decade this has been steadily declining as people seek opportunities outside of these sectors. In 2002, the number of households engaged in agricultural activity from those surveyed was recorded as 2 364 (Figure 5.9) (El Nido LGU 2002). Data in the proceeding Census years is not complete, however, in 2008, 3 677 households surveyed (El Nido LGU 2008) were engaged in agricultural activity, and in 2014 this figure was at 1 713 households (El Nido LGU 2014) for the data available on 12 of the Municipal's barangays. The community participatory workshops undertaken as part of the fieldwork component for this research, recorded agricultural activity of some form i.e. cropping, rice growing, gardening or livestock raising, is practiced in all 18 barangays in the El Nido Municipality (Figure 5.2), thus highlighting its continued importance as a primary or secondary food security source and livelihood for many of the population.

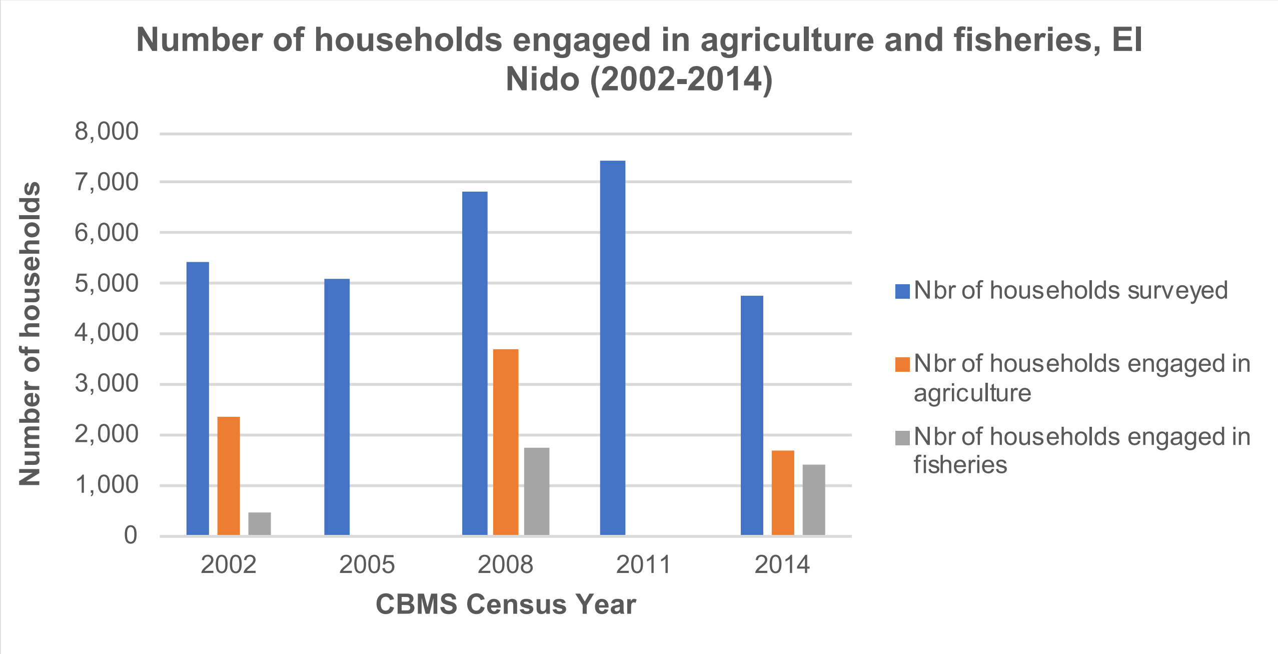

Figure 5-9. Number of households engaged in agriculture and fisheries sectors in El Nido (2002 - 2014)

No data is available for the 2005 and 2011. Data on only 12 barangays was included in the 2014 CBMS Census figures (Source: El Nido CBMS Census 2002-2014).

Agriculture is now a dominant force behind many environmental threats, including climate change, biodiversity loss, and degradation of land and freshwater (Foley et al. 2011). Whilst many of these threats are now seen in El Nido, the community participatory workshops highlighted a number of additional threats or pressures to farming in the Municipality including:

- Increasing demands for food from a growing local and tourist population
- Small farm size
- The lack of land ownership for farmers
- Competing demands for land due to the growth in both the local and tourist populations
- Attractiveness of other employment sectors for livelihoods and incomes other than farming
- Pests and diseases for crops and livestock
- The high cost of farm inputs such as fertilisers, pesticides, herbicides and seeds
- The difficulty in accessing markets due to poor road conditions and transportation

Mapping the drivers and pressures on the agricultural system from information collected through the fieldwork components has led to the construction of a causal loop diagram detailing 26 feedback loops - 13 reinforcing loops and 13 balancing loops (Figure 5.18) which relate to these drivers and are either affecting or will affect, the communities' ability to produce enough food, have access to food and utilise food to ensure nutritional value. Table 5.2 outlines these feedback loops, the variables, drivers, relationship with the food security pillars and the systems behaviour which are created from these feedback loops. The details of these feedback loops are analysed in this section.

Table 5-2. Description of the feedback loops for the agricultural food system illustrated in Figure 5.18

Loop Name		Variables involved	Key message	Food Security Focus	Information Source
Reinforcing	R1	Births, Local population	Population Growth	Availability	CBMS, El Nido Local Government Unit, Philippines Statistics Authority
	R2	Immigration, Local population	Population Growth	Availability, Access	Community Participatory Workshops, El Nido Local Government Unit
	R3	Tourist population, Tourism Development, Attractiveness of the area to tourists	Tourism	Availability, Access	El Nido Tourist Office, Community Participatory Workshops, El Nido Local Government Unit, Bio-LEWIE Household Surveys, Field Observations
	R4	Demand for agricultural and fisheries products, Imports of agricultural and fisheries products, Supply of agricultural and fisheries products, Supply / Demand ratio for agricultural and fisheries products, Market prices of agricultural and fisheries products	Supply and demand for food	Access	Expert elicitation, Semi-structured interviews
	R5	Demand for agricultural land, Land used for agriculture, Agricultural production	Land availability, Agricultural production	Availability	Literature reviews, Expert elicitation, Community Participatory Workshops
	R6	Attractiveness of farming, Demand for agricultural land, Clearing of land for agriculture (i.e. *kaingin*), Land used for agriculture, Agricultural production	Agricultural production, Land availability, Agricultural sector retention	Availability, Access	Community Participatory Workshops, Informal interviews, Expert elicitation, Field observations
	R7	Demand for agricultural land, Clearing of land for agriculture (i.e. kaingin), Land used for agriculture, Agricultural production	Agricultural production, Land availability	Availability	Community Participatory Workshops, Informal interviews, Expert elicitation, Field observations
	R8	Demand for agricultural land, Illegal occupancy of land, Land clearing for ownership, Land used for agriculture,	Land availability, Agricultural production	Availability, Access	Community Participatory Workshops, Expert elicitation

		Agricultural production			
	R9	Attractiveness of farming, Demand for agricultural land, Land used for agriculture, Agricultural production	Agricultural production, Land availability, Agricultural sector retention	Availability, Access	Community Participatory Workshops, Semi-structured interviews
	R10	Demand for agricultural land, Illegal occupancy of land, Land clearing for ownership, Land zoned for agriculture, Land available for agriculture, Land used for agriculture, Agricultural production	Agricultural production, Land availability	Availability, Access	Community Participatory Workshops, Expert elicitation
	R11	Attractiveness of farming, Selling of agricultural land for development, Land zoned for agriculture, Land available for agriculture, Land used for agriculture, Agricultural production	Agricultural production, Land availability, Agricultural sector retention	Availability, Access	Community Participatory Workshops, Informal interviews, Expert elicitation
	R12	Tourism development, Demand for land for development, Land reclamation, Cutting and logging, Mangrove forests, Land available for development	Tourism, Competition for land, Habitat degradation	Availability	Community Participatory Workshops, Expert elicitation, Informal interviews, Field observations
	R13	Demand for land for development, Selling of agricultural land for development, Land zoned for development, Land available for development, Tourism development	Competition for land, Land availability, Tourism	Availability	Community Participatory Workshops, Informal interviews, Expert elicitation
Balancing	B1	Deaths, Local population	Population Growth	Availability	El Nido Local Government Unit, Philippines Statistics Authority
	B2	Emigration, Local population	Population Growth	Availability	El Nido Local Government Unit
	B3	Local population, Labour, Labour / Job Ratio, Immigration Rate, Immigration	Population Growth	Availability, Access	Community Participatory Workshops, Expert elicitation
	B4	Local population, Labour, Labour / Job	Population Growth	Availability, Access	Community Participatory Workshops, Expert elicitation

	Ratio, Emigration Rate, Emigration			
B5	Tourism Development, Demand for land for development, Land available for development	Tourism, Land availability, Competition for land	Availability	Community Participatory Workshops, Informal interviews, Semi-structured interviews, Expert elicitation
B6	Land zoned for development, Land available for development	Land availability	Availability	Informal interviews, Literature review, Expert elicitation
B7	Tourist population, Tourist activities, Boat anchoring and trampling on corals, Marine tourist site damage, Attractiveness of the area to tourists	Tourism, Habitat degradation	Availability	Community Participatory Workshops, Informal interviews, Expert elicitation, Field observations
B8	Demand for agricultural and fisheries products, Supply / Demand ratio for agricultural and fisheries products, Market prices of agricultural and fisheries products	Supply and Demand for food	Access	Community Participatory Workshops, Semi-structured interviews, Expert elicitation, Field observations
B9	Land available for agriculture, Land used for agriculture	Land availability, Agricultural Production	Availability	Community Participatory Workshops, Informal interviews, Semi-structured interviews
B10	Local population, Demand for housing, Land available for development, Tourism development, Attractiveness of area to tourists, Tourist population, Jobs, Labour / Job ratio, Immigration rate, Immigration	Competition for land, Population growth, Tourism	Availability, Access	Community Participatory Workshops, Expert elicitation, Informal interviews
B11	Agricultural production, Demand for water, Water supply / demand ratio, Water shortages, Yield per ha	Resource demand, Agricultural production	Availability	Community Participatory Workshops, Expert elicitation, Informal interviews, Literature review
B12	Incidence of pests and diseases, Use of pesticides	Agricultural production, Water quality	Availability	Community Participatory Workshops, Literature review, Informal interviews
B13	Yield, Use of fertilisers, Soil fertility	Agricultural production, Water quality	Availability	Community Participatory Workshops, Literature review, Informal interviews

5.3.1 Supply and demand for agricultural products

Within El Nido, the ability to access food is connected not only to the ability to grow or produce one's own food, but also to the economic aspects of income generation either through employment or other livelihood options (refer Section 5.3.4). This determines whether or not a household can generate the income needed to procure food if there is not enough food produced at the household level to meet the household's hunger and nutritional needs. During the semi-structured interviews with community leaders in seven barangays, concerns were voiced regarding the increasing population and what this means as to the ability of people to access food to meet their needs. Furthermore, concerns were raised as to the impacts on the local supply of food as competition for land is increasing, access to land is decreasing, and people are seeking alternative livelihoods away from the traditional agricultural and fisheries sectors.

The impacts of supply and demand for agricultural produce from both the local population and the tourism sector is illustrated below (Figure 5.10). As these populations continue to grow, this drives the *demand for agricultural products*. Increasing demand for products leads to a change in the *supply / demand ratio*. As demand increases, this leads to an imbalance in the supply / demand ratio, as the demand outstrips supply. As the supply falls and demand continues to increase, the *price of locally produced agricultural products will also increase*. However, as prices continue to increase beyond the means of the population to procure the food, the *demand for agricultural products* will then decline (balancing loop B8).

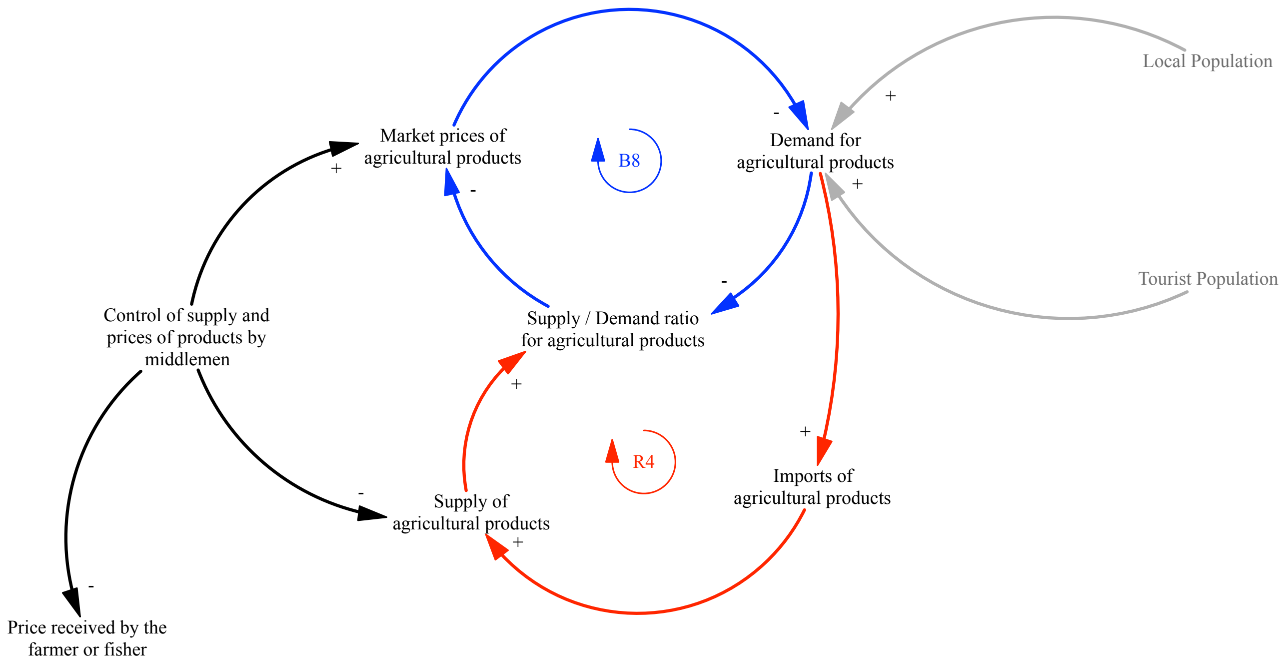

Figure 5-10. Impacts of population and tourist growth on the supply and demand for agricultural products

Semi-structured interviews and informal discussions demonstrated that whilst many households in El Nido retain what they grow or catch for household consumption, with only excess produce sold, there still remains a shortage of locally produced food to feed households, and therefore there is an increasing reliance on imports of *agricultural products* to fill this gap. For example, 107 500 tonnes of rice, 544 482 tonnes of assorted vegetables and fruit, and approximately 600 heads of cattle and pigs were imported into the Municipality during the period from December 2015 to December 2016 (El Nido Municipal Agricultural Office 2017) (Figure 5.11) to meet the growing demand. Whilst exports of agricultural or fisheries produce is low, there were some exports including bananas (6 689kg), cashews (5 676kg), cashew seedlings (26 995) and mangoes (1 500kg) (El Nido Municipal Agricultural Office 2017).

The demand for these imported food products is not only limited to the local population, but is also driven by the tourism sector, as imports enables a consistent supply chain in terms of quality and quantity, as well as meeting the particular demands of tourists for specific produce. Increasing the volume of imports will then increase the *supply of agricultural products*, which in turn, leads to an increase in the *supply / demand ratio* (i.e. supply redresses the imbalance of demand outweighing supply). As the importation of produce leads to an increase in the overall supply, this leads to a decline in the *price of agricultural produce*, which in turn can lead to an increase in the demand as the lower prices enables more affordable options (reinforcing loop R4).

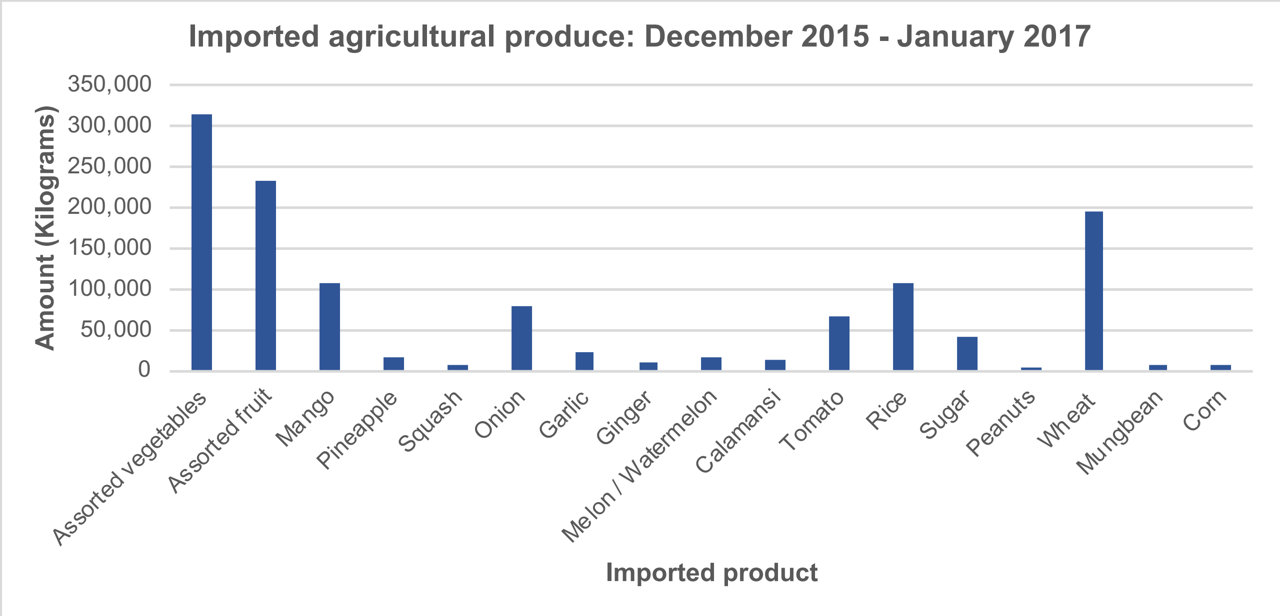

Figure 5-11. Imported agricultural products into El Nido

The graph illustrates the volume by kilograms for the 12-month period from December 2015–January 2016 to December 2016-January 2017. (Source: El Nido Municipal Agricultural Office 2017)

An added element to the supply and demand chain which arose during the semi-formal interviews with barangay community members, is the role 'middlemen' play within the market, particularly with buying and selling rice. These middlemen are common throughout the barangays and both supply the market with produce and buy produce from the local farmers. The admission of these middlemen has three flow-on effects. Firstly, the middlemen control supply to the market and can limit the volume of produce entering the marketplace. Secondly, the middlemen control prices through (i) controlling supply would drive up prices of agricultural products as demand outstrips supply, and (ii) the middlemen directly control the price of the product in the marketplace. Thirdly, as the middlemen purchase the produce from farmers, they control the buying price – *price received by the farmer* - thus reducing the amount of income earnt by farmers for their produce. In some rural barangays if prices for products are high and beyond the means of households to purchase, or if production levels on crops or fish catch are low, households will source wild meats from the local forests for household consumption and for selling at local markets for additional income. This relationship is described in more detail in Section 5.5.

5.3.2 Competition for land and water

Fertile land and freshwater constitute two of the most fundamental resources underpinning the production of food, however with growing populations and changing food consumption patterns increasing the demand for food (Sauer et al. 2009; Godfray et al. 2010; Foley et al. 2011; Alexandratos and Bruinsma 2012), more land and water will be required to meet these needs. The challenge will be how to meet the demands of the growing population in El Nido whilst still ensuring the natural resource base which the food production systems rely upon, remains intact. Globally, there is a mismatch between resource availability for increasing production, i.e. access to relatively arable land and reasonable quality water resources (FAO 2011) and expected needs from the places where food insecure and poverty-affected people live and will live in the near future (Barron et al. 2013), and this is particularly highlighted in the El Nido Municipality. This provides a fundamental challenge on how to ensure food security, due to competition for suitable and available land, water and a rapidly degrading resource base.

5.3.2.1 Demand land for agriculture

Within El Nido, drivers for competing demands on land include the growing local population as more people seek land ownership and undertake some form of farming for both subsistence and livelihood purposes, demands for land for local housing, and demands from the tourism industry for land to build new tourist developments and supporting infrastructure. As the El Nido Municipality is only 92 326 hectares, of which a large portion of the land area is steeply sloping, close to 70 percent, with only 19 percent suitable for urban or agricultural development (PCSDS 2003; PCI 2006), therefore also leading to competing demands for what land is available.

El Nido has previously been heavily reliant an agriculture and fisheries as the mainstays for both subsistence and livelihoods. However, as the local population continues to grow *demand for agricultural land* intensifies as long-standing farmers seek larger land holdings and migrants seek land for agricultural livelihood opportunities. However, the amount of agricultural land utilised to meet the growing demands for food from both the local and tourist population, is dependent upon the amount of land available through either natural geography (*total land suitable for agriculture*) and the amount of *land zoned for agriculture* (Figure 5.12) under the Comprehensive Land Use Plan (CLUP).

The availability of suitable land for farming is the principal driver on agricultural production and people remaining within the farming industry. Of the 92 326 hectares of land area in the municipality approximately 31 139 hectares or 34 percent was zoned for agricultural use under the Municipality's *Comprehensive Land Use Plan and Zoning Ordinance, Municipality of El Nido 2003-2012* (PCSDS 2003)[12]. However, despite an increase in the amount of land zoned for agricultural purposes from the previous Land Use Plan (11 871 hectares or 12.86 percent), the actual area of land under crop cultivation has declined. For example, the land area under rice production has declined, with a drop from 20 percent in 1999 (PCSDS 2003) to 15 percent in 2017 as reported by the El Nido Agricultural Technician. This is due to a number of reasons including; small land holdings which make farming unprofitable, land ownership issues with land owned by only a few people in some barangays, the selling of land to foreigners or developers, and a shift from farming to other employment or livelihood opportunities. This shifting of land use is affecting agricultural production, for example, the President of the Municipal Agricultural and Fisheries Council reported in late 2014 that the barangay of Villa Libertad in El Nido, had lost 1 500 sacks of rice production due to agricultural land being lost to development, and this was now causing rice shortages in the barangay (Smith et al. 2014).

The diagram below (Figure 5.12) outlines this situation with the amount of land available for agriculture determining the amount of land used for agriculture. As the amount of *land available for agriculture* increases this leads to an increase in the amount of *land used for agriculture*. However, as more land is used for agriculture, this in turn, decreases the amount of *land available for agriculture*, creating a balancing loop (B9). If the amount of *land used for agriculture* increases this in turn, will lead to an increase in *agricultural production*. *Agricultural production* increases not only to land size but also other factors such as improved soil fertility or a reduction in the number of pests and diseases on crops and livestock (discussed in Section 5.3.3). As production improves this can lead to an increase in the *demand for agricultural land* as farmers seek more land to maximise yield which leads to an increase in the amount of *land used for agriculture* creating a reinforcing feedback loop (R5). Increases in *agricultural production* can also improve the *attractiveness of farming* which in turn, increases the *demand for agricultural land* and

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[12] This is the latest zoning figures under the CLUP as the 2012-2022 plan has not been approved by the Local Government Unit.

thereby increases the *land used for agriculture*, creating another reinforcing feedback loop (R9).

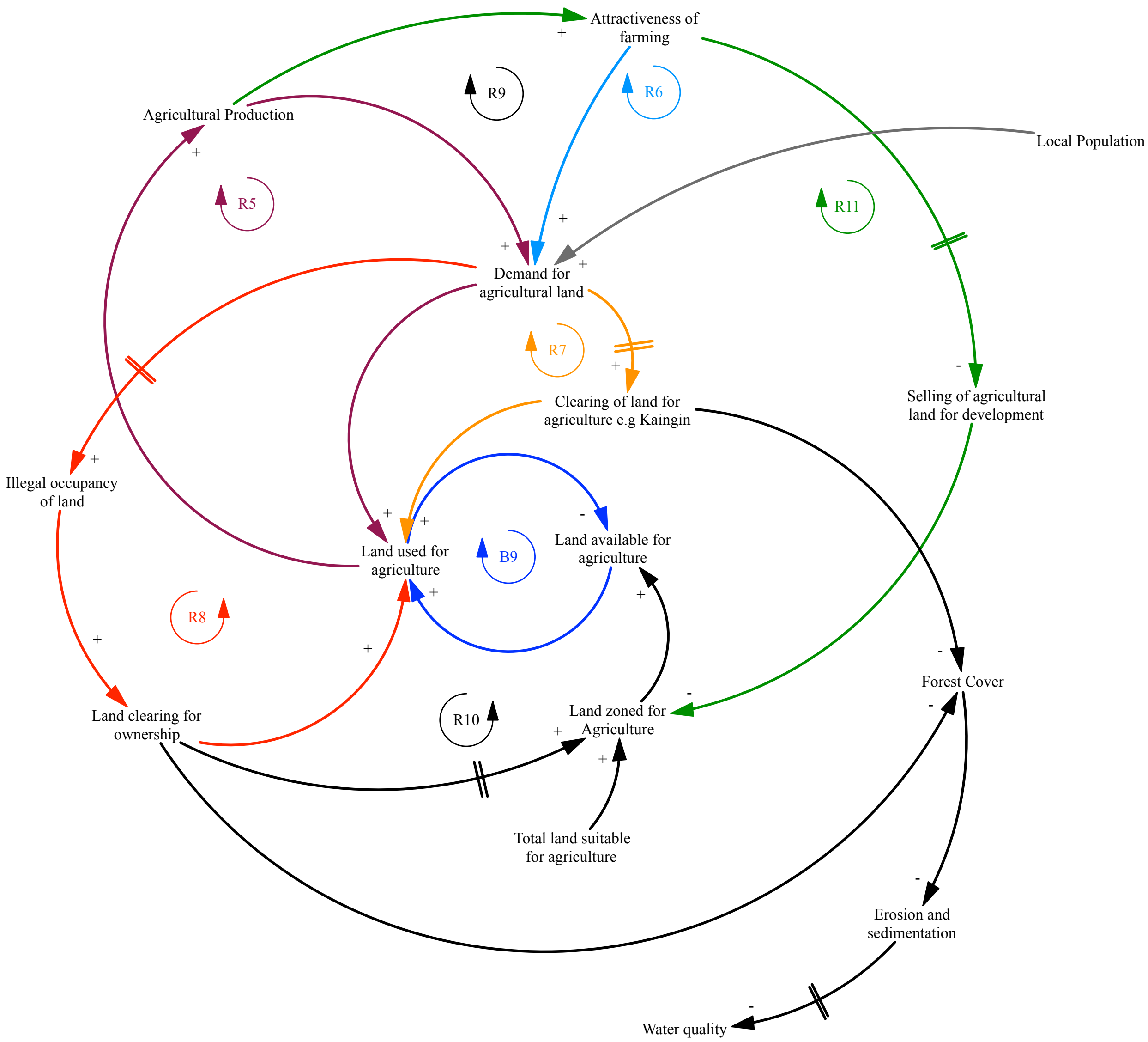

Figure 5-12. Agricultural land loops illustrating the demand for agricultural land for farming

The growing demand for agricultural land by migrants entering the area seeking livelihood opportunities in the farming sector creates a twofold effect (Figure 5.12). As demand for agricultural land increases, migrants entering El Nido are illegally occupying timberlands in the barangays. In the Corong-corong barangay, it was reported during the community participatory workshops that migrants into the area are taking up residency in the timberlands through illegal occupancy. The land is cleared by the squatters and cultivation of cash crops such as cashews is undertaken. When there is visible improvement the squatters seek an inspection from the national Department of Natural Resources and

Environment in order to obtain amendment of the zoning regulations and have the changed land practice registered[13]. The land use change is approved and rezoned as agricultural land and becomes taxed (King 2016a). This practice is illustrated in balancing loop (R8) whereby the *demand for agricultural land* leads to an increase in *illegal occupancy of land*. Once occupied, *land clearing for ownership* is undertaken which in turn leads to an increase in the *land available for agriculture*, the *land used for agriculture* and ultimately contributes to an increase in *agricultural production*. However, the illegal occupancy of land and the changing land use has a two-fold effect. Firstly, the clearing of land and the rezoning, increases the amount of *land zoned for agriculture*, which in turn increases the amount of *land available for agriculture* and therefore, the amount of *land used for agriculture*. As the land is now under production, this increases the volume of *agricultural production* which in turn can drive the demand for agricultural land (reinforcing loop (R10)). Secondly, the action of clearing forest land for agricultural reduces forest cover. This leads to an increase in soil *erosion and sediments* entering the watershed, which over time, reduces the water quality of the terrestrial water sources, and ultimately impacts on the *water quality* in the marine environment as the sediments travel downstream. The further impacts of this activity on the water quality and coral reefs in the Municipality are discussed in Section 5.4.4.2 regarding the fisheries food system.

The demand for land for agricultural activity is also driving an increase in the amount of *kaingin* (slash and burn method of clearing forested land) in the upland or forested areas of El Nido, despite zoning which makes land clearing in these areas illegal. Informal interviews with farmers outlined the practice used to secure land for dryland rice production. After a number of rotations, as the soil quality declines, the rice crops are replaced by perennial crops such as coconuts, fruit or root crops. This practice of land clearing increases the amount of *land used for agriculture* and therefore increases *agricultural production* further increasing the *demand for agricultural land* (reinforcing loop (R7)). The increase in *agricultural production* caused by the practice of *kaingin* can also increase in the *attractiveness of farming*, creating a reinforcing feedback loop (R6).

Whilst the 2014-2015 CBMS Census indicated that 1 713 or 36 percent of households surveyed are engaged in agricultural activities in El Nido, the attractiveness to continue

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[13] This is considered one of the challenges in which there are multiple layers of governance over different resources within the Municipality and it is not the remit of the Local Government Unit to be able to have input into the rezoning of lands which come under the jurisdiction of the DENR

farming is underpinned by multiple factors including land availability, improved livelihoods through income generation, and increasing agricultural production. Reinforcing loop (R11) illustrates the relationship when the attractiveness of farming remains low and other opportunities are deemed more attractive. In El Nido, as the attractiveness to farm declines, this is leading to a selling off of farmland to developers for tourist resorts (Figure 5.12). During informal discussions, it was highlighted that in some cases, farmers will undertake *kaingin* to clear forested land they own in order to rezone it as agricultural land and in turn, create an opportunity to sell this land to developers (Smith et al. 2014). The *selling of agricultural land for development* leads to a decline in the amount of *land zoned for agriculture* which in turn, leads to a decline in the amount of *land available for agriculture,* ultimately impacting on agricultural production.

5.3.2.2 Demand for land for tourism developments and local housing

The increasing demand for land suitable for tourism developments and local housing is directly competing with agricultural interests, given the limits to the amount of useable land in the Municipality, leading to complex interactions within the system in El Nido. The amount of *land available for development* – both tourist and urban housing – is restricted by the amount of *land zoned for development*, which in itself, is dependent upon the amount of *land suitable for development* (balancing loop (B6)). In El Nido the current Comprehensive Land Use Plan has zoned 15 766 hectares or 17.1 percent of the land for built-up use. However, currently the high demand for tourism developments is leading to increased *pressure to disregard the development ordinances and regulations*, with many of the developments in urban areas such as the Poblacion and Corong-corong unregulated and illegal (Figure 5.13). Given the lack of enforcement of development ordinances and regulations, and the lack of political will from the local government[14] to enforce these ordinances, this practice will continue into the foreseeable future.

As outlined in Section 5.2.2, the increase in *tourism development* is driving a significant increase in the *demand for land for development* (Figure 5.13). As the demand for land grows over time, the *land available for development* will decline as demand outweighs supply, particularly given that available land is a finite resource. As the amount of land

[14] In early 2016 the Mayor of El Nido noted the LGU's proposal to enforce building regulations against all illegal constructions i.e. provide a 12-month 'grace period' for all buildings not meeting the regulations to be altered or pulled down. However, given the complexity of the situation in El Nido with building ownership, it was noted that whilst the regulations needed to be enforced this would not occur during that particular mayoral tenure.

available decreases, this in turn, will lead to a decrease in tourist developments, thus creating a balancing feedback loop (B5).

Other methods to increase the amount of land available for tourist development involves land reclamation of mangrove areas. As mangroves grow in the coastal areas attractive to developers for tourist resorts, developers are undertaking *land reclamation* by *cutting and logging* the *mangrove forests*[15] (Figure 5.13). Whilst the reclaimed mangrove forests increase the amount of land available for development (reinforcing loop (R4)), it also leads to further habitat degradation impacting on the fisheries production system as outlined in Section 5.4.4.2.

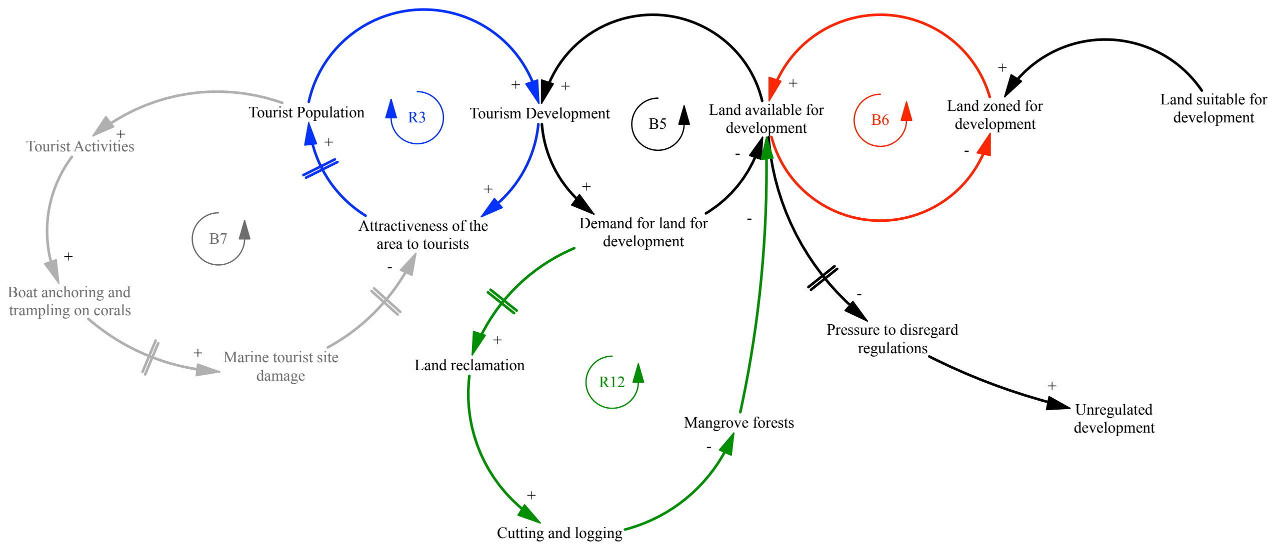

Figure 5-13. Impacts of tourism and the expansion of tourist developments on land availability in El Nido

Furthermore, as the *demand for land for development* by tourism developers increases, this is now leading to an increase in the selling of agricultural land in highly desirable areas such as the coastal lowlands or urban centres. Farmers are finding the offers for their land more attractive than the continuation of farming which produces low returns (Smith et al. 2014). The *selling of agricultural land* leads to an increase in the amount of *land available for development*, creating a reinforcing loop (R13) (Figure 5.14). The selling of agricultural

[15] Whilst the clearing of mangroves is illegal, it stills occurs in areas of the Municipality

land for development reduces the amount of land zoned for agriculture. Over time, as agricultural production decreases, this reduces the attractiveness for farming, and leads farmers to the cycle of selling off their land, creating reinforcing feedback loop (R14). However, this “fix” to increase the amount of development land will only last as long as there is suitable agricultural land in areas where tourists will find it attractive, and as long as the shifting from farming into other employment sectors remains more attractive.

Placing further pressure on land resources is the increased demand for local housing in the urban areas due to the increase in population growth. As *demand for housing* increases, this leads to an increase in the *demand for land for development*. If more of the urban land is developed for local housing, this leads to competition for land, leading to a reduction in *tourism development*. Over time, a reduction in *tourism developments* leads to a *loss in the attractiveness of the area* as tourists seek newer establishments to meet their needs, and if there is not enough accommodation for the tourist population, tourists will either go elsewhere, leading to a decrease in the tourist population. The flow-on effects of this are seen in a reduction in *tourism employment* in the Municipality, and a decline in *immigration* and therefore in the *local population*, creating a balancing loop (B10) (Figure 5.14). Overall, this continued competition for land from agriculture, tourism and urban development, demonstrates the constraints within the system as land is a finite resource, and the limits to growth is reached once all of the suitable land is cleared and used for these functions.

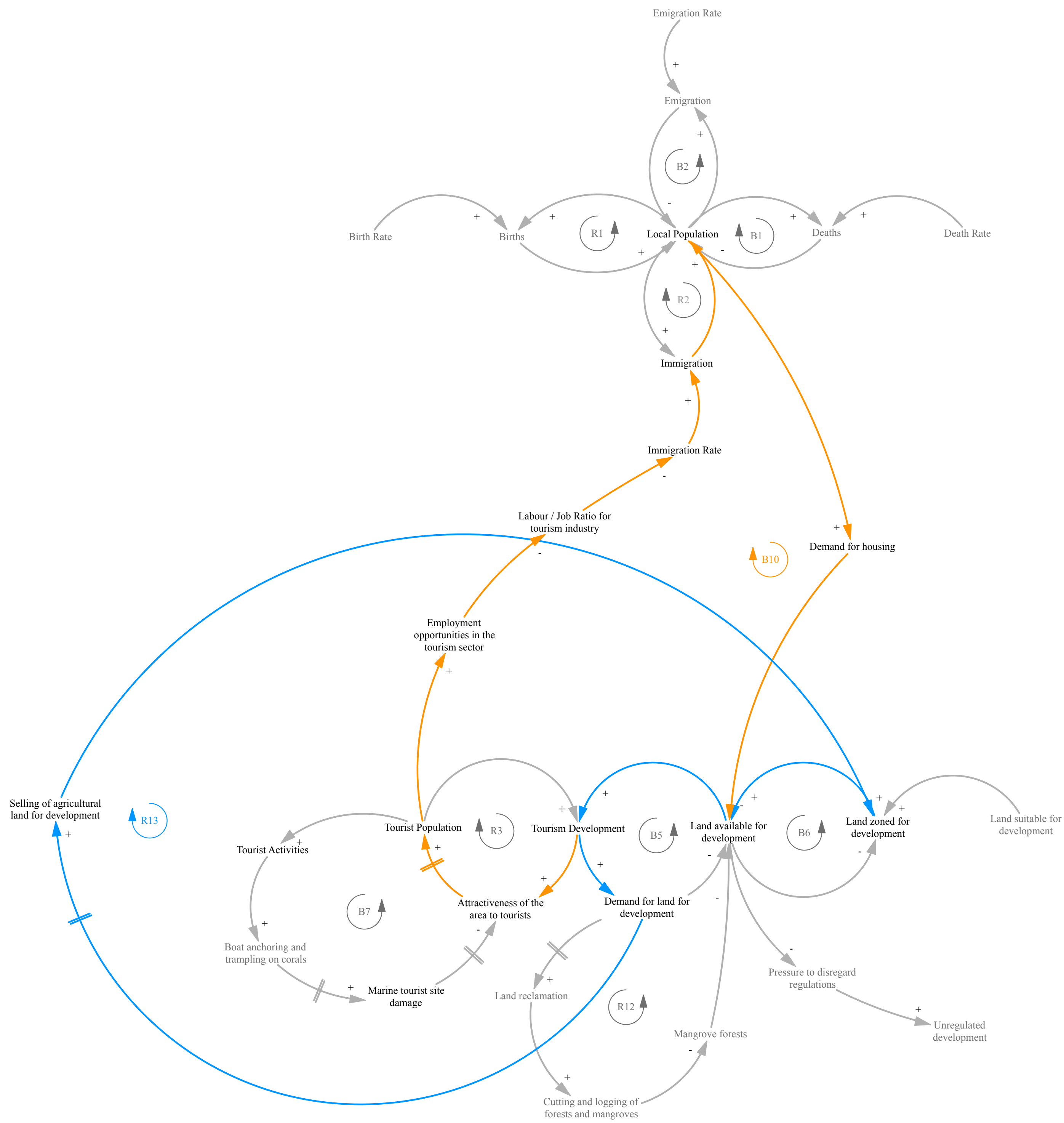

Figure 5-14. Causal loops illustrating the competition for land between agriculture, tourist developments and urban housing

5.3.2.3 Competing demands for water

A further constraint on meeting the demand for food through agricultural production, is that of the availability of water resources. Water availability is one of the main factors limiting future food production, particularly in the poorest areas of the world, where access to water, and its timely availability, are especially challenging (Barron et al. 2013). Agriculture competes with domestic, commercial and industrial consumers and users, and continued growth in these sectors' water consumption will decrease the available water volume for agriculture (Sauer et al. 2010). Water is also required to maintain functioning ecosystems and environmental flow requirements, with sufficient environmental flow critical for freshwater ecosystems and also for some terrestrial ecosystems (Godfray et al. 2010) and competing usage from multiple stakeholders diminishes these functions. Given the evident competing demands on water in the El Nido Municipality, the lack of available water for agricultural production was identified as the third highest pressure in the Municipality during the CPWs (Figure 5.3).

The water supply in El Nido is rainfed and restricted to rivers, creeks, streams and wells, which remain reliant upon the wet season for the majority of the annual rainfall which supplies them. Water management tends to be poor with little in the way of water storage even in the urban areas. Globally, agriculture accounts for 85 percent of global consumptive use (Foley et al. 2005), however, in El Nido, competition for water (much of it rainfed) is a driving factor in the inability to improve agricultural production as farmers compete with demands from the growing tourist and local populations. As the local and tourist populations increase, this in turn drives demand for water for domestic, commercial and agricultural use (Figure 5.15).

As *demand for water increases* from the agricultural sector for irrigation purposes, and the local and tourist population for commercial and household use, this leads to a decrease in the *water supply / demand ratio* as demand goes up. The variable, *water supply,* also has an influence on this ratio as it controls the amount of supply available. If water supply increases through rainfall or groundwater, then the supply will increase to meet the demand, thus a positive polarity. However, as demand increases over supply, this will lead to *water shortages* which in turn will lead to a downturn in *yield per hectare* in crop production which leads to a decline in agricultural production, thus creating balancing loops (B11) (Figure 5.15). One major determinant to the water supply in El Nido is that it is reliant on *rainfall*, which in turn is susceptible to seasonal variability and extreme weather events such as drought and *climate change*. One intervention to improving the water situation for agriculture has been the installation of irrigation channels with the El Nido Municipal Agricultural Technician reporting it feeds approximately 460 hectares of farmland, mostly for rice production. However, this method is costly for most farmers and remains reliant on rainfall as water is pumped from the rivers, creeks or wells for the irrigation.

Overall, informal discussions in barangays highlighted an awareness that if the population continues to grow, this will place undue pressure on food security as the amount of land and water available for agriculture will be reduced, and therefore reduce the ability of the barangays to produce the food needed to support its local population (F. M. Lim 2017, pers. comm., 11 May; Kgd. S. Batoy 2017, pers. comm., 13 May).

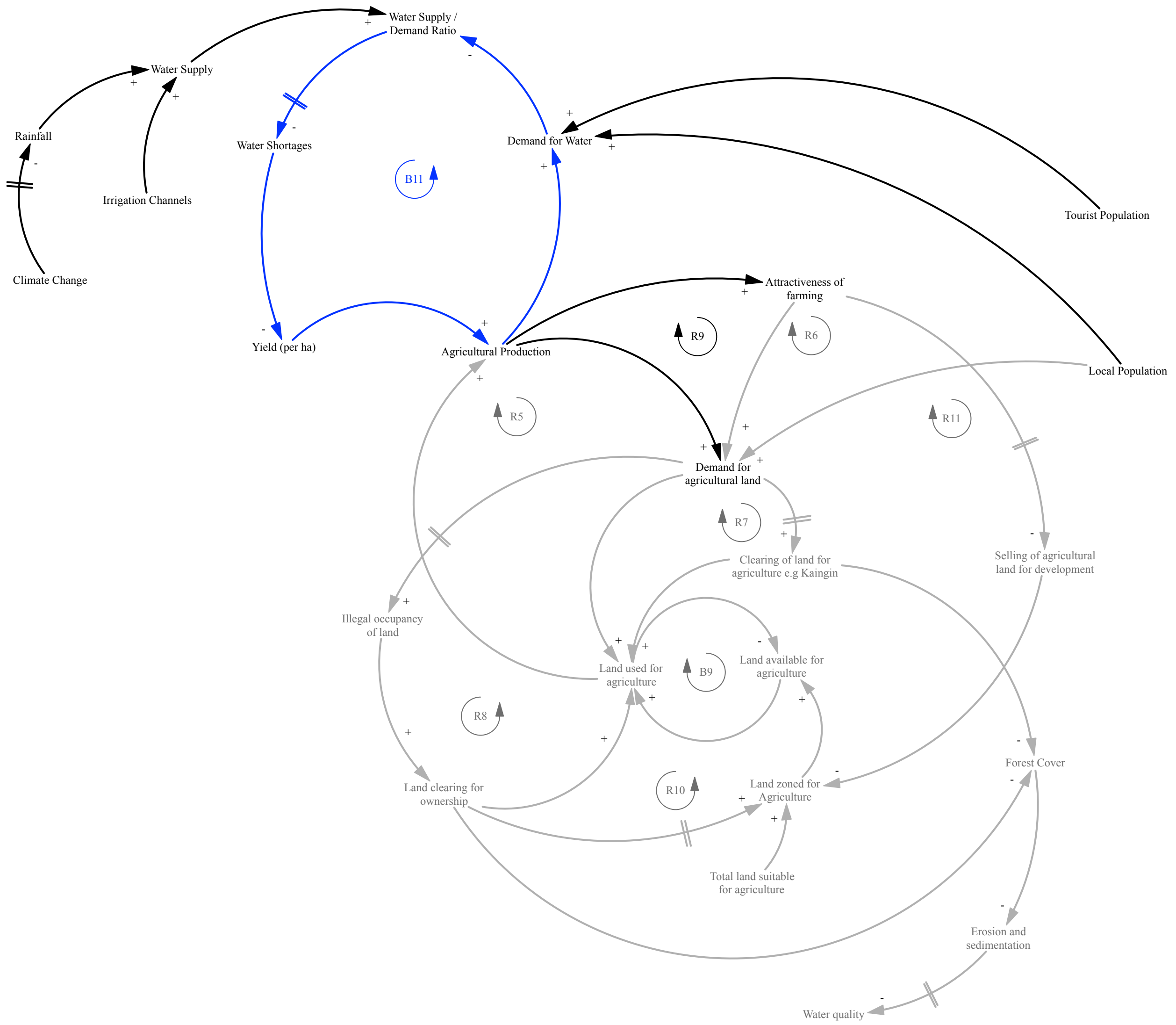

Figure 5-15. Impacts of increasing demand for water on the water supply and agricultural production

5.3.3 Impacts of soil fertility, pests and diseases on agricultural productivity

Whilst the environmental drivers of land and water availability are core to the ability of the agricultural system to produce enough food to ensure food security within the Municipality, production systems are also dependent on soil fertility and an absence of pests and diseases for continued healthy crops. However, the management regimes to improve these elements in the farming sector are also responsible for habitat degradation, particularly within the waterways and the flow-on effects into the marine ecosystem.

As the soils in El Nido tend to be poor and infertile, and susceptible to erosion (PCSDS 2003), farmers mitigate against the low fertility through the increasing *use of fertilisers* which add nutrients into the soils to improve the fertility of the soil. As the soil fertility increases, this provides for more *yield per hectare* for crops, which in turn, increases the level of *agricultural productivity*. Similarly, farmers have increased the *use of pesticides* to combat the ongoing threat from pests and diseases (balancing loop (B12))- recorded as the number one pressure during the community participatory workshops - to both crops and livestock. The increase in pests and diseases not only decreases the quality and quantity of stock, it also impacts on farmers' ability to sell their produce in external markets. For example, El Nido is a major grower of mangoes, however markets are limited to within the Municipality rather than exporting to external markets, due to mango pulp weevil (Smith et al. 2014). Increasing the *use of pesticides* will lead to a decline in the number of pests and diseases affecting both crops and livestock, therefore leading to an increase in both the *yield per hectare* for crops, and overall *agricultural production* of crops and livestock. Ultimately, the use of fertilisers and pesticides to increase *agricultural production* will generate an increase in the amount of *income from farming,* however it will also increase the cost of production. Increased yields can lead to an increase in *demand for agricultural land* as the *attractiveness of farming* improves, particularly if yields and prices are high and therefore the return on effort is rewarded.

The community participatory workshops highlighted the use of fertilisers and pesticides as a key pressure due to overuse. Whilst their use leads to short-term increased agricultural productivity, over time, this has flow-on effects into the water resources, degrading water (Foley et al. 2005) and adjacent marine ecosystems. Agriculture is the largest source of excess nitrogen and phosphorous to waterways and coastal zones (Foley et al. 2005), and further degrades water quality through intensive agricultural practices increasing erosion and sediment loads, and leaching nutrients and agricultural chemicals to groundwater, streams, and rivers (Tong and Chen 2002; Foley et al. 2005). Therefore, the continued and increased usage of both fertilisers and pesticides leads to increased runoff in the form of *agrochemical runoff* into the waterways and affecting the water quality. The decline in water quality impacts onto the surrounding marine environment resulting in coastal hypoxic or "dead" zones which severely constrain the productivity and ecosystem integrity of marine ecosystem (Moomaw et al. 2012). Whilst this affects corals, seagrass and other important habitats as well as the marine animals they support, while also having a detrimental effect on tourism and fishing industries (Wooldridge and Done 2009; Great Barrier Reef Authority 2017).

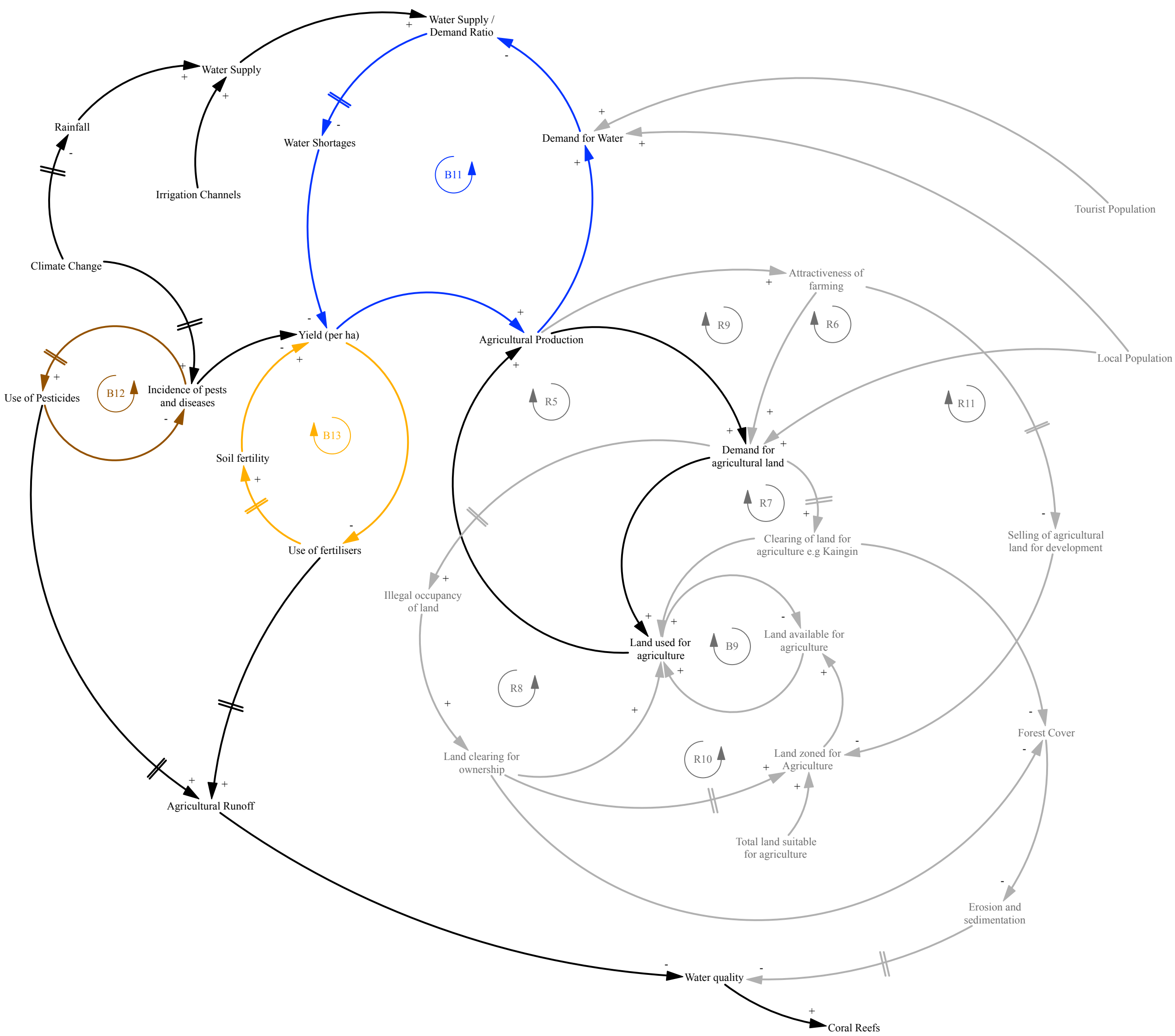

Figure 5-16. Impacts of soil fertility, pests and diseases on the agricultural production system

5.3.4 Retention of agricultural livelihoods

The agricultural sector in El Nido has historically provided food and income for many in the Municipality, however, over the past decade this has been steadily declining, dropping by 14 percent from 2002 to 2014 (El Nido LGU 2002-2014) as people seek opportunities outside of these sectors, particularly in the tourism sector. This decline in the agricultural sector is related to a number of factors highlighted during the community participatory workshops and informal and semi-structured interviews including the loss of farming land, lack of suitable land for farming, other sectors becoming more attractive in terms of income and benefits, low returns in farming. For example, during discussions with the cashew cooperative in El Nido, the manager indicated cashew farmers are no longer interested in cashew production due to the seasonality of the crop (e.g. one-crop per year), and prices received for cashews are low which makes incomes very low, and the high cost of farm inputs such as fertilisers, pesticides, herbicides, seeds and transport to market are making earning an income from farming difficult.

As these factors continue to play a major role in the agricultural sector in El Nido, farmers and farm workers are seeking other opportunities to improve their livelihoods and generate income elsewhere, mainly through: (i) the selling of agricultural land to developers or external buyers, thus reducing the amount of land being farmed. For example, the barangay captain in Villa Paz noted that land is being sold to foreigners for PhP100 000 per hectare; (ii) shifting land use from farming to the tourism sector as it is perceived to have greater returns (e.g. income) for less work; (iii) undertaking illegal poaching of wildlife when prices received for local peoples' produce is low or when there has been a poor crop; (iv) shifting to alternative livelihoods such as cutting and logging of timber and non-timber resources for the growing construction sector, or undertaking *uling* (charcoal making) for household use (Figure 5.17).

As farming has become less attractive, many of the farmers are seeking opportunities generated from the tourism sector (discussed below), or they move into other alternative livelihood areas such as *uling* (charcoal making), cutting of timber or non-timber resources, furniture making for local households, and household construction (Figure 5.17), all of which impact on the supporting environment of the food system through the cutting and logging of forests and mangroves, leading to an increase in erosion and sedimentation entering the waterways and affecting water quality. The impacts these activities have on the food system is analysed in Section 5.4.4.2.

This shift away from the farming sector has a number of flow-on effects within the El Nido system. During the CPWs, it was noted the attractiveness of farming is dependent largely upon the volume of agricultural production and the price received for the produce. Much of this is therefore linked to market forces in a number of ways. As mentioned in Section 5.3.1, in the majority of the rural barangays, 'middlemen' control the price paid to the farmer for their produce. For the farmer, the price for agricultural produce equates to their income earned and if this remains high, the attractiveness to continue farming remains as denoted by the blue arrows in Figure 5.17. If the income received is low and continues to be low over a long period of time, farmers will start to move into other income generating sectors. In other instances, if the price received is low or a crop has failed, farmers also turn towards the poaching of wildlife either for selling on the black market or for wild meat as illustrated by the orange arrows in Figure 5.17 (refer Section 5.5 for details). The attractiveness of farming is also linked to the ability of the farmer to be able to move the produce to market, thus generating income. This is dependent on market linkages across the Municipality, such as the road network, transportation to the markets or storage for produce. If there is a lack of market linkages the ability to move produce to market for selling is reduced and over time, the lack of returns such as income, will reduce the attractiveness of farming.

Over time, as the attractiveness of farming reduces, many farmers and farm workers are shifting towards the tourism sector to take advantage of the opportunities presented in this growing sector. This shift from farming into the tourism sector is leading to an increase in the amount of agricultural jobs available, leading to a decline in the labour / job ratio as the amount of jobs available becomes more than the amount of labour available to undertake the jobs. The shift in occupations also impacts on the amount of labour available to fill roles both in the agricultural sector and the tourism sector. The agricultural sector will decline as it becomes more difficult to find people willing to work on farms, whilst the labour pool for the tourism sector will expand.

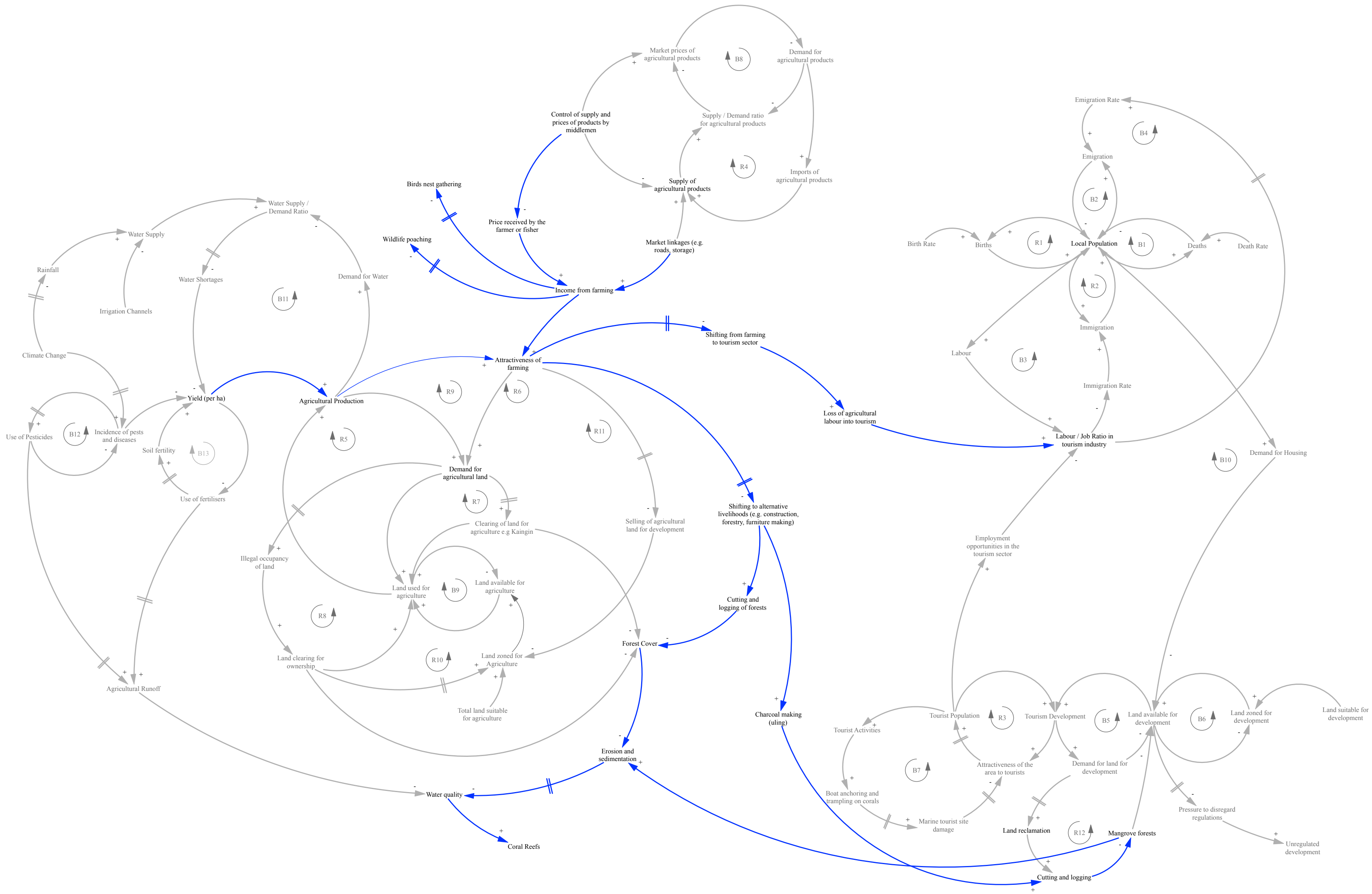

Figure 5-17. Causal loops illustrating the relationship between income, livelihoods and farming in El Nido Municipality

5.3.5 Summarising the agricultural food system in El Nido

Agricultural production is underpinned by the availability of land and water and without sufficient amounts of either, production declines. In El Nido, whilst land availability for agriculture has been increased under the Comprehensive Land Use Plan (PCSDS 2003), the actual amounts of land under cultivation for crops has declined in real terms, leading to substantial declines in local production and difficulty for the local population to grow enough food to be self-sufficient. The Municipality is therefore, becoming heavily reliant on the importation of food products, many of them food staples, to feed both the local and tourist population. As more people are also moving away from the traditional livelihoods of farming and fishing towards the tourist-oriented sector, this places increasing pressure on the system as demands for food grow with the increasing wealth generated from improved incomes.

A major challenge for the Municipality, is with declining local production and increased imports, how will people access or economically procure food in the future whereby system shocks impact on food availability and pricing i.e. access? For example, with the population heavily reliant on the tourism sector and related industries for income generation, if there is a decline in the tourist numbers or once all of the natural resources have been depleted, where will incomes to procure food be generated from and how do people then access food at market prices?

When capturing the dynamic hypothesis for the agricultural system in El Nido through the creation of the causal loop diagrams, it demonstrates potential for change driven by socio-economic factors such as population and tourism growth. The system will need to be able to adapt and adjust to these changes through policy actions as explored in Chapter 6.

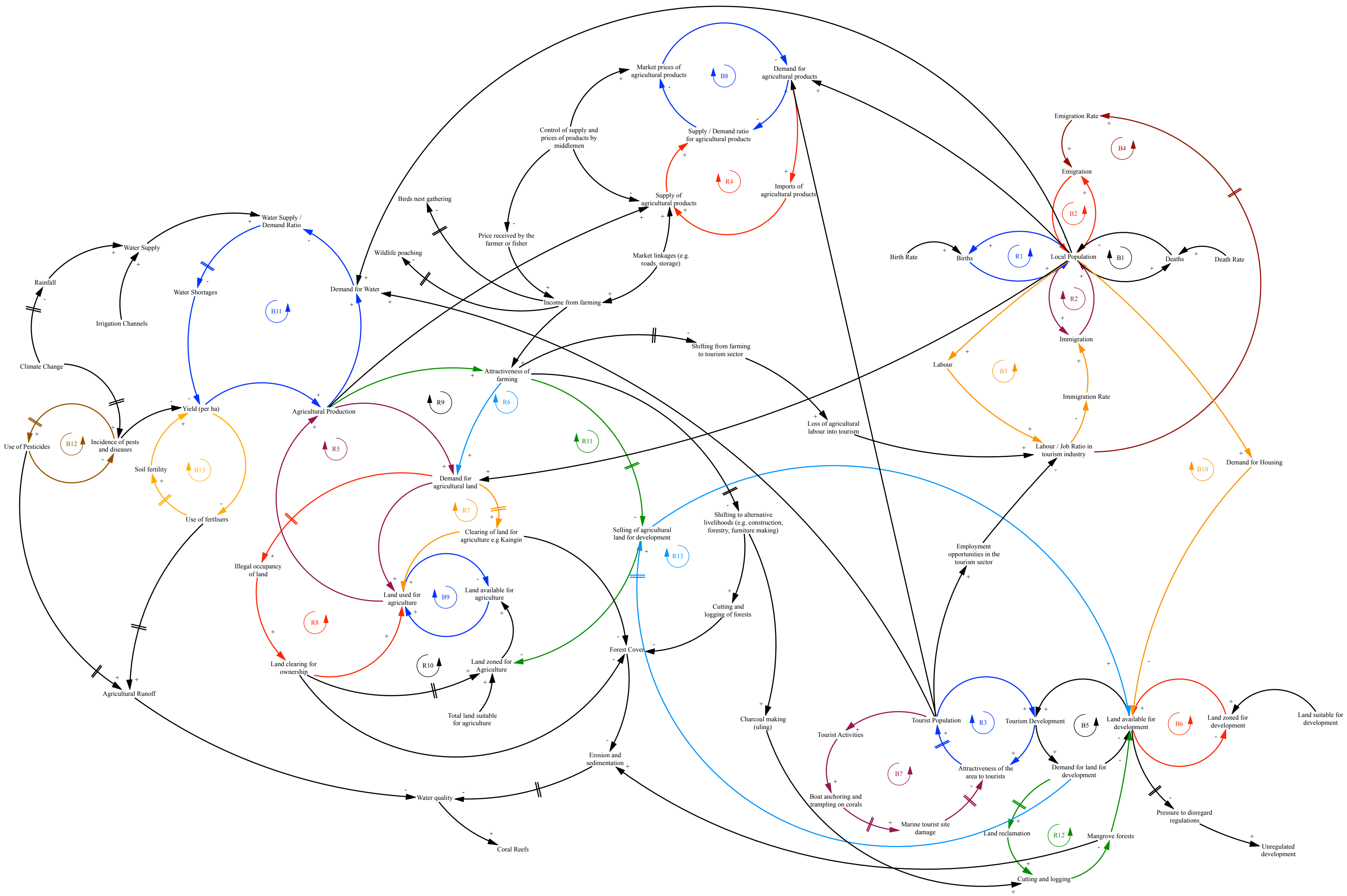

Figure 5-18. Dynamic hypothesis for the agricultural system in El Nido Municipality

5.4 The fisheries food system in El Nido

At the local level fisheries have historically played a major role in providing food, income and livelihoods for the population of El Nido. The CBMS Census data (El Nido LGU 2002 - 2014) illustrates a steady increase in the number of households engaged in fisheries activities from 2002 with 458 households engaged in fisheries, to 1 415 households engaged in fisheries in 2014[16] (Table 4.5). The growing importance of fisheries was further highlighted during the community participatory workshops, whereby fisheries resources were identified in 17 barangays with fishing activity identified in 16 barangays (Figure 5.2) (King 2016a).

However, with the continued reliance on fisheries for both food and income, stocks within the Municipality are becoming depleted due to overfishing and habitat degradation. Figures from the El Nido Municipal Agricultural Office show fish catch has declined approximately 40 percent from 701 metric tonnes caught in 2007 down to 261 metric tonnes in 2014 (Figure 5.19) (El Nido Municipal Agricultural Office 2014; Pontillas et al. 2015). The decline in fish catch is leading to an increasing number of fish imports to meet the growing demand (Table 4.3).

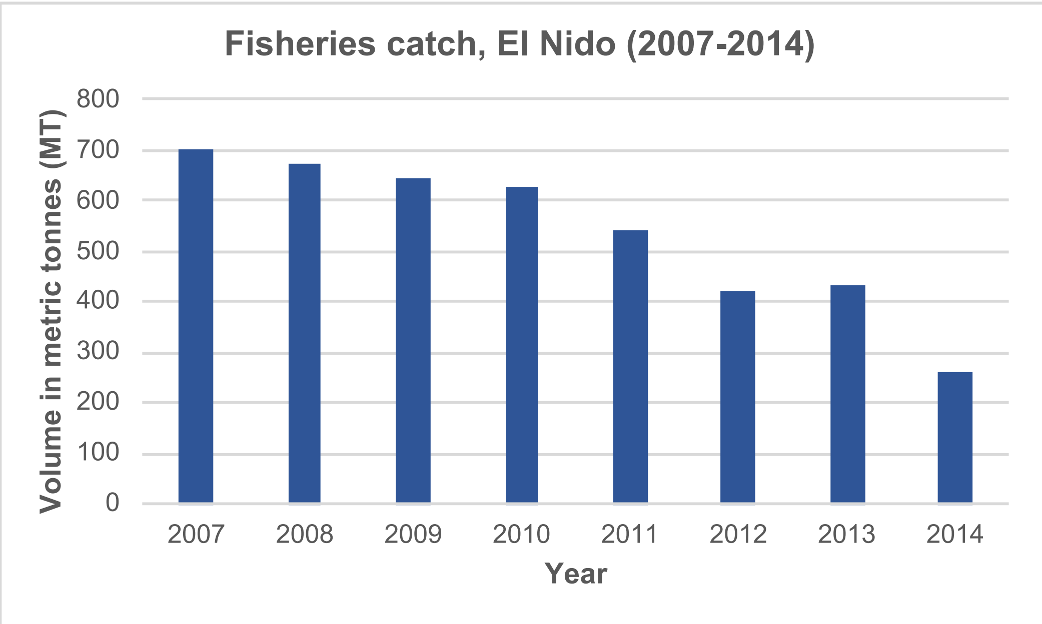

Figure 5-19. Fisheries catch in El Nido Municipality for the period 2007 - 2014

(Source: El Nido Municipal Agricultural Office 2014)

[16] The data for 2014 is only available for 12 barangays, however, the available data suggests a 22 percent increase in the number of households surveyed undertaking fishing activities from the 2002 CBMS to the 2014 CBMS.

To mitigate against declining fish stocks the establishment of marine protected areas (MPAs) has been implemented in some areas in El Nido. Whilst in some barangays the MPAs are not seen as conducive for fishing, in other barangays such as San Fernando, there is support for the closure of fishing grounds as they are deemed a successful mechanism to increase fish stocks. The observation was made by a barangay council member that the "*fish will still come from within the barangay because of the MPA*". However, even with strategies such as implementing MPAs it is unclear as to their value towards increasing fish stocks in El Nido, as it is reflective of the global situation whereby MPAs or no-take areas are considered to be too small and too far apart to sustain processes within the broader seascape and monitoring and enforcement are often inadequate (Berkes et al. 2006).

The causal loop diagram (CLD) for the fisheries food system in El Nido is reflecting the global situation of declining stocks and habitat degradation with a large number of drivers and pressures on the system weakening the ability of the fisheries system to regenerate. The fisheries food system demonstrates 29 feedback loops - 13 reinforcing feedback loops and 16 balancing feedback loops (Figure 5.29). As with the agricultural system, the socioeconomic drivers of population and tourism growth driving demand for fisheries are placing the greatest pressure on the ability of the system to produce adequate food. Furthermore, the pressures on the ecosystems underpinning the fisheries system is also impacting on the ability of the food system to continue to provide to meet these demands. A description of the feedback loops including variables, drivers, and the food security pillars they relate to, is outlined below (Table 5.3).

Table 5-3. Description of the feedback loops for the fisheries food system in El Nido Municipality illustrated in Figure 5.29

Loop Name		Variables involved	Key message	Food Security Focus	Reference
Reinforcing	R1	Births, Local population	Population Growth	Availability	CBMS, El Nido Local Government Unit, Philippines Statistics Authority
	R2	Immigration, Local population	Population Growth	Availability, Access	Community Participatory Workshops, El Nido Local Government Unit
	R3	Tourist population, Tourism Development, Attractiveness of the area to tourists	Tourism	Availability, Access	El Nido Tourist Office, Community Participatory Workshops, El Nido Local Government Unit, Bio-LEWIE Household Surveys, Field Observations
	R4	Coral reefs, Fish stocks	Fisheries productivity	Availability	Literature review, Expert elicitation, Community Participatory Workshops
	R5	Fish catch, Fishing effort	Fisheries productivity, Supply and demand for food	Availability, Access	Literature review, Expert elicitation, Community Participatory Workshops, Semi-structured interviews, Informal interviews
	R6	Demand for agricultural and fisheries products, Imports of agricultural and fisheries products, Supply of agricultural and fisheries products, Supply / Demand ratio for agricultural and fisheries products, Market prices of agricultural and fisheries products	Supply and demand for food	Access	Expert elicitation, Semi-structured interviews
	R7	Tourism development, Demand for land for development, Land reclamation, Cutting and logging of forests and mangroves, Mangrove forests, Land available for development	Tourism, Land availability, Habitat degradation, Fisheries productivity	Availability	Community Participatory Workshops, Expert elicitation, Informal interviews, Field observations, Literature review
	R8	Attractiveness to fish, Fishing effort, Fish catch	Fisheries sector retention, Fisheries productivity, Supply and demand for food	Availability, Access	Community Participatory Workshops, Informal interviews, Semi-structured interviews, Expert elicitation

	R9	Destructive fishing methods, Coral reefs, Fish stocks, Fish catch	Fisheries productivity, Supply and demand for food	Availability, Access	Community Participatory Workshops, Informal interviews, Literature review
	R10	Tourist population, Untreated raw sewage, Water quality, Disease outbreaks, Attractiveness of the area to tourists	Tourism, Habitat degradation	Availability	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations
	R11	Local population, Untreated raw sewage, Water quality, Disease outbreaks, Attractiveness of the area to tourists, Tourist population, Employment opportunities in the tourism sector, Labour availability for tourism sector, Labour / Job ratio, Immigration rate, Immigration	Population growth, Habitat degradation	Availability, Access	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations
	R12	Attractiveness to fish, Shifting to alternative livelihoods, Cutting and logging of forests and mangroves, Forest cover, Erosion and sedimentation, Seagrass meadows, Fish stocks, Fish catch	Fisheries productivity, Habitat degradation, Livelihoods	Availability, Access	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations
	R13	Attractiveness to fish, Shifting to alternative livelihoods, Cutting and logging of forests and mangroves, Mangrove forests, Fish stocks, Fish catch		Availability, Access	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations
Balancing	B1	Deaths, Local population	Population Growth	Availability	El Nido Local Government Unit, Philippines Statistics Authority
	B2	Emigration, Local population	Population Growth	Availability	El Nido Local Government Unit
	B3	Local population, Labour, Labour / Job Ratio, Immigration Rate, Immigration	Population Growth	Availability, Access	Community Participatory Workshops, Expert elicitation
	B4	Local population, Labour, Labour / Job Ratio, Emigration Rate, Emigration	Population Growth	Availability, Access	Community Participatory Workshops, Expert elicitation

B5	Tourism Development, Demand for land for development, Land available for development	Tourism, Land availability, Competition for land	Availability	Community Participatory Workshops, Informal interviews, Semi-structured interviews, Expert elicitation
B6	Land zoned for development, Land available for development	Land availability	Availability	Informal interviews, Literature review, Expert elicitation
B7	Tourist population, Tourist activities, Boat anchoring and trampling on corals, Marine tourist site damage, Attractiveness of the area to tourists	Tourism, Habitat degradation	Availability	Community Participatory Workshops, Semi-structured interviews, Expert elicitation, Field observations
B8	Demand for fisheries products, Supply / Demand ratio for fisheries products, Market prices of fisheries products	Supply and Demand for food	Access	Community Participatory Workshops, Semi-structured interviews, Expert elicitation, Field observations
B9	Fish stocks, Fish catch	Fisheries productivity, Supply and demand for food	Availability	Literature review, Expert elicitation, Community Participatory Workshops, Semi-structured interviews, Informal interviews
B10	Demand for fisheries products, Destructive fishing methods, Coral reefs, Fish stocks, Fish catch, Supply of fisheries products, Supply / demand ratio for fisheries products, Market price of fisheries products	Supply and demand for food, Habitat degradation, Fisheries productivity	Availability, Access	Literature review, Expert elicitation, Community Participatory Workshops, Semi-structured interviews, Informal interviews
B11	Tourist population, Untreated raw sewage, Water quality, Attractiveness of the area to tourists	Tourism, Habitat degradation	Availability	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations
B12	Local population, Untreated raw sewage, Water quality, Attractiveness of the area to tourists, Tourist population, Employment opportunities in the tourism sector, Labour availability for tourism sector, Labour / Job ratio, Immigration rate, Immigration	Population growth, Habitat degradation	Availability, Access	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations

B13	Tourism development, Demand for timber for construction, Cutting and logging of forests and mangroves, Forest cover, Erosion and sedimentation, Water quality, Attractiveness of the area to tourists, Tourist population	Tourism, Habitat degradation	Availability	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations
B14	Tourism development, Demand for sand and gravel for construction and roads, Quarrying in river beds and beaches, Erosion and sedimentation, Water quality, Attractiveness of the area to tourists, Tourist population	Tourism, Habitat degradation	Availability	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations
B15	Local population, Demand for local housing, Demand for non-timber resources for construction, Cutting and logging of forests and mangroves, Forest cover, Erosion and sedimentation, Water quality, Attractiveness of the area to tourists, Tourist population, Employment opportunities in the tourism sector, Labour availability for tourism sector, Labour / Job ratio, Immigration rate, Immigration	Population Growth, Habitat degradation	Availability, Access	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations
B16	Local population, Demand for charcoal for household use, Charcoal making (*uling*), Cutting and logging of forests and mangroves, Mangrove forests, Erosion and sedimentation, Water quality, Attractiveness of the area to tourists, Tourist population, Employment opportunities in the tourism sector, Labour availability for tourism sector,	Population growth, Habitat degradation	Availability, Access	Literature review, Expert elicitation, Community Participatory Workshops, Informal interviews, Field observations

	Labour / Job ratio, Immigration rate, Immigration	

5.4.1 The fisheries production system

Healthy marine environments are critical to sustaining fish stocks, however, factors such as overfishing (Hughes et al. 2007a; Burke et al. 2016), declining water quality (Hughes et al. 2007a) through agricultural runoff (Burke et al. 2016) and industrial and urban pollution (Kleypas and Eakin 2007), direct and indirect impacts of climate change (Hughes et al. 2007a; Hughes et al. 2007b; Hoegh-Guldberg et al. 2007), destructive fishing, storm damage, tourism (coral contact), coral mining, coral diseases (Kleypas and Eakin 2007), coastal development and shipping (Burke et al. 2016) are among many pressures impacting on the status of coral reefs worldwide. These pressures now make coral reefs among the most threatened ecosystems (Pratchett et al. 2014). Furthermore, the increasing demand for fisheries resources, is leading to overexploitation of fish stocks and the degradation of the marine habitats which support fisheries (Pauly et al. 2002; Berkes et al. 2006).

Coral reefs, mangroves and seagrass meadows play important roles as the habitats which sustain fish stocks[17] (Cruz-Trinidad et al. 2014), and in turn, fish populations play an important role in maintaining the health of coral reefs (Figure 5.20 and Figure 5.21). Corals create three-dimensional habitats for fishes and other organisms and their contribution to reef growth as either primary or secondary framework builders (Bellwood et al. 2004). The loss of macro-fauna, reduced fish stocks, a shift from fish-dominated to echinoid-dominated herbivory, destructive overgrazing and bioerosion by food-limited sea urchins and reduced coral recruitment (Bellwood et al. 2004) all impact on a reef's health and its ability to sustain fish populations (Adams et al. 2006).

Similarly, different groupings of fish – bioeroders, scrapers and grazers - play different and complementary roles in preconditioning reefs to permit recovery of corals (Mumby et al. 2004; Bellwood et al. 2004). Bioeroding fishes remove dead corals, exposing the hard, reef matrix for settlement of coralline algae and corals (Bellwood et al. 2004). Scrapers directly remove algae and sediment by close cropping, facilitating settlement, growth and

[17] In the diagrammatic illustrations in this study, fish stocks include fish, crustaceans, shellfish, molluscs and echinoderms.

survival of coralline algae and corals whilst grazers remove seaweed, reducing coral overgrowth and shading by macro-algae (Bellwood et al. 2004; Mumby et al. 2004). Mumby et al. (2004) also notes the importance of fish stock to reefs, arguing that reductions in herbivory may reduce the resilience of coral reefs to algal overgrowth.

This relationship is illustrated in Figure 5.20 whereby the arrow from *coral reefs* to *fish stocks* demonstrates the importance of coral reefs as fisheries habitats (Robertson and Duke 1987; Mumby and Hastings 2008; Mumby et al. 2004; Pratchett et al. 2014), whilst the arrow from *fish stocks* to *coral reefs* illustrates the role fish play in maintaining coral reef health, thus creating a positive reinforcing loop (R4). Similarly, the effect is reversed if fish stocks decline then the health of the reef may also decline as fish populations contribute towards the maintenance of healthy reefs. If the reef health declines, then so too do fish stocks as it is no longer capable of supporting fish (Mumby et al. 2004).

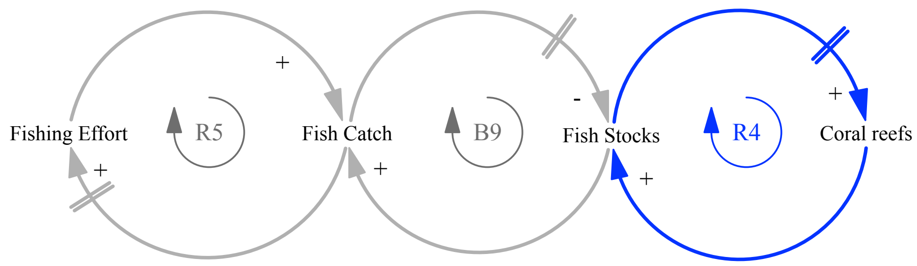

Figure 5-20. Causal loops illustrating the relationship between coral reefs and fish stock

Mangroves and seagrass meadows also play a critical role in providing important habitats for fish populations (Figure 5.21) both as nurseries, as an influence on the community structure of fish in other adjacent habitats such as coral reefs (Mumby et al. 2004; Jelbart et al. 2007; Wolf 2012), as filtration systems of pollutants (Tallis and Polasky 2009; Wolf 2012), and as habitats for crustaceans and shellfish (Robertson and Duke 1987). Many coral reef fish utilise mangroves as nurseries during their juvenile phase as they provide refuge from predators and / or plentiful food (Mumby et al. 2004) and then migrate seaward to their adult reef habitat (Mumby et al. 2004; Mumby & Hastings 2008;). In experiments conducted on the largest herbivorous fish in the Atlantic, the rainbow parrotfish, Mumby and Hastings (2008) found there was a functional dependence on mangroves with the parrotfish distribution confined to shallow reefs neighbouring mangroves. Furthermore, they found biomass of the common grazing species found in the region was enriched significantly when reefs were connected to mangroves, with a 42 percent increase over non-mangrove systems (Mumby and Hastings 2008). In the Philippines for example, it has been estimated that fisheries associated with mangrove forests, contribute approximately 0.67 tonnes of fish per hectare of mangrove forest per year to the total fisheries catch (PCSDS 2015).

Seagrass meadows also provide a critical role in marine ecosystems with it estimated that seagrass meadows provide an estimated $1.9 trillion per year in the form of nutrient cycling, enhancement of coral reef fish productivity, habitat for thousands of fish, bird and invertebrate species, and a major food source for marine animals (Waycott et al. 2009). In many coastal areas including El Nido, seagrass meadows provide the habitat for sea cucumbers since the larvae and juveniles rely heavily on seagrass for their settling cues and early life stages (Wolkenhauer et al. 2010). There is also a reciprocal relationship as sea cucumbers provide a positive effect on seagrass and algae through direct release and recycling of nutrients as they feed on bacteria, microalgae and organic detritus attached to sediment grains, thus increasing the nutrient levels in the water column (Wolkenhauer et al. 2010).

Lastly, studies have also demonstrated the connectivity amongst estuarine habitats such as mangroves and seagrass beds. Coral reef fish in tropical waters can move between different marine habitats in close proximity, including mangroves and seagrasses. At low tide when fish cannot occupy mangroves, they might utilise adjacent habitats, including seagrass meadows (Sheaves 2005). These shallow seagrass meadows provide important habitat for juvenile fish and small, cryptic adult fish (Jelbart et al. 2007). Jelbart et al’s (2007) study in the Caribbean finding that the species richness of juvenile coral fish was greater in seagrass meadows adjacent to mangrove forests than in seagrass meadows in bays without mangroves. It was found that juveniles of some species of coral reef fish shelter in the mangroves during the day and forage in the seagrass at night.

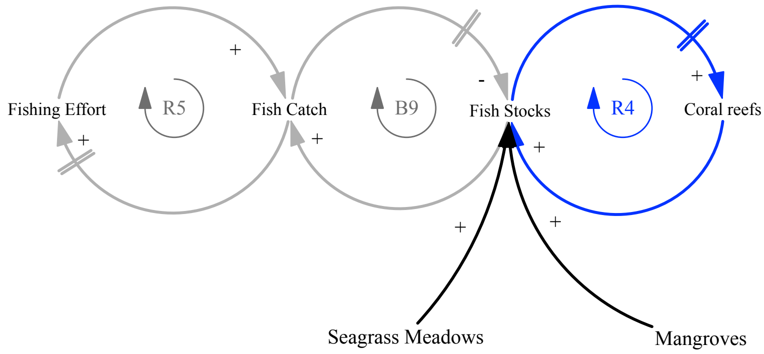

Figure 5-21. Causal loops illustrating the relationship between mangroves and seagrass meadows to fish stocks

In the 2006 ECAN Zones Management Plan for El Nido Municipality plan, it is estimated mangroves accounted for approximately 2 645 hectares in El Nido (PCI 2006). Under the Comprehensive Land Use Plan (CLUP) mangroves are considered as part of 'forestland' and as such, zoning for mangroves is included in the 29 352 hectares zoned as forest zones in the CLUP (PCSDS 2003). Anecdotal evidence from the community participatory workshops, informal interviews and field observations illustrate the mangrove forests are being slowly degraded due to land reclamation for tourist developments and for charcoal for household use. Given the relationship between mangroves and fish, if these habitats remain intact and healthy the *fish stocks*, over time, will increase, therefore leading to a potential increase in the *fish catch* which increases the supply of fisheries products. However, if fish catch increases, following delays in the system, this leads to a decline in fish stocks unless the fisheries are properly managed, thus creating a balancing loop (B7) (Figure 5.22).

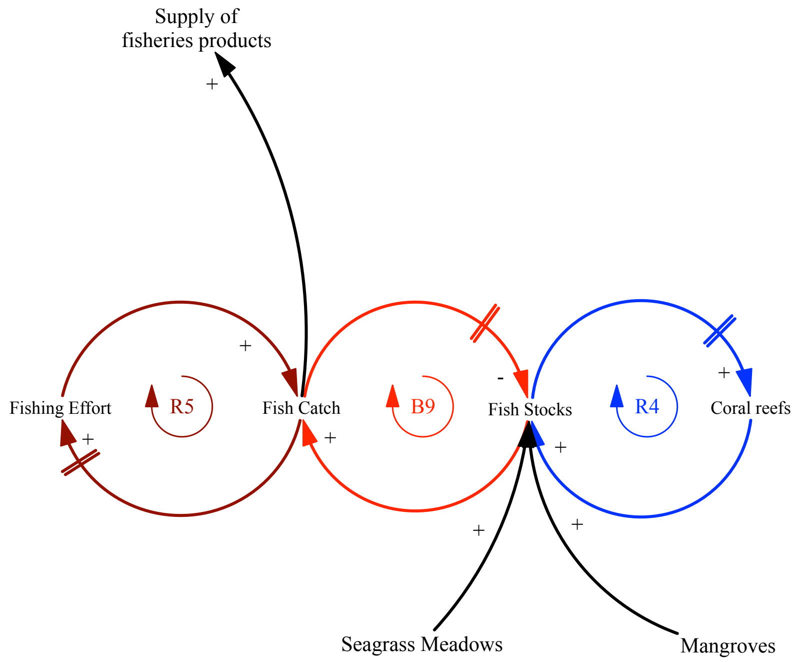

Figure 5-22. Causal loops illustrating the relationship between fish stocks and fish catch, and the impact on supply of fisheries products in the market

As *fish catch* increases, this leads to an increase in the number of fishers in the Municipality or *fishing effort*[18], and over the short term, an increase in fishing effort will result in an increase in the *fish catch* (reinforcing loop (R5)) (Figure 5.23). In El Nido, despite the decline in fish stocks and a shifting away from fishing to tourism activities, there still remains a large number of local fishers. Interviews with local government officials and community members has indicated the increase in fishers is related to the influx of migrants, many of whom are traditional fishers from areas within the Philippines such as other parts of Palawan, Masbate, and provinces such as Bacolod, Bataan, Cebu, Iloilo, Quezon, and Samar (Uy et al. 2016). However, over time, this increase in the number of fishers and therefore fishing effort, leads to a decline in fish catch as *fish stocks* decline through overfishing, destructive fishing methods, and poor fisheries management. If fish catch continues to decline, fishing effort may be reduced as people depart the fishery to take up employment or livelihood opportunities elsewhere (refer Section 5.4.3).

[18] Fishing effort refers to the number of artisanal fishers or households i.e. those fishing within the 15km municipal boundary. It does not refer to commercial fishers who are restricted to fishing outside the 15km boundary.

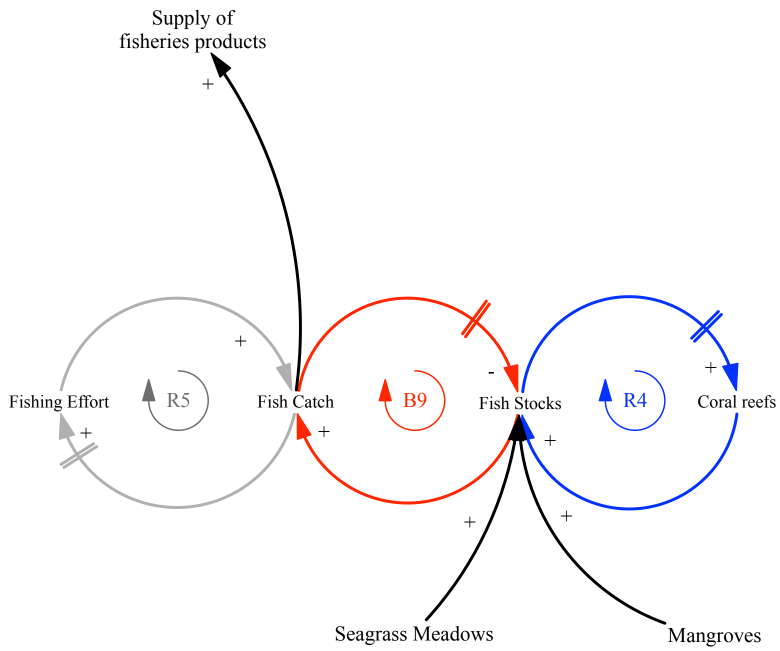

Figure 5-23. Causal loops illustrating the relationship between fish catch and fishing effort

5.4.2 Supply and demand for fisheries products

As highlighted previously, fish catch in El Nido has declined by approximately 40 percent in the seven years from 2007 to 2014 (El Nido Municipal Office 2014; Pontillas et al. 2015). Given this significant decline in fish catch and evidence collected through the community participatory workshops, field observations and informal and semi-structured interviews, many in the Municipality agree fish catch will continue to decline due to low fish stocks. To fill the shortfall between demand and supply, most fisheries products are now imported (Table 4.3) from major fisheries centres such as TayTay to the south of El Nido and as discussed with a barangay council member, this is believed to be the 'business as usual' case into the future.

Supply and demand for fisheries products in El Nido is driven by the local and tourist population, and as these sectors continue to grow, *demand for fisheries products* continues to rise (Figure 5.24). Increasing *demand for fisheries products* leads to a change in the *supply / demand ratio for fisheries products*. As demand increases, this leads to an imbalance in the supply / demand ratio, as the demand outstrips supply. As the supply falls and demand continues to increase, the *price of locally produced fisheries products* will also increase. However, as prices continue to increase beyond the means of the local population to procure the food, the local *demand for fisheries products* by the local population will then decline (balancing loop B8). In El Nido prices are also driven by the tourism sector, as the prices at restaurants are geared towards the ability of the tourist to pay. Anecdotal evidence captured during informal interviews and field observations show the price locals pay for fish is increasing in line with the tourism market. As with agricultural produce, the supply of produce to the market is also controlled by middlemen. By reducing the supply into the market, they can control the price to the consumer i.e. low supply and high demand can lead to higher prices in the marketplace. The middlemen also control the price paid for fish direct to the fisher, thus limiting the amount of income earnt by the fisher.

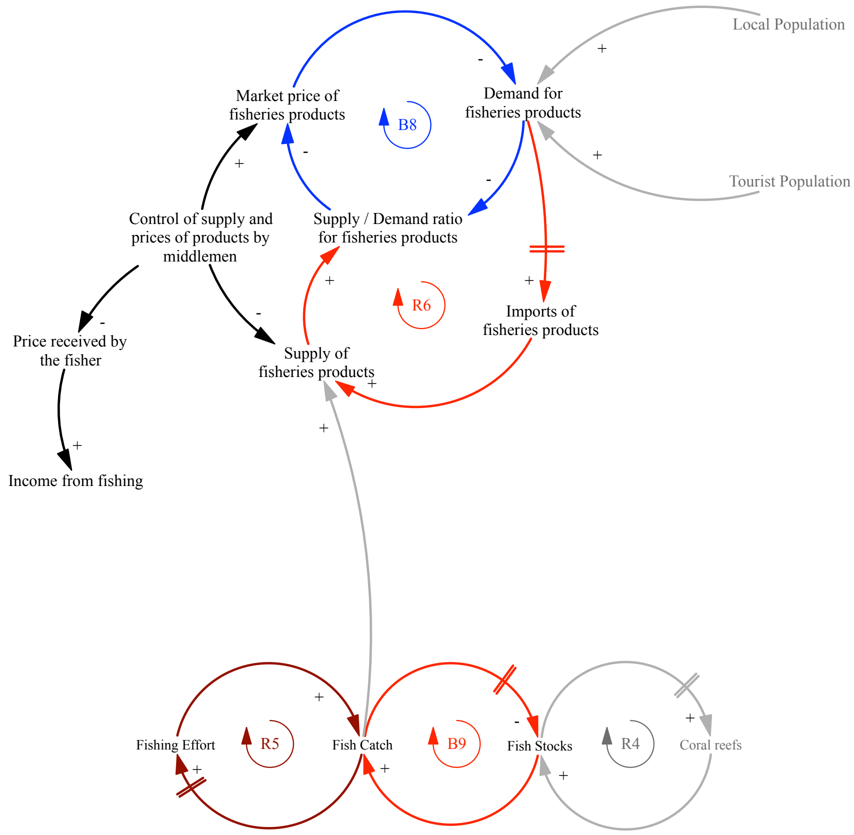

Figure 5-24. Causal loops illustrating the relationship between supply and demand variables for fisheries products

If the supply of fisheries products cannot be met by the local catch, demand is then supplemented by cheaper imports from outside of the Municipality – therefore the volume of *imports of fisheries products* increases. Field observations in May 2017 of the Corong-corong market (the main market in the Municipality) demonstrates approximately all of the catch except for some local squid, was imported from areas outside of El Nido (Table 4.3). An increase in the volume of *imported fisheries products* improves the *supply of fisheries products* and the availability of them to the local communities. If supply increases this will lead to an increase in the *supply / demand ratio for fisheries products* as supply either meets the demand or exceeds the demand. If supply exceeds demand, the *price of the fisheries products* will tend to decrease, and this will in turn increase the *demand* for the products as they become more attractive and affordable for purchase (reinforcing loop (R6).

5.4.2.1 The relationship between supply and demand, fishing effort and destructive fishing

There is a relationship between the demand and supply for fish in the Municipality and the amount of fishing effort and the types of fishing methods (Figure 5.25). If the fishery is attractive enough to remain in or to enter, i.e. fish catch is high and price for the product is high therefore fishing is profitable or at least generates an appropriate income, then the *fishing effort* or number of fishers entering the sector will increase. As the *fishing effort* increases, this will lead to an increase in *fish catch*, which in turn, increases the *attractiveness of fishing* as the fishers catch more fish and increase their income. This relationship creates a positive reinforcing feedback loop (R8).

However, the amount of fishing effort can also have detrimental effects on fish catch. As *fishing effort* increases (both through legal and illegal mechanisms), this leads to overfishing, leading to a decline in *fish stocks* and subsequently, *fish catch*. The decline in fish stocks is further exacerbated through *destructive fishing methods* such as cyanide, dynamite fishing and compression fishing impacting on the carrying capacity of the *coral reef* (reinforcing loop R9) (Figure 5.25). Furthermore, destructive fishing methods are further exacerbated by increases in demand for fisheries products from both the local and tourist populations. As the *demand* increases, some fishers turn to *destructive fishing methods* to increase fish catch which in turn destroys the *coral reefs*, leading to a decline in *fish stocks* and *fish catch*, which ultimately leads to a decline in the *supply of the fisheries products* to market and increases the price of the product, generating a balancing feedback loop (B10).

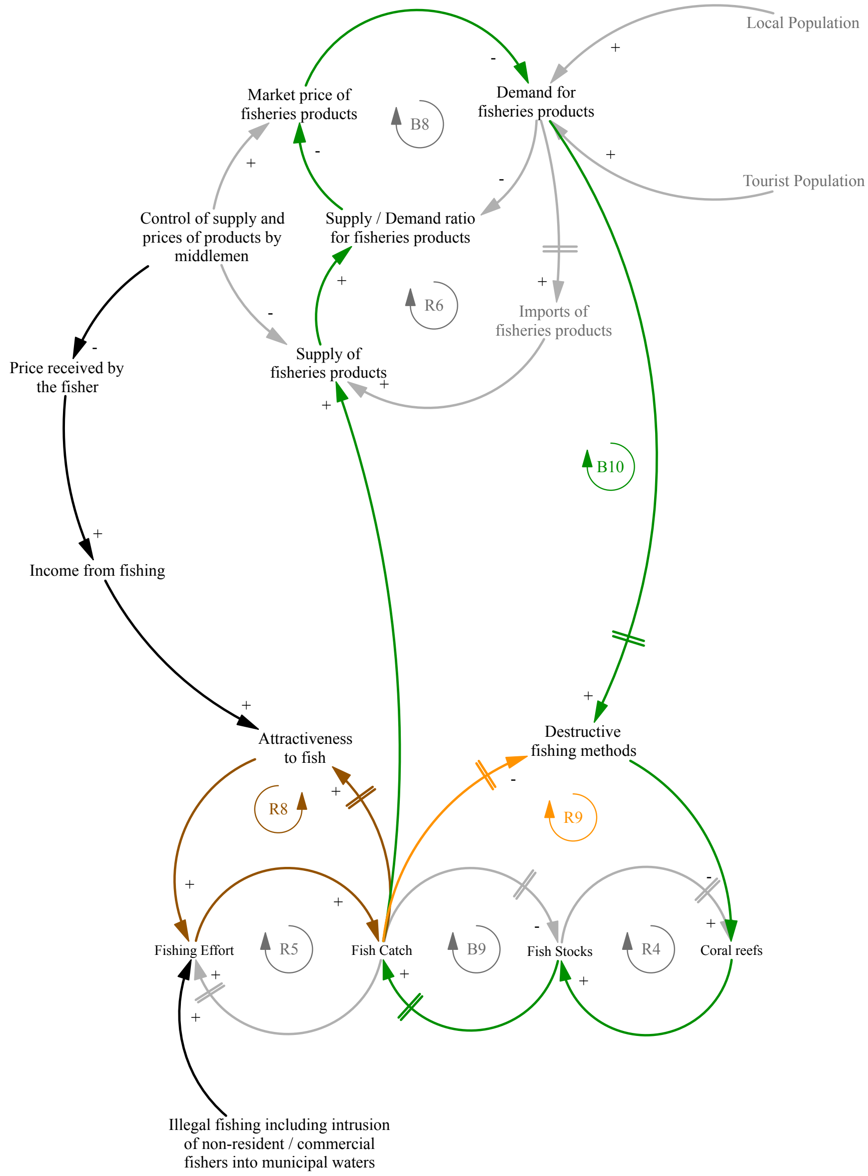

Figure 5-25. Relationship between demand for fisheries and destructive fishing practices

5.4.3 Retention of fisheries livelihoods

As the local stock of fish has been previously overexploited and the habitats supporting them come under pressure (Section 5.4.4), leading to low fish catch and low incomes, there is a shift from fishing to other employment opportunities such as in the tourism sector. Much of the attractiveness of fishing is linked to income generation. A survey from Muallil et al. (2014b) across 20 fishing municipalities in the Philippines (including El Nido) noted that only three percent of the respondents considered fishing as financially rewarding whilst 53 percent said that the catch was barely enough to provide for the daily needs of their households. The rest of the respondents reported that income from fishing is no longer enough even for the daily needs of their households, and supplemental income from other sources was needed.

In El Nido, generating income from fishing is hampered not only by the degradation of the marine system supporting fish stocks, but also by the fishing gear e.g. the size of fishing boats which are only able to fit one or two people and the limited catch the boats can carry which is less than 100 kilos (Uy et al. 2016). For fishers in the Municipality the most common mode of compensation is the "*partehan*", a system by which the fishers on the boat divide the catch amongst themselves, with owner of the boat getting two parts of the catch whilst the other fishermen divide the remaining share (Uy et al. 2016). However, the expenses for the fishing trip must also be deducted from the catch income and on a regular trip, expenses range from P150 to P1 235 for the fuel, the bait to be used for fishing, ice blocks (if they will spend several days at sea), and their food for more than one day stay in the sea (Uy et al. 2016). It is therefore foreseeable that at times, losses are incurred if the fish catch is not enough to meet expenses and provide a suitable income. About one-third of the fishermen earn less than P4 000 per week, about one-fifth earn more than P4 000 per week, while almost half cannot determine how much they earn (Uy et al. 2016).

If the price fishers receive for their catch is high then the *attractiveness to fish* will remain high, however, if the price is low, income remains low and the willingness to remain in the fishery declines. During the community participatory workshops and informal interviews with community members, it was indicated there was distinct shift from the traditional fishing as an occupation to more tourist-oriented employment such as boat tours as the *attractiveness of fishing* declines (Figure 5.26).

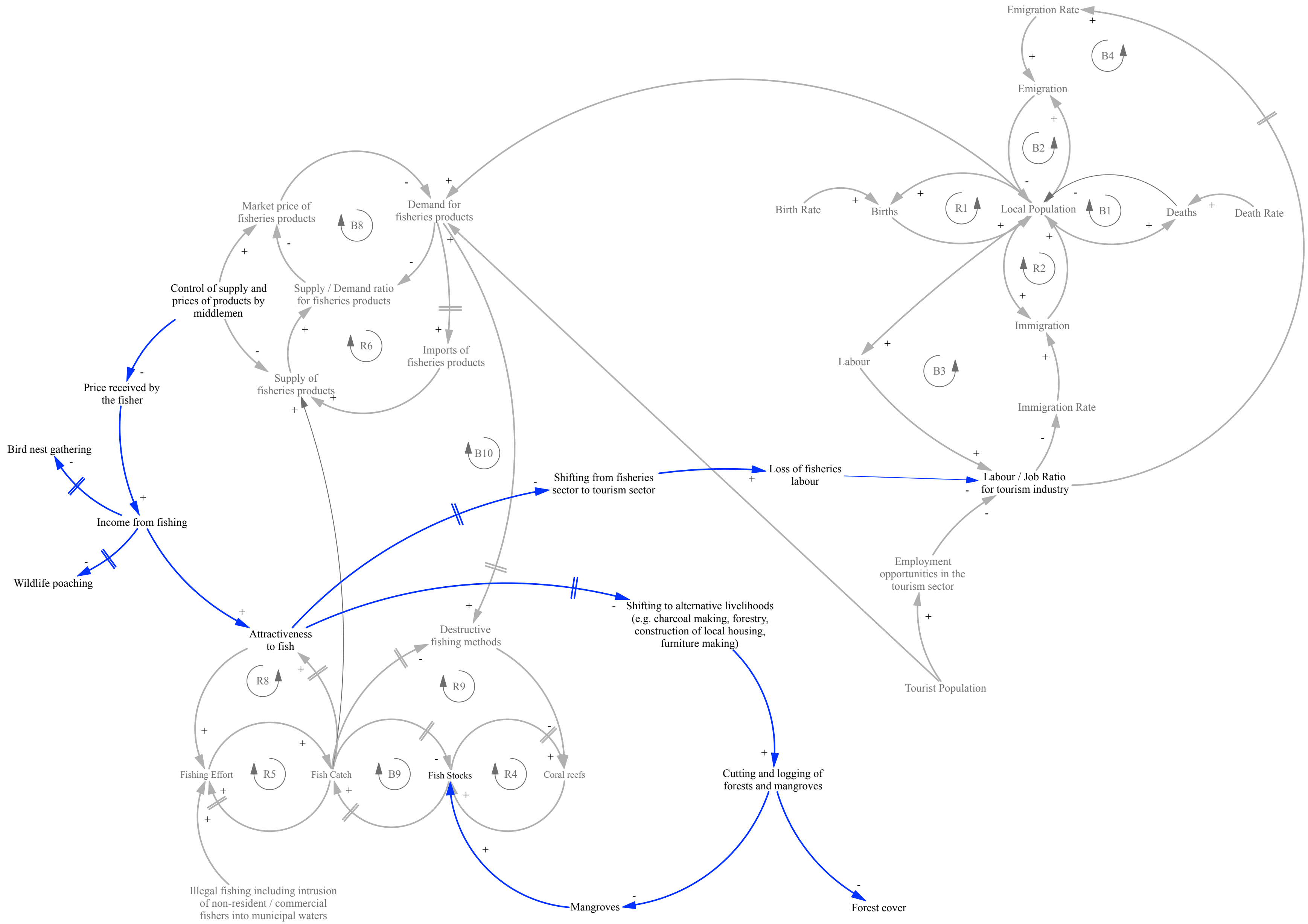

Figure 5-26. Causal loops demonstrating the shifting from fisheries to tourism related jobs or into alternative livelihoods

5.4.4 Habitat degradation affecting the fisheries food system

Whilst the attractiveness of the El Nido area is driving the influx of tourists with many coming to experience the "natural environment of limestone cliffs, clear water and coral reefs" (PCSD 2006), the sudden rise in the tourism industry and the local population is directly and indirectly impacting on the area's water quality leading to the degradation of the marine ecosystem. Water quality plays an important role in both coral reef health and human health. Poor water quality impacts on coral reef health as excess nutrients and turbidity continue to be significant stressors and over time, the reef system collapses (Fabricius 2005), thus negating not only the habitat for fisheries, but also one of the attractions of the area, whilst the discharge of sewage constitutes a significant pollution source in all coastal waters due to the detrimental effects on exposed organisms and the altering of key structural and functional attributes of ecosystems that are affected by wastewater loads (Reopanichkul et al. 2009).

In El Nido, the surface waters are contaminated by human activities in two ways: (i) through point or diffuse sources such as sewage treatment discharge and storm-water runoff (Sliva and Williams 2001) whereby the resulting degradation of inland and coastal waters impairs water supplies, causes oxygen depletion and fish kills, increases blooms of cyanobacteria and contributes to waterborne disease (Foley et al 2005), and; (ii) by non-point sources such as urban stormwater and agricultural areas (Sliva and Williams 2001), caused by the degradation of the terrestrial ecosystem. Both the point and non-point sources of contamination are impacting on the marine ecosystem (of El Nido) underpinning the fisheries food system and leading to added pressure on its ability to sustain productivity.

5.4.4.1 Point source contamination impacts on water quality and the fisheries system

Water pollution has arisen as a disturbing phenomenon in the more congested sections of the Municipality with recent water analyses revealing high coliform levels exceeding (3 000 percent of) allowable limits set by the Philippine Clean Water Act of 2004 (Regoniel et al. 2015). The high coliform level renders beaches unsuitable to swimmers. Domestic sewage also enters into the groundwater and contaminates it, thus causing various waterborne illnesses such as loose bowel movement, sepsis, and cholera (Regoniel et al. 2015). The degrading water quality is leading to water pollution problems particularly for those residents and tourism sectors located in the urban environments.

Additional pressure from the continued growth of the area is being placed the waste management system in El Nido. Field observations, informal interviews and anecdotes from the community participatory workshops continued to highlight a number of issues including: a lack of planning for waste management by the Local Government Unit; a lack of clean drinking water; untreated sewage in the streets and flowing directly from urban areas into the Bacuit Bay and other local receiving waters particularly during periods of heavy rainfall; many establishments do not have proper sewage systems installed, and; enforcement of regulations is problematic. The lack of an effective waste management system due to cross-jurisdictional issues e.g. the local government is responsible for domestic waste whilst the national government through the Department of Environment and Natural Resources is responsible for commercial waste (Smith et al. 2014), is also exacerbating the problem.

The wastewater management system in El Nido is pump-out septic tanks and there is only one sewage desludging plant which is privately owned and operated (Smith et al. 2014). Despite the local government negotiating a loan with the Development Bank of the Philippines for PhP 259 million in 2014 for a wastewater treatment facility with pipelines (Regoniel et al. 2015) to service the Poblacion (main town area), this is still under construction in early 2018 and has already hit some challenges including: (i) the pumping station was being constructed on non-government land without permission of the land owner; (ii) the pumping station was constructed on the harbour at sea level, causing seawater inundation and potential problems in the future. As such the project on this aspect of construction has now been abandoned; (iii) it is unclear how the pipeline will link in all of the houses and businesses in the Poblacion area to capture the waste (this is particularly challenging given the different waste systems in place), and; (iv) the treatment facility and pipeline only covers a very small portion of the urban area, leaving many households without access into the system.

Untreated sewage not only impacts on the water quality and on the fisheries habitat, but it also impacts on the future livelihoods of the local population, and therefore their ability to earn income to procure food through fisheries (Figure 5.27). As both the *tourist and local populations* grow, the level of *raw sewage discharge* into the system increases, exacerbated by the inadequacies of the waste management system and degrades *water quality* and leads to increases in the *incidence of disease outbreaks* (i.e. Hepatitis A) and coliform (Balita 2014; Inquirer 2014). Declining water quality will lead to a loss in the attractiveness of the area leading to (i) a decline in tourist numbers, and (ii) as tourist numbers decline, the tourism employment opportunities decline. Over time, both of these variables will lead to a decline in the *attractiveness of the area* to tourists as poor water quality impacts on the tourist value (i.e. capacity to swim at the tourist sites), increased incidences of disease, and on coral reef health thereby reducing fish stocks (balancing loop B11 and reinforcing loop R10). If the tourist population declines, after delays in the system, this will lead to a decline in employment and people will emigrate out of the area to seek other opportunities if the tourism industry opportunities do not improve, or if other employment opportunities do not emerge to compensate for the loss of the tourism industry (balancing loop B12 and reinforcing loop R11).

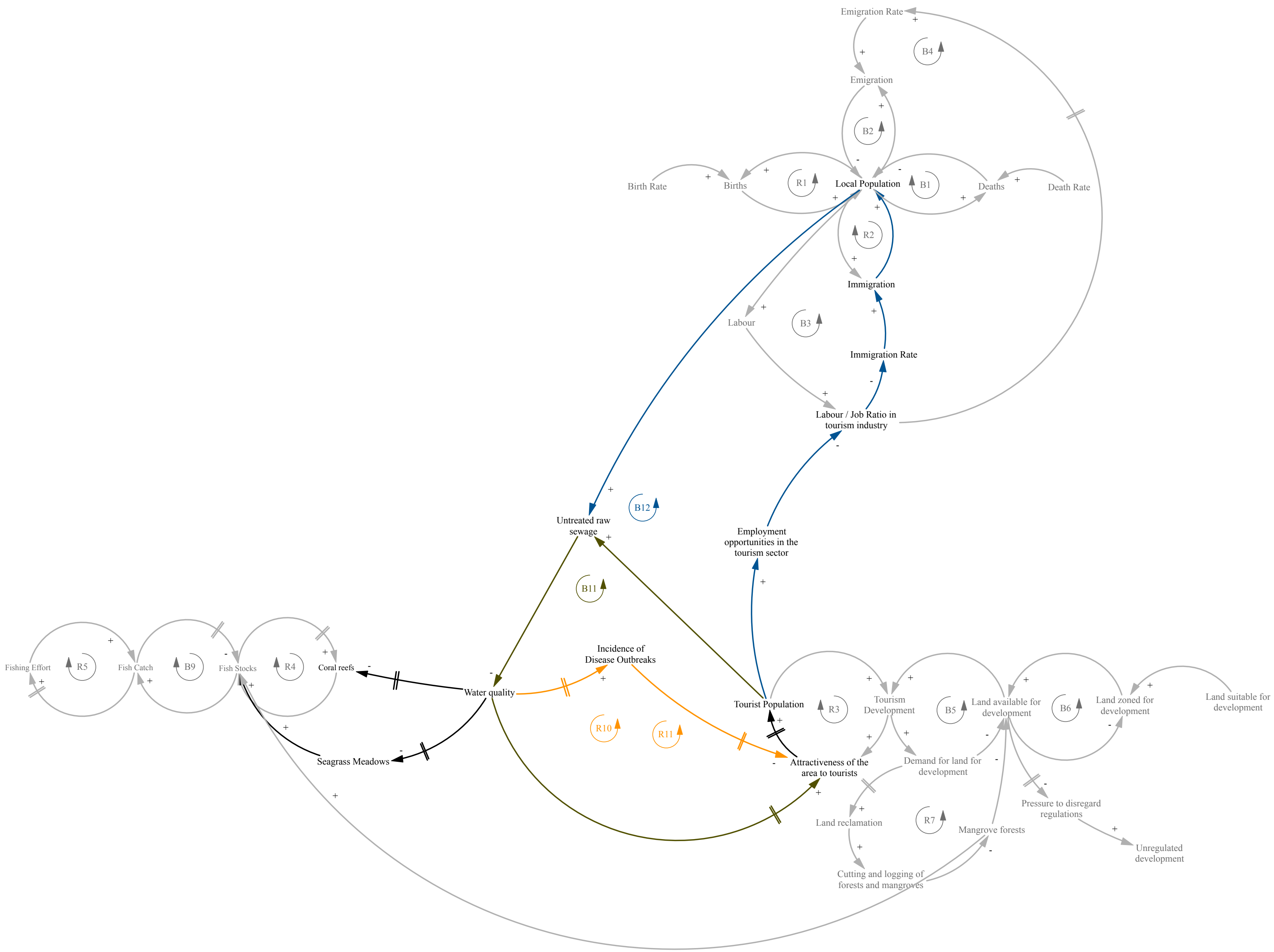

Figure 5-27. Causal loops illustrating the problem of sewage entering the waterways

5.4.4.2 Non-point source contamination impacts on water quality and the fisheries system

There is now abundant evidence that many human-dominated ecosystems including the biophysical systems at all levels, have become highly stressed and dysfunctional (Rapport et al.1998; Foley et al. 2005). The services provided by terrestrial and marine ecosystems are extremely important to human welfare (Rapport et al. 1998; Brown et al. 2007; Beaumont et al. 2007; Costanza et al. 2014), with humans depending on the integrity of the natural systems to provide the goods and services they need for survival (Jewitt 2002). However, many ecosystems are now becoming highly degraded and incapable of supplying services to the same levels as in the past (Rapport et al. 1998; Cumming et al. 2014; Pratchett et al. 2014; Turner et al. 2016). This is becoming increasingly evident in El Nido with non-point sources of contaminants such as runoff from urban and agricultural areas (Sliva and Williams 2001), caused by the degradation of the terrestrial ecosystem well documented through the community participatory workshops, expert elicitation, informal interviews, semi-structured interviews and evidenced through field observations.

Land-use practices such as forest and mangrove clearing for timber and fuel-wood collection is degrading forest ecosystem conditions in terms of productivity, biomass, stand structure, and species composition (Foley et al. 2005). Forests (including mangroves) are considered to be the highest profile victim of changing food consumption patterns (Moomaw et al. 2012), and this trend is illustrated in the El Nido Municipality. As highlighted during the community participatory workshops, forests are being degraded from four drivers of land use change: agricultural practices; tourism development; local population resource demands, and; shifting from farming and fishing into alternative livelihoods. Land use can disrupt the surface water balance with surface runoff and river discharge generally increasing when natural vegetation is cleared (Sliva and Williams 2001; Tong and Chen 2002; Foley et al. 2005). This leads to increased rates of soil erosion, raising the levels of sediments entering the watersheds. The flow-on effects of this result in three outcomes seen in El Nido: (i) declining water quality impacts on adjacent coral reefs, leading to reef health decline and an inability to support fish stocks; (ii) increased sediments flow from the waterways into the marine environment, smothering coral reefs and seagrass meadows, and; (iii) over time, as water quality deteriorates this will lead to a decline in the attractiveness of the area for tourists (Figure 5.28). This section provides an outline of the interactions and impacts between the demands from the socio-drivers and the ecosystems underpinning the food system.

a) Agricultural practices

As outlined in Section 5.3.2.1, the demand for agricultural land and land ownership is driving an increase in land clearing through *kaingin* (slash and burning of forested areas for rice growing) and from the illegal occupancy from migrants of timberlands which are cleared and planted with cash crops. As the forests are cleared this leads to an increase in soil erosion, which in turn increases the amount of sediments entering the waterways, impacting on water quality and the marine ecosystem. The revised CLD incorporating these relationships is shown in Figure 5.28.

b) Tourism development

The expansion of the tourism sector is leading to a rapid supply of tourism developments such as resorts, hotels, and restaurants particularly in the urban and nearby coastal barangays, which is driving the demands for timber and sand and gravel. The increasing demands for timber for the construction of the tourist infrastructure is causing a rise in illegal logging[19] in the Municipality's forests as developers and other users of the timber are seeking cheap construction materials with minimal transportation costs. As the *cutting and logging of the forests* increases to meet demand, the amount of *forest cover* declines.

Forests supply a range of ecosystem services including stabilising landscapes, protecting soils and helping them to retain their moisture and to store and cycle nutrients (Myers 1997). Furthermore, forests provide a watershed function through the regulation of water flows in terms of both quantity and quality (Myers 1997). Soil *erosion and sedimentation* in the waterways increase due to the disturbances in forest cover leading to a decline in water quality (balancing loop (B13)) from a range of catchment disturbances including nutrient concentrations from diffuse or point sources, changes to the quantity and composition of organic carbon inputs, alterations to the light regime and sedimentation (Bunn et al. 1999). The impacts of sediments into waterways and the marine ecosystem are wide-ranging and include: decreasing water clarity thereby blocking light that allows algae (an important food source) to photosynthesise; harming fish gills; smothering important habitats (reinforcing loop (R12)), and; decreasing the ability of fish from seeing well enough to move around or feed (NIWA 2018).

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[19] The matter of illegal logging is highly contentious in El Nido with incidents between the loggers and the barangays protecting their resources. For example, as recently as December 2017, the barangay captain in Villa Libertad was killed whilst attempting to arrest illegal loggers in his barangay.

The impacts of sediment loading into the waterways and on water quality are also contributed to by the practice of quarrying in the waterways and beaches of El Nido to meet the demands from the tourism development sector for sand and gravel used in construction and road development. Balancing loop (B14) illustrates the cause and effect from increased tourism (and therefore development) driving the extraction of raw materials such as sand and gravel in the Municipality. The extraction of these materials affects water quality through increased levels of sedimentation and chemical residue, which over time, affects the attractiveness of the site to tourists as the habitat declines, and agricultural food production as the water becomes too contaminated for agricultural use. For example, in the CPW discussions in Aberawan barangay, the barangay chief noted he had refused access to construction companies to quarry for sand and gravel due to the chemical residue and sedimentation from the practice impacting on the barangay's waterways and therefore their ability to use the water for their crops, an important source of livelihoods and food for many farmers in the barangay.

c) Population demands for natural resources

Population growth within the Municipality brings with it demands for housing and fuel for household use such as cooking. The *demand for housing* is driving the supply of *non-timber resources* such as bamboo, buho, nipa, yantok, and rattan which are used in their construction and for furniture. These resources are found in the forested areas of the barangays and as the demand rises, this is leading to a rise in the *cutting and logging of forests and mangroves* for these resources. As *forest* cover declines the incidence of *soil erosion and sedimentation* flowing into the watershed and impacting on *water quality* (balancing loop (B15)) increases with the same results as those outlined above for tourism development.

In addition to the demand for resources for housing construction, the rise in the number of households, many of whom remain without a stable supply of electricity, is driving a rise in the *demand for charcoal* to be used as fuel for cooking. During informal discussions with community members, it was noted that culturally, there is a preference for mangrove charcoal due to the perceived flavour for cooking and it is inexpensive to purchase. Kathiresan (2012) notes that one tonne of mangrove firewood is equivalent to five tonnes of Indian coal, and it burns producing high heat without generating smoke.

Despite mangroves being protected under the 1981 Presidential Proclamation No. 2152[20] (PCSDS 2015), the CPWs highlighted the practice of *uling* or charcoal making has increased, leading to a rise in the *cutting of mangroves*, leading to a rapid decline in the amount of mangrove forest in the Municipality (balancing loop (B16)). The rate of mangrove destruction can be seen in the barangay of New Ibajay, whereby a field visit revealed a number of illegal kilns in the mangrove forests. It was estimated that one of the kilns visited produced 14 sacks of charcoal per week. To provide for this, 400m^2 of mangroves are cleared to fill the kiln once. The authorities have found 28 illegal kilns within the 394-hectare patch of mangroves, all of which can produce up to 42 sacks each per week (Smith et al. 2014).

Mangroves provide many services including as habitats and nurseries for fish, acting as natural buffers between the land and sea and protect against storm surges, counteracting erosion from wave surges, and act as sediment traps in neutralising sediment runoff from both natural and human activities (Wolf 2012). As the mangroves are cleared, this adds to the increasing *erosion and sedimentation* entering the marine ecosystem, as the mangroves are no longer able to act as sediment traps. It is recognised in literature that dense vegetation cover reduces water flow velocities, turbulent flows and shear stress over the seabed, promoting sediment deposition, which can create accretion (Spalding et al. 2014). In this process, the mangrove root structures inhibit tidal flows and as the soil particles are carried in suspension into mangrove forests from seawater by the flood tide, these soil particles are left behind in the adjacent habitats and within the mangrove root system by the ebb tide (Ewel et al. 1998; Van Santen et al. 2007; Kathiresan 2012; Yip Lee et al. 2014). In this manner, the mangrove root systems keep the substrate firm (Kathiresan 2012) as the roots themselves can present a physical barrier between the water and soil, particularly in places where root systems extend below low tide levels (Spalding et al. 2014), and in doing so, contribute to a lasting stability of the coast (Kathiresan 2012).

Furthermore, the destruction of the mangrove areas leads to declines in fish stocks as highlighted in Section 5.4.1. Many coral reef fish utilise mangroves as nurseries during their juvenile phase and then migrate seaward to their adult reef habitat (Mumby et al. 2004; Mumby and Hastings 2008), and so this has a two-fold effect. Firstly, it is destroying

[20] The Proclamation declared the entire province of Palawan a Mangrove Swamp Forest Reserve. This prohibited the entry, sale, settlement or other forms of use of all mangrove areas subject to existing private rights.

the nursery habitat for fish and crustaceans and secondly, it is causing increased sedimentation to enter the marine environment and stifle the growth of seagrass meadows which also serve as a habitat and nursery habitat for fisheries. As the habitats which support the fisheries decline, the volume of fish stock may also decline, leading to declining fish catch which drives the attraction to fishing (reinforcing loop (R13)).

d) Shifting to alternative livelihoods and the impacts on ecosystems

As fishing or agricultural activity becomes less attractive, people are shifting away from these sectors into the alternative livelihood activities including forestry industries i.e. logging of timber for tourism developments and cutting non-timber resources for household construction, and *uling* or charcoal making. This shift towards livelihoods bounded by natural resources, compounds the problem of habitat degradation. As with the impacts from demands from both the tourism sector and the growing local population, the shift from farming and fishing into these alternative livelihoods, exacerbates the problem of increased erosion and sedimentation, leading to a decline in the water quality.

Summary

Ultimately these activities impact upon the system in two-ways: (i) impinge on coral reefs and hamper their ability to support fisheries, and; (ii) reduce the attractiveness of the area for tourists. Coral reefs, like other marine coastal ecosystems, are increasingly exposed to nutrients, sediments and pollutants discharged from nearby catchments (Fabricius 2005), with field studies showing that sedimentation, nutrient enrichment and turbidity can degrade coral reefs at local scales. As nutrient concentrations in the receiving waters increase, coral reef communities change from dominance of nutrient-recycling symbiotic organisms such as corals, to increasing proportions of macroalgae, and further to heterotrophic filter feeders (in nutrient-enriched areas of upwelling or lagoons) (Fabricius 2005). As poor water quality and sedimentation impacts on the health of the *coral reefs* the reduction in healthy habitat for fish will lead to a decline in the fish populations that these habitats can support.

Secondly, the reduction in water quality reduces the *attractiveness of the area to tourists* as the area becomes problematic for health reasons, and following delays, will lead to a decline in *tourist numbers* and therefore *development*. As the number of tourists decline, this will lead to a reduction in the number of *jobs*, and ultimately, as the number of job opportunities decline, this will lead to a rise in emigration as people seek opportunities elsewhere, and a decline in immigration as the area is no longer attractive for job or livelihood opportunities.

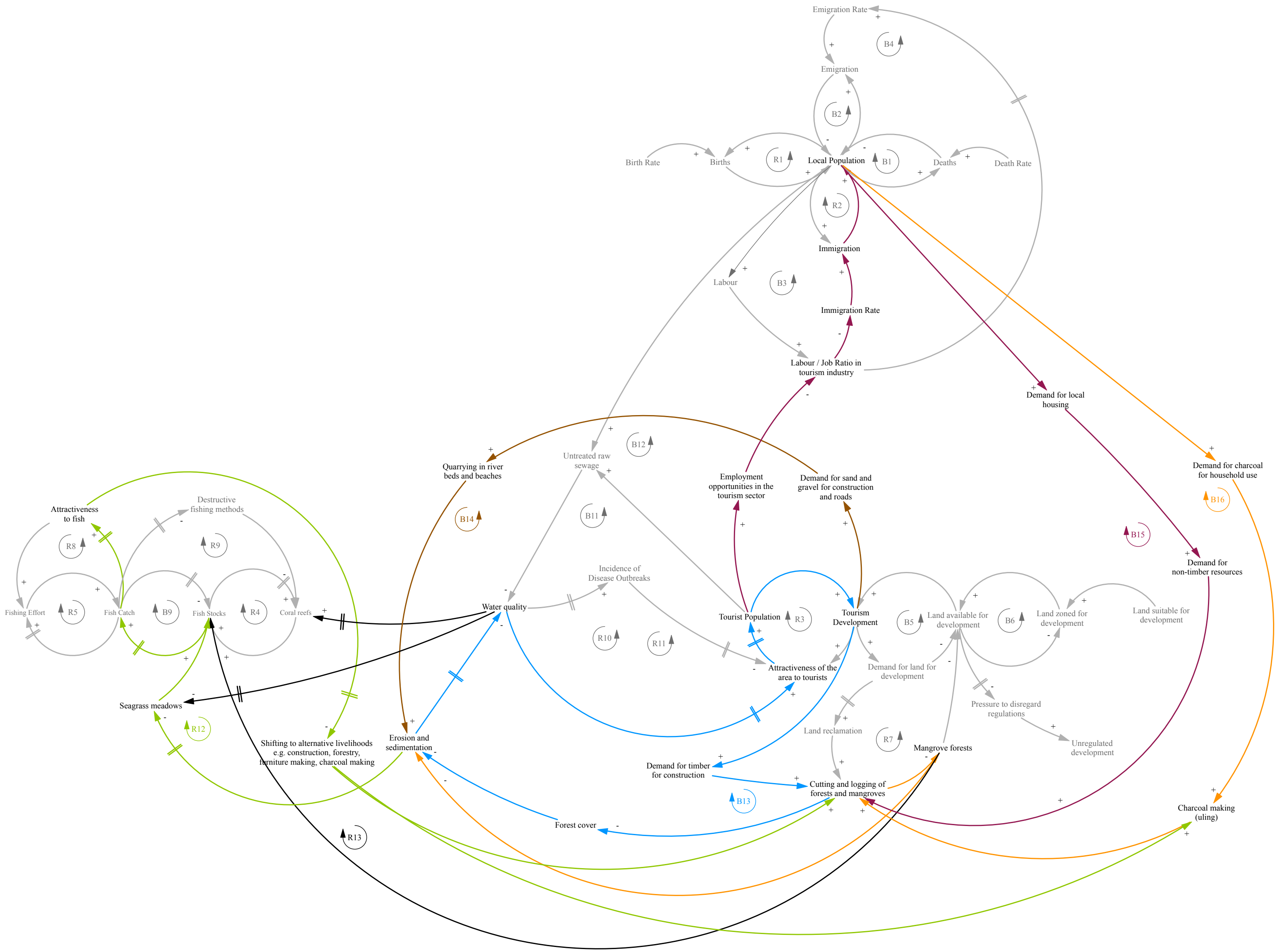

Figure 5-28. Causal loops illustrating the impact on the fisheries system from natural resources demand

5.4.5 Summarising the fisheries food system in El Nido

The fisheries food system in the Municipality of El Nido is entirely reliant upon the health of the marine ecosystem which underpins its productivity, and the ability of the system to continue to meet current and future demands for fisheries produce. Currently, fisheries catch in the Municipality is declining rapidly with fish catch falling by 40 percent in the past decade, with the number of people engaged in fishing activity increasing. The causal loop diagram (Figure 5.29) for the fisheries food system hypothesis shows 27 feedback loops (11 reinforcing and 16 balancing), many of them connecting human activity with the ecosystem degradation. Fisheries management schemes and controls over the loss of habitats will need to be strengthened to reduce or stop further degradation and to stabilise and / or increase fisheries stocks. As the marine ecosystem becomes unable to support the volume of fish required to meet the demand for fisheries produce within the Municipality, this demand is now being met by large-scale imports from further south in the province. However, the ability for people to access fisheries produce remains a question of livelihoods and income generation. Policy and management interventions mitigating against further declines in stocks and habitats will be explored further in Chapter 6.

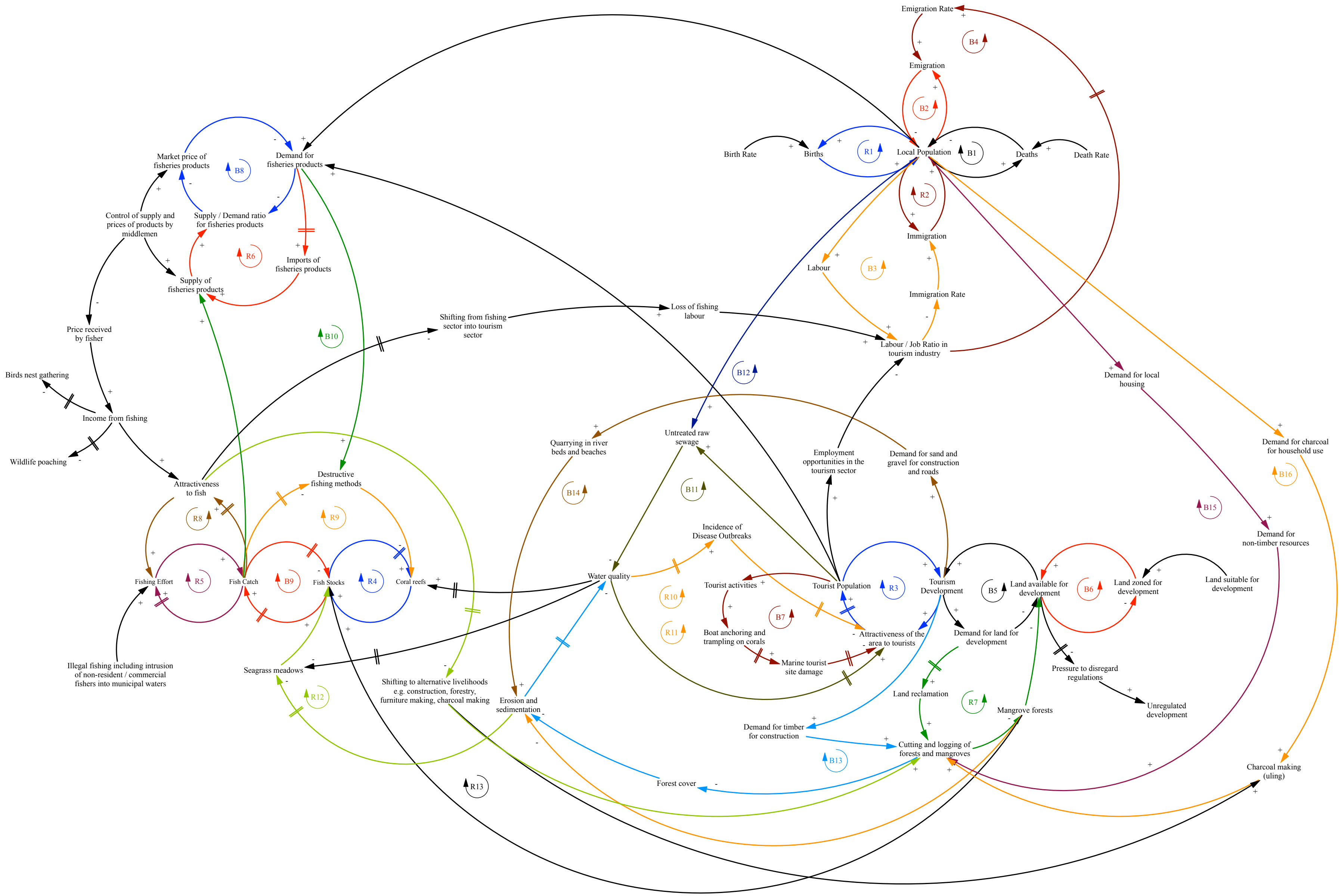

Figure 5-29. Dynamic hypothesis for the fisheries system in El Nido Municipality

5.5 Alternative food and livelihood systems in El Nido

The ability to generate food for household consumption, and/or an income from farming or fishing is core to the food security outcomes of availability and access and is an important driver as to whether people seek alternative food sources outside of these sectors. Whilst agriculture and fisheries are the main providers of food to people within the Municipality, for some barangays, there is an inability to either produce or procure produce either due to a lack of land or access to fishing boats, and food insecurity has occurred in some of the barangays.

During the community participatory workshops, the procurement of 'wild meat' was identified as a food source, and the poaching of wildlife as an income supplement. For example, the rural barangay of New Ibajay reported wild meat (i.e. wild boar, monkey and squirrel) as one of the main sources of meat and protein for many households and is sold in the local markets for P150 per kilo (wild boar) and P70 per kilo (monkey). In the barangays of Bebeladen and Aberawan, wildlife poaching is considered an important alternative income source[21] when income generated from crops or fish catch is low, or when crops or fish catch is poor. The wildlife trade for the Chinese market (Bebeladen CPW Round One April 2015) is therefore seen as lucrative and an important income earner.

Figure 5.30 illustrates this alternative food and income source outside of the traditional sectors. As households require food or income to procure food and as prices of agricultural or fisheries products rise, this will generate an increased demand for wild meat as either a subsistence mechanism or a cheaper alternative for meat consumption which would usually be filled by livestock or fish. Increasing *demand for wild meat* will lead to an increase in *wildlife poaching,* which in turn, will increase the *supply of wild meat*. Increased supply of wild meat will therefore increase the *supply / demand ratio for wild meat*. If the supply outweighs demand, this will cause a decline in the *price of wild meat*, leading to an increase in the *demand for wild meat* (balancing loop B1). However, if demand outweighs supply, the price of wild meat will increase, leading to a decline in demand for wild meat.

[21] For example, a kilogram of anteater scales will sell for PhP800

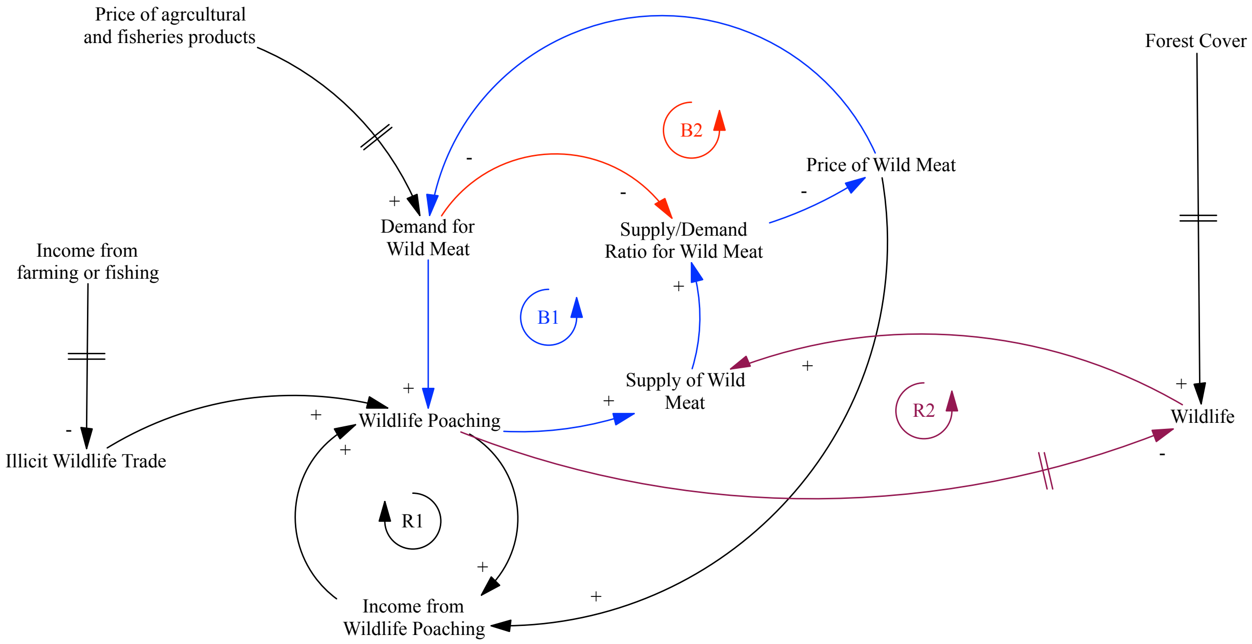

Figure 5-30. Causal loops illustrating influence of food price increases on demand for wild meat and poaching

However, there is a limits to growth scenario for this situation with both the gathering of wild meat and the wildlife trade reliant on the availability of wildlife, which in itself, requires *forest cover* as habitat. As the forests are being degraded, over time, this will also reduce the amount of wildlife as their habitat is destroyed. Added to this, increasing demand for wildlife either for the illicit wildlife trade or as an alternative food source, will place increasing pressure on wildlife, and will eventually lead to an overshoot and collapse in the system if it is not managed effectively, and interventions put in place.

Figure 5.31 further illustrates the alternative food and livelihood system as it outlines the dynamics of *balinsasayaw* (swiftlet) nest harvesting, which is extremely lucrative in the Municipality, as it is renowned for the bird's nests which is sold to the Chinese market. Whilst the bird nest harvesting is regulated through licensing, there still occurs illegal harvesting from within the barangays which generates income (reinforcing loop (R2)). Balancing loop (B1) highlights the closed system with increased birds nest poaching impacting on the supply and price of the birds' nest. However, overharvesting of the birds' nest is leading to a decline in the number of *bird's nest* and therefore leading to a decline in the *supply of bird's nest* as evidenced in balancing loop (B2). Anecdotal evidence from the community participatory workshops and field visits illustrated impacts on the supply of nests from a decline in the number of swiftlet population due to reduced food supply for the swiftlets. For example, the bird's natural food base of insects was declining due to the practice of "fogging" (i.e. chemical spray) to reduce mosquito populations (balancing loop (B3)), overharvesting and changes in climate.

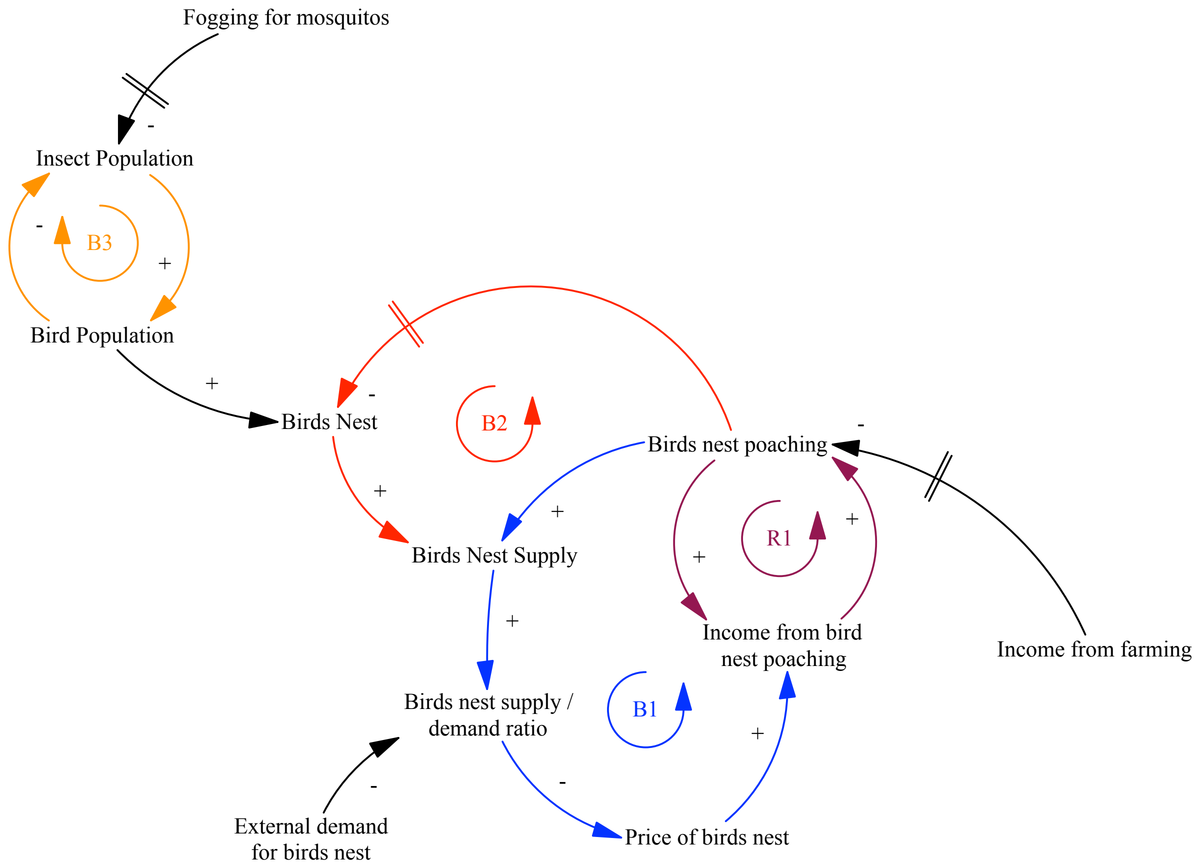

Figure 5-31. Causal loops highlighting birds' nest gathering as an alternative livelihood

5.6 System Archetypes

Successful systems thinking is about being able to see the whole picture or context of a situation and its interconnections to its environment, enabling unintended consequences of well-intended actions to be pre-empted and minimised (Wolstenholme 2003). To adequately understand the behaviour over time of dynamically complex systems, it is necessary to understand the relationships between system behaviour and system structure (Sterman 2000; Ford 2010).

System archetypes are therefore effective tools to use as 'lenses' (Kim and Lannon 1997) for gaining insight into patterns of behaviour and the nature of the underlying problem (Braun 2002) as part of understanding the whole picture. Each systems archetype embodies a particular theory about dynamic behaviour that can serve as a starting point for selecting and formulating raw data into a coherent set of interrelationships (Kim and Lannon 1997). There are ten system archetypes highlighted across the literature: limits to growth; shifting the burden; eroding goals; escalation; success to the successful; tragedy of the commons; fixes that fail; growth and underinvestment; accidental adversaries, and; attractiveness principle (Braun 2002). Mapping the food system in El Nido, three archetypes emerge which affect the behaviour of the system over time determined from the causal loop diagrams and the subsequent modelling, and which in turn, impact upon the food security pillars of food availability and food access: (i) limits to growth; (ii) tragedy of the commons, and; (iii) fixes that fail.

5.6.1 Limits to Growth

The limits to growth archetype states that a reinforcing process of accelerating growth or expansion will encounter a balancing process as the limit of that system is approached (Braun 2002; Wolstenholme 2003). This archetype hypothesizes that continuing efforts will produce diminishing returns as one approaches the limits (Braun 2002). Three problematic situations within the food system were identified to have this archetype: limits to agricultural land, natural resource demand and fish productivity – all of which impact upon food availability through local production. The key leverage point to this archetype is to find an intervention which relaxes or removes the constraint (Maani and Cavana 2007) or an intervention which constrains growth to ensure the limits to growth are not exceeded.

5.6.1.1 Limits to agricultural land

As mentioned in Section 5.3.2.1, agricultural production is dependent upon the amount of *land available for agriculture* and the amount of *land used for agriculture* (B loop in Figure 5.32). However, this in turn, is dependent upon: (a) *land suitable for agriculture* and, (b) *land zoned for agriculture*.

As the *land used for agriculture* is utilised, farmers undertake land *clearing of land for agriculture* to increase the amount of *land used for agriculture*. This loop repeats as a reinforcing cycle (R loop in Figure 5.32). However, despite efforts to increase the amount of land available and used for agricultural purposes, this will only increase in the short term. Ultimately, land is constrained to (a) what is available, and (b) what is zoned.

Shortages in agricultural land available limits production activities, affecting both food availability (i.e. as yield reaches a limit as to what can be produced per hectare), and food access (i.e. the ability of people to grow their own food to meet both subsistence and livelihood needs).

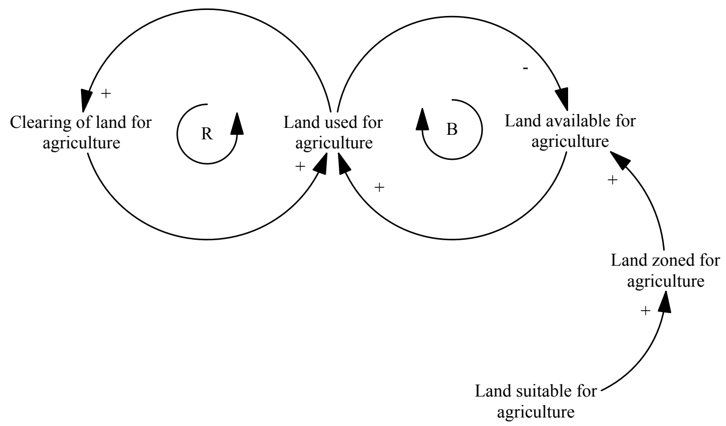

Figure 5-32. Land availability for farming: Limits to growth archetype

5.6.1.2 Fisheries productivity

Fish stock and coral reefs have a reinforcing relationship as each is interdependent upon the other for long-term sustainability as outlined in Section 5.4.1. Fisheries is declining in the Municipality due to a number of *human induced pressures* impacting on the coral reefs and over time the flow-on impacts from these pressures affect reef health. As the health of *coral reefs* declines due to human-induced pressures, *fish stocks* will also decline as their habitat is degraded (R1 loop in Figure 5.33). The opposite balancing loop to this interaction is that of *fish catch* reducing the *fish stock* in the Municipal's waters (B loop in Figure 5.33). However, as *fishing effort* increases, so too, does *fish catch* (R2 loop), in turn reducing *fish stocks*.

Both food availability and physical food access are affected if fish stocks decline to levels of collapse either through overfishing or degraded habitats. Furthermore, economic access to food is further hampered as lower fish catch reduces income levels for fishers, and this in turn reduces their ability to procure food to meet their needs.

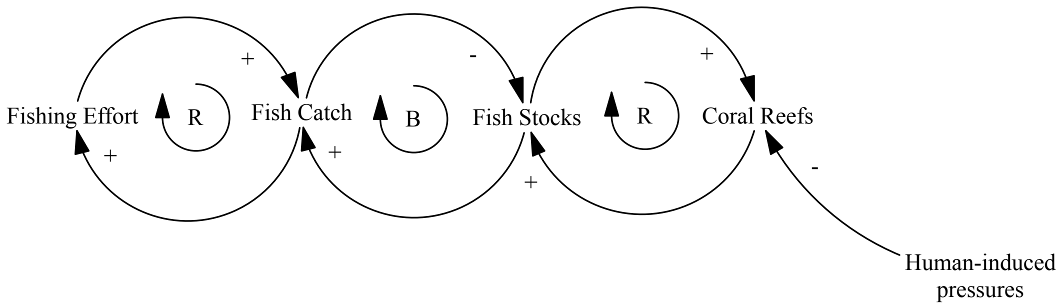

Figure 5-33. Fisheries productivity and fish catch: Limits to growth archetype

5.6.1.3 Natural resource demand

As demand for both terrestrial and marine resources escalate, and the ecosystems become more degraded through exploitation, the environment to support a growing population is eroded or consumed by the population itself (Sterman 2000), and the threat of reaching the carrying capacity of the system intensifies, until overshoot and collapse occur. This relationship is highlighted in Section 5.4.4.2 illustrating the increasing demand for natural resources (timber, non-timber resources, charcoal, sand and gravel) from the local population and the tourism sector and the flow-on effects onto the marine ecosystem. The continued demand on natural resources has a twofold effect on the food system: (i) it impacts on food availability through the reduction of land for agriculture and the impacts of land demands on the marine ecosystem; (ii) food access is impacted as the effect from the continued degradation of the ecosystems leads to an overall loss of income through loss of production or fish catch.

Figure 5.34 illustrates the limits to growth archetype relating to the demand for charcoal. As the local population increases, demand for charcoal increases leading to increases in charcoal making (*uling*) and subsequently in the cutting of mangroves to make the charcoal. This has a reinforcing feedback effect as seen in the 'R' loop in Figure 5.34. However, charcoal making is limited to the availability of mangrove forests. As the cutting of mangroves reduces forest cover, this in turn reduces charcoal making (B loop in Figure 5.34). A limits to growth is reached as the availability of charcoal is directly linked to the availability of the mangrove resource. If mangroves are not replenished through reforestation programs, the equilibrium of the system will become extinct in due course (Sterman 2000).

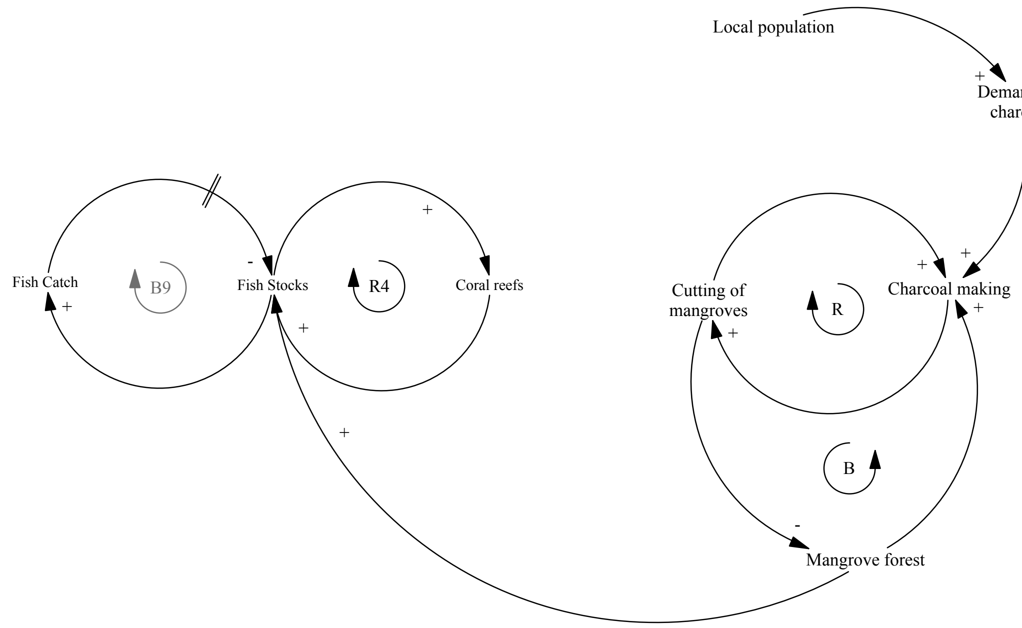

Figure 5-34. Feedback structure for natural resource demands

The degradation of the mangrove forests has a direct impact on food availability as the loss of the nursery habitat for fisheries over time, leads to a loss in fish stocks which in turn, leads to declining fish catch. Furthermore, the loss of mangroves leads to sedimentation directly onto the coral reef habitat, reducing reef health and the ability to sustain fish stocks. Lastly, food access is affected through direct access to a food source if fisheries stocks are depleted, and secondly to an income source both from fisheries and from the charcoal making as an alternative livelihood.

5.6.2 Tragedy of the commons

The commons is a resource that is simultaneously made available to multiple people and is regarded as being uniquely available for their own purposes (Braun 2002; Acaroglu 2018). The “tragedy of the commons” thereby relates to a freely accessible (or open-access) resource which is competitively depleted (Berkes et al. 2006). There is no incentive to conserve as whatever they do not take will be harvested by others (Berkes et al. 2006) and as each person increases their demands and expectations of the commons in the name of their own goals, the commons itself finds itself under increasing pressure to perform whilst steadily eroding towards collapse (Braun 2002). The tragedy of the commons archetype therefore, is illustrated by a reinforcing loop created by the activity of the system’s actors with the intentions of increasing rewards for themselves. However, an unintended consequence is that the activity results in overuse and damage to the environment, which reduces the magnitude of the outcome for all (Wolstenholme 2003).

Tragedy of the commons archetype can be seen in El Nido through the exploitation of the shared fisheries resources and the natural resources (e.g. forests and mangroves) impacting fish populations, fish catch and ultimately livelihoods. In both of these examples, the extraction of these resources is leading to more competitive extraction, which will eventually lead to the collapse of the system (Acaroglu 2018). In Figure 5.35, the example used to illustrate this archetype is for the fisheries resources. Fishing effort in El Nido generates income received from selling the catch (R1 and R2 loops in Figure 5.35), thus affecting food access through income generation and food availability through fish supply. Whilst fish stocks remain high, the level of fishing effort required per fish caught remains low. However, as more fishers enter the system or fish stocks continue to decline, a higher amount of effort is required to generate the same income earnt as before. As fisheries remain open access, there are no limits on the number of fishers entering the system nor on catch limits – thus, as fishing effort increases, more fish are taken out of the system. This eventually leads to a collapse of the system.

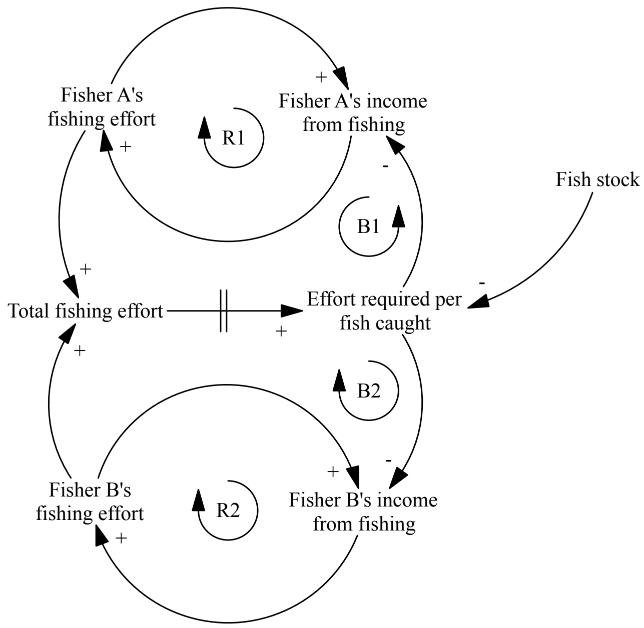

Figure 5-35. Fishing effort and fish stocks: Tragedy of the Commons archetype

5.6.3 Fixes that fail

Fixes that fail is based on a response that is primarily aimed at the problem symptom rather identifying the underlying, systematic problem (Braun 2012). The ‘quick-fix’ solution can have unintended consequences that exacerbate the problem (Kim and Lannon 1997).

The fixes that fail archetype can be illustrated using demands for agricultural land and land clearing in El Nido.

As the availability of land for agricultural use declines due to continuing demand and competition for land from other sectors, land is cleared to make way for more farm land (B loop in Figure 5.36). However, the unintended consequence of land clearing is higher rates of soil erosion which then moves sediments into the watershed in the Municipality and pollutes the water resources, in some cases, making the water resources unsuitable for agricultural use due to the high sediment or agrochemical content. Over time, the increased incidence of erosion makes the land unsuitable for cropping and so has to become fallow (R loop in Figure 5.36). This cause and effect relationship impacts upon food availability over time through reducing suitable land for farming, and reducing crop yields and livestock holdings.

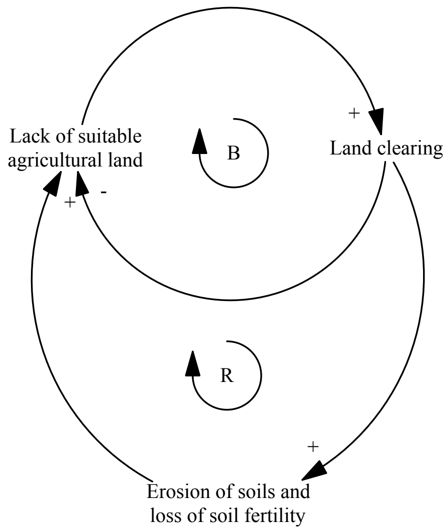

Figure 5-36. Land clearing for agriculture: Fixes that Fail archetype

5.7 Chapter Summary

Chapter 5 formulates the dynamic hypothesis for the food system in El Nido – exploring the dynamics of the feedback structure through the development of maps, or causal loop diagrams. The development of these maps has illustrated the food system in the Municipality is complex and adaptive (refer Chapter 2). As a social-ecological system, it is influenced by social drivers (i.e. tourism and population) and remains heavily reliant upon the ecosystems, both terrestrial and marine, to meet food demand. Reconciling the demands of the growing population with ecological sustainability is increasingly difficult as demand for resources is leading to the overexploitation of the environment and is driving the degradation of ecosystems and biodiversity loss (Cumming et al. 2014). The capacity of the food system in El Nido to continue to produce local food, or enough local food for the population, under these conditions is explored in the simulation model outlined in Chapter 6.

6 Modelling the food system in El Nido

This chapter outlines the results of model simulations of the system behaviour over time against the dynamic hypothesis described in Chapter 5 and tests the effectiveness of interventions on the El Nido Municipality's food system. The use of a system dynamics model to assess the performance of a local food system enables the complex dynamics and interactions within the food system to be analysed, and the efficacy of interventions and indicators to be assessed for different sub-parts of the model. In particular, the system dynamics approach facilitates the linking of system structure to system behaviour (Sterman 2000; Ford 2010).

6.1 Model development and rationale

The simulation model (the model) used in this research is a custom-made, fully-developed socio-ecological model, developed by Drs Carl Smith and Russell Richards at The University of Queensland using Stella Architect© software (http://ccres.net/resources/ccres-tool/system-simulation-model). It is a systems dynamics model consisting of a series of coupled ordinary differential equations (ODEs). Each stock and flow system within the Stella model represents an ODE. The model is designed to simulate long time horizons (e.g. 20 – 50 years) at one-week time steps. The short time steps reflect that some of the dynamics captured occur on a weekly basis. For this research, the model is used to explore the potential future trajectories of El Nido's food system out to the year 2050 at one-week time steps. The model incorporates a range of dynamics including population, tourism, housing, employment and environment. This functionality of the model enables: (i) quantification of the interactions between social, economic and environmental components that characterise the food system; (ii) the ability to capture the feedback loops and interactions between the system's components that were identified during the development of the dynamic hypothesis, and; (iii) the ability to test the efficacy of various policy scenarios.

A key limitation of the simulation model used in this assessment is the dearth of historical data for the case study site and the inability to access available data from data custodians. Whilst the model, where possible, uses site-specific data, the model has also been parameterised by the researcher utilising generic data collected from other sources or sites, expert elicitation[22], field observations and literature reviews. Given the data limitations, this research study has used the model as a tool for understanding system structure versus system behaviour and not a model for prediction.

The simulation model aims to address the last research question (RQ 3) *"What scenarios would affect the ability of local communities to produce and procure food?"* A series of sub-questions were developed to support RQ3 (Table 6.1). These sub-questions are designed to ascertain how the food system in the El Nido Municipality is likely to respond to a suite of scenarios.

Table 6-1. Set of sub-questions generated to respond to overarching research questions

1.	Under the current situation, what are the implications for food security over the next 30 years (until 2050) if the El Nido Local Government continues along this path?
2.	What are the implications for food security over the next 30 years (until 2050) if the El Nido Local Government implements its current set of policies?
3.	What are the implications for food security over the next 30 years (until 2050) if the El Nido Local Government implements an ideal set of policies?
4.	How resilient is food security in El Nido to shocks under the previous three sets of scenarios?

To showcase the behaviour and trends occurring under these policy scenarios, a user-friendly interface was developed for the model as part of this research (Figure 6.1). The interface enables the user to adjust or change specific model parameters without having to access the 'back end' of the model. Using a user-interface provides a straightforward process for setting up different scenarios and evaluating these against various performance measures and assists in identifying leverage points within the system where changes in existing policy or resource use could lead to improvements within the food system (refer Section 6.2). The changes are managed through a series of sliders (continuous) and switches (Boolean[23]), providing continuous and numeric adjustments of the selected parameters. The sliders and switches enable changes to model parameters against the three identified policy objectives to ascertain the impact on food security:

a. Increasing tourist numbers
b. Increasing the volume of local agricultural production

[22] Expert elicitation in the model development refers to a series of discussions the model developers undertook with experts across a range of fields (e.g. fish modellers; research experts on fisheries, mangrove and seagrass processes; fisheries economists, and; experts on the processes relating to runoff, groundwater etc).

[23] Boolean models are often able to reproduce qualitative behaviour of a system (Wittmann et al 2009)

c. Increasing fish catch through sustainable fisheries management

The sliders[24] enable a range of values to be tested across the specified variable, whilst the switches[25] provide for two possible states i.e. ‘on’ or ‘off’ related to the variable it controls. The switches do not revert back to an initial state and must be adjusted for each scenario. Once adjustments have been made against each of the scenarios, the model is run, with simulations for each scenario corresponding with ‘run’ trendlines e.g. ‘Run 1’ (baseline of business-as-usual scenario), ‘Run 2’ (policy implementation scenario), and ‘Run 3’ (resource-efficient consumption scenario).

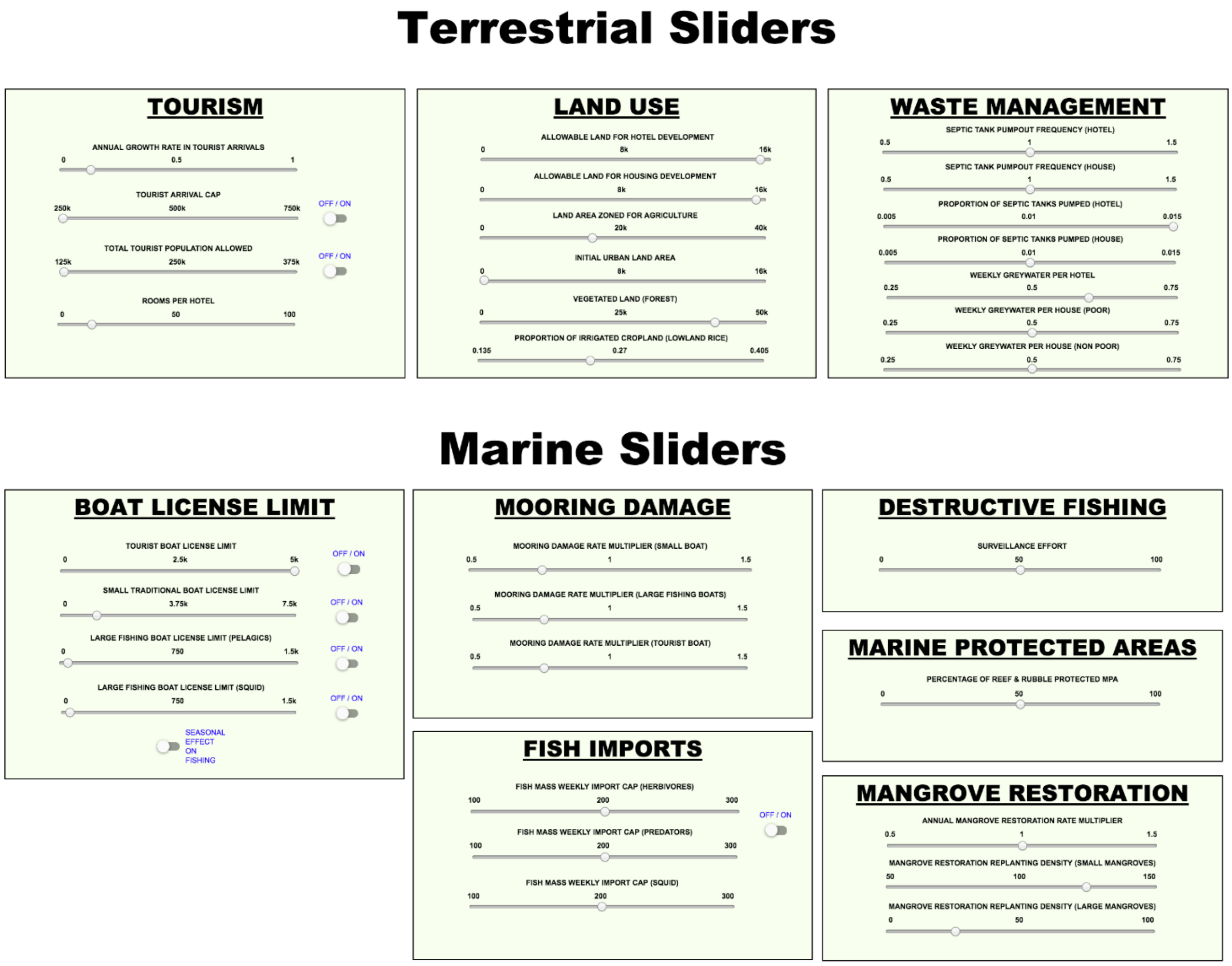

Figure 6-1. Simulation model interface for terrestrial and marine sliders and switches

[24] Sliders allow an input parameter of the model to be adjusted on a continuous scale between specified minimum and maximum values

[25] Switches allows constraints to be applied (switch = ON) or ignored (switch = OFF)

6.1.1 Overarching model parameters and limitations

This research utilises the model to understand the system behaviour relating to the food security pillars of food availability and food access under various policy scenarios and leverage points within the food system. Food availability links the supply side of the food system and refers to the availability of sufficient quantities of food of appropriate quality (FAO 2006), sourced from either local production and/or importation. The model simulates the dynamics on the availability of sufficient quantities of food produced through the local agricultural and fisheries systems and through the importation of agricultural and fisheries goods. However, the model lacks the capacity to simulate the *quality of food* as a component of the food availability question and this research study is not designed to address this question.

The food access pillar reflects the demand side of the food system, referring to the physical and economic access to food, whereby people are able to physically produce or access food, or have the economic ability to procure food (FAO 2006). Whilst the model is designed to simulate the ability of people to physically or economically access food through growing, catching or purchasing food, it does not simulate system behaviours relating to components of physical access which assist in the movement of food to markets or for people to gain access to food e.g. road networks and transport linkages.

In undertaking the scenario assessments against these pillars, the model simulates the system behaviour occurring within and across five core components identified in the dynamic hypothesis created for the El Nido Municipality's food system discussed in Chapter 5: (a) socio-economic drivers affecting the food system; (b) agricultural production; (c) fisheries catch and fish population; (d) habitat condition and; (e) livelihoods. These components are discussed in more detail below.

a. Socio-economic drivers on food production systems

The model simulates the influence of the socio-economic drivers of local population, tourism and the supply - demand relationship on the production systems for agriculture and fisheries. The key variables in the model include:

- *Local population*: Births, deaths, immigration and emigration have been identified as the major influences on the growth rate of the local population in the El Nido Municipality (refer Section 5.2.1).

- *Tourism*: Key variables including tourist numbers, tourism development (hotels, restaurants), land available for development and tourism activities – have been identified as either influences on the expansion of tourism or as a result of the growth in tourism within the Municipality (refer Section 5.2.2).
- *Supply - demand of food*: Supply and demand is connected through food consumption, local production, imports of agricultural and fisheries produce and price elasticity. The model assumes that any deficit in supply (compared to demand) is filled by imports, although there will be a delay in this occurrence. For food pricing, economic modelling modules explore system behaviours relating to food pricing based on actual price.

b. Agricultural production system

The model simulates the effects of land availability, and demand for land and water on the local agricultural production system with key variables including:

- *Land zoned and / or suitable for agriculture*: This has been formulated from information in the El Nido Local Government's Comprehensive Land Use Plan 2003-2012 and the ECAN Resource Management Plan 2015-2020. Due to geographical limitations on land, the model simulates changes based on changing zoning parameters within the geographical limitations and policy frameworks.
- *Cropping and livestock production*: This includes the total yields of lowland rice, crops and livestock produced. Connected to the production is the amount of land available (as outlined above) and water availability or usage. The model simulates water usage in agricultural and urban (domestic and hotels) sectors, however, as data for water usage and availability is unknown, assumptions have been made in calculating these variables. It is noted, there is a level of uncertainty associated with modelling water availability and proxies such as *water table depth below the surface* have been utilised in this situation to illustrate how groundwater depth influences production. Whilst the model does not explicitly incorporate climate change aspects, it does include rainfall as an annually repeating time series due to its importance in the model's calculations of runoff. Furthermore, adjusting weekly rainfall can be used to signify decreases in rainfall and the potential for drought as a proxy for climate change influences. Lastly, whilst the causal loop diagram developed for agricultural production (Figure 5.16) incorporates soil fertility and

pests and diseases as influences on yield per hectare, the model does not include these variables.

c. Fisheries system

The fisheries food system is simulated in the model through key variables including:

- *Fish catch*: the model simulates adult and juvenile fish mass catch at site level for three groups of fish (herbivorous, predators and squid) across three habitats (reefs, mangroves and seagrass meadows). This is related to the fishing effort (hours per boat per week) and the catch per unit effort (CPUE), which represents the 'catchability' of the different fish at the different habitats for each fishery. In the model, the CPUE has a positive relationship with fish population.
- *Fish density (population)*: models fish density (fish per hectare) and fish population (total number of fish) for the reefs, mangroves and seagrass habitats respectively. It also incorporates cross-habitat recruitment dynamics, which reflects that some habitats are known to be more important as 'nursery' habitats (mangroves and seagrass) that move to other habitats (coral reef, pelagic zone) upon maturation.
- *Carrying capacity and habitat density*: models the ability of the ecosystem (reef, mangrove and seagrass) to sustain fish populations. The carrying capacity of a habitat is dynamic in the model and is linked to the condition and size of the habitat. For example, clearing mangroves for urban development reduces the mangrove carrying capacity, whilst the activity of destructive fishing (bomb, poison) reduces the condition of the reef.
- *Habitats density*: the model simulates the dynamics for three marine habitats; reef, mangroves and seagrass. For each habitat, the area and condition are calculated at each time step.
    - *Reef* - The reef is further divided into non-MPA and MPA components to reflect the divide between protected and non-protected reef. The determinants of reef condition are destructive fishing, boat mooring (fishing, tourism), water turbidity and symbiotic grazing by herbivorous fish.
    - *Mangroves* - The mangroves sub-module is a size-structured (small, large) model, which allows the size-specificity of mangrove harvesting for fuel and timber to be simulated. It also allows the effects of mangrove density on regulating pollutants entering the marine system from catchment runoff.

  - *Seagrass* – this sub-module simulates the growth of seagrass in response to photosynthesis, nutrients (food) and water temperature. The condition of the seagrass is influenced by mooring damage from fishing and tourist boats and water quality.
- *Fishing effort*: modelled as the number of hours fished per week per boat across habitats. In the model, fishing effort is influenced by the subsistence and commercial needs of boats. The model assumes that fishers will target habitats where they are likely to make the most amount of money, based on the current fish prices and CPUEs. The model also assumes fishers move between fisheries (e.g. traditional (reef, mangrove, seagrass), pelagic, squid and destructive fisheries) and move in and out of the fishery sector into other sectors such as tourism.
- *Fishing boats*: includes traditional small boats, large boats (i.e. pelagic and squid) and destructive fishing boats (bomb and poison fishing).
- *Policy interventions*: The model enables policy interventions on the fisheries system to be evaluated, through the application of marine protected area (MPA) establishment and no-take zones (through MPAs) for coral reefs. Interventions such as closed fishing seasons and catch quotas can also be modelled through proxies such as *seasonal effect on fishing*. The model does not explicitly simulate technological changes however, proxies such as changes in catch per effort unit and mooring damage are used to illustrate some of these interventions e.g technology might be used to increase CPUE for a particular fishery or to reduce anchor damage or fishing equipment damage.

Given the complexity of the fish population component of the model, there is a high level of uncertainty in the model parameters around fish population, fishing and fish catch due to an absence of historical data. For example, there is no current knowledge of the fish population across fish species and fish groups in the case study site. This is compounded by the complexity of fisheries including different fish groups (predators, herbivorous and squid), different fish ages (juvenile, adult) and different fish habitats (coral reefs, mangroves, seagrass and pelagics). However, the model developers have worked closely with experts in the field to ensure improved certainty over the structure of these fisheries related models so that the behaviour of the fishing and fish dynamics aligns with current knowledge.

d. Habitat condition

The model simulates the effects the tourist and local populations have on the terrestrial and marine ecosystems underpinning the production of food as described in the causal loop diagrams in Chapter 5. Key variables modelled include:

- *Urban development*: this sub-module relates to the total urban area and how much is used for hotel and housing development. It includes development in both non-mangrove and mangrove areas. The sub-module has links to habitat condition through runoff from forest and mangrove clearance and waste pollutants into the watersheds impacting on water quality.
- *Water quality*: this sub-module relates to the water quality of the coastal receiving water. Pollutant (nitrogen, phosphorus, sediment) production is modelled through the sub-modules for septic tanks and land runoff. Pollutant loading from the catchment includes stormwater from urbanised areas and rural runoff from farms and forested areas and is dependent on rainfall-driven runoff as the mechanism for delivery to the receiving water. The model uses rainfall-runoff curves and pollutant loading concentrations for the different land uses to capture this relationship. Pollutants generated from septic tanks is dependent on the number of houses, which itself is dependent on the population and is not dependent on rainfall.
- *Habitat area, carrying capacity and density*: as outlined above, the model provides representations of the health of the habitats through carrying capacity and habitat density to support fish populations.
- *Policy interventions*: The model enables the simulation of policy effectiveness through the use of various proxies such as:
    - Using boat moorings to manage the effects on reefs and seagrass
    - Septic tank management to reduce pollutant loading effect on seagrass (nutrients, sediment) and reef (sediment).
    - Mangrove reforestation leading to flow-on effects for seagrass and reefs, and fisheries (e.g nursery habitat for juvenile fish).
    - Changing the weekly use of mangroves for fuel, charcoal and timber (to increase/reduce mangrove harvesting) and changing the mangrove restoration rate to simulate enforcement of logging and cutting of mangroves and forests.

e. Livelihoods

Key variables simulating the system behaviours impacting upon economic access to food include:

- *Jobs*: the model simulates tourism jobs, other jobs[26] (domestic jobs), agricultural and fisheries[27] jobs to assess the impact of migration on the population, employment and income on food demand and access.
- *Income*: the model simulates income per capita generated from the tourism, agriculture and fisheries sectors. In calculating the income per capita the model utilises the following equations: (i) tourism income is calculated by estimating how much of tourist spending remains within the site; (ii) agricultural income per capita is calculated through the total weekly income for the site from farming (crops and livestock) divided by the population, and; (iii) fisheries income is calculated using the weekly income per capita from small boats at present value divided by the local population.
- *Actual net site savings*: The model simulates whether people are spending more (>1) or less (<1) on food (fish, crops, meat). Whilst there is some uncertainty regarding this variable in terms of value, it remains an important determinant in demonstrating economic growth and rising food demand and consumption patterns.
- *Food Pricing*: the model simulates actual prices for crops, cattle, pigs and fish (herbivorous, predator and squid).

6.1.2 Model parameterisation and calibration

Whilst the simulation model was provided fully parameterised for this research, the input variables and initial conditions were not compiled critically for the case study site. Therefore, a critical assessment of parameters and calibration to represent the initial conditions for the site was undertaken by the researcher to ensure preparedness of the model for the scenario simulations (Sterman 2000; Smajgl and Barreteau 2014).

It is acknowledged there are technical uncertainties concerning the quality of data available to parameterise such a large (approximately 1000 state variables) model and to determine input assumptions for drivers of change. Additionally, due to a lack of historical

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[26] Other jobs are defined as 'total jobs required for domestic jobs' and are directly coupled with population in the model.

[27] The model calculates fishing jobs as equivalent jobs i.e. when someone is fishing what is the equivalence of their job. For example, if there are no fish and they catch little, then even though one person is fishing their contribution is less than one fisher. A low number indicates the combined equivalent of fishers may only be the same as half the number of fishers if there are plenty of fish.

data to fully parameterize the model with, many of the input parameters have been based on expert opinion and on data that have been derived from processes that are analogous to that being modelled and/or from locations different from the case study area. Consequently, there is a high level of uncertainty associated with many of the model parameters[28]. To parameterize the model used in this research, a dataset consisting of: (a) collected data for the El Nido Municipality, and; (b) 'default' data based on assumptions based on expert elicitation, literature reviews and field observations provided with the model.

Following the completion and uploading of the dataset into the model, a limited calibration of the model was undertaken. The two parameters used to calibrate the model against were local population and tourist numbers. These two parameters were selected because there were time series data available to compare the model output with. Model parameters associated with population birth, death, immigration and emigration rates were then modified to reduce the difference (error) between model output and actual for local population and tourists. The calibration objective was to minimise this error.

The selection of this subset of the parameters allows for calibration and enables the model to be tuned to the historical data. However, it is noted that there is unlikely to be a unique solution for calibration in such a large model (i.e. there are multiple paths to the end state, 'equifinality' (Jacobs and Jacobs 2010)) and therefore considerable effort (including consultation with the model developers) was undertaken in judiciously selecting the most appropriate parameters for adjustment (i.e. birth rate, death rate, immigration and emigration rates).

The model was tested to compare the predicted versus actual for both the local population and tourism. The model was run with the set of input parameters for the years 2000 (local population) and 1998 (tourist numbers). This was then compared with the known historical trends over time between the years 1998 / 2000 – 2015. The calibration parameters were used to reduce the difference between the model projections and actual for the population and tourist numbers. This minimsation process was done manually as the model is too

[28] The original model dataset is available at https://ccres.net/resources/ccres-tool/system-simulation-model, including information on the source of the data.

large to be automatically fitted. The following steps against both the local population and the tourist numbers were undertaken.

b. Local population

Historical figures for the local population were obtained from the Philippines Statistics Authority (the Authority) for the following Census years: 2000, 2007, 2010 and 2015 (Table 6.2). Whilst these datasets provided for the overall population numbers and growth rates, there still required a parameterisation of the input variables influencing local population – initial population, births, deaths, immigration and emigration. To ensure the population figures in the model simulation corresponded as closely as possible with those of the Census years, the calibration used an average annual growth rate of 4.13 percent[29]. Whilst this provided an annual growth rate, it still required testing the calibration against other input variables influencing population – births, deaths, immigration and emigration (Table 6.3).

Figure 6.2 illustrates the results of the data input into the model and the resulting simulations. As illustrated, the trend lines in the model simulations produce a similar trend to the real situation.

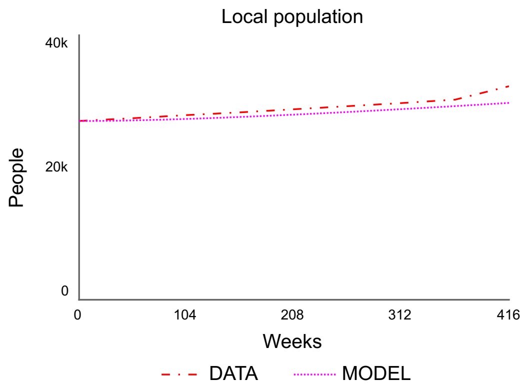


Figure 6-2. Simulated El Nido population trends

The 'Data' run illustrates the trend against the Census population data and the 'model' run simulates the population trend in the model

[29] The average annual growth rate was calculated using the following growth rates calculated across the 15-year period based on the Census population figures: (i) 2.96% (2000-2006); (ii) 6.74% (2007-2008); (iii) 2.69% (2009-2015).

Table 6-2. Local population and tourist numbers in El Nido (1998 - 2015)

Year	Local Population	Tourist Numbers
1998	-	12,000
1999	-	12,200
2000	27,029	15,000
2001	-	12,300
2002	-	12,300
2003	-	12,300
2004	-	16,000
2005	-	20,000
2006	-	19,000
2007	30,249	21,000
2008	-	21,000
2009	-	22,000
2010	36,191	38,000
2011	-	38,000
2012	-	50,087
2013	-	63,000
2014	-	82,000
2015	41,606	98,000

Table 6-3. Initial data inputs used for population statistics

Variable	Growth Rate per Annum (2015 figure)	Data Source
Birth rate	2.5%	Philippines Statistics Authority. Based on the official rate for Palawan and confirmed by the El Nido LGU.
Death rate	3.3%	Philippines Statistics Authority. Based on the official rate for Palawan.
Immigration rate	4.5%	El Nido Local Government Unit
Emigration rate	1.05%	Based on data collected under the University of California (Davis) BioLEWIE surveys undertaken in El Nido in 2014

c. Tourism population

The second set of data used in the model parameterisation is tourist arrivals. Tourism in El Nido has grown exponentially since 1998 from 12 000 tourists per year to 98 000 in 2015 (El Nido Municipal Tourism Office 2014). Recent newspaper reports indicate tourist numbers reached 200 000 in 2017 (Fabro 2018). Of the tourist numbers 40 percent of the arrivals are domestic tourists and 60 percent are international tourists (El Nido Municipal Tourism Office 2013). Note that the model explicitly accounts for these two tourist groups separately.

i. Tourist arrivals

The initial conditions or values were set as at the year 2000 and were established based on initial tourist arrivals which calculates the number of arrivals (domestic and foreign) per week. The initial condition for the variable was set as:

Domestic tourists:

*Weekly domestic tourist arrival rate = Annual rate / 52 * 0.4*
*= 15,000 / 52 * 0.4*
= 115

Foreign tourists:

*Weekly foreign tourist arrival rate = Annual rate / 52 * 0.6*
*= 15,000 / 52 * 0.6*
= 173

ii. Tourists

The initial conditions were set based on the number of people per week (domestic and foreign) in the Municipality at any one time during that week – this provided for the initial number of tourists at the site. There is an assumption that there is a constant number of tourists arriving in El Nido each week across the year. An average tourist stay is 3.6 days (Gilliland 2014), however, the model is constrained to a minimum rate of 7 days[30]. Within the model simulation, the calculations are undertaken on the assumption each tourist stays

[30] The model is constrained to a weekly time step. Therefore, whilst the average duration of tourists is 3.6 days or 0.52 weeks, this has had to be parameterised in the model's dataset as an assumption that each tourist will stay an average of 1 week. It does not affect the calculations for the 'initial tourist' rate.

for a 7-day period. To calculate this, the following equations were utilised with the results provided in Table 6.4.

Domestic tourists:

Initial number of domestic tourists at site at one time = Weekly domestic tourist arrival rate / 2

Foreign tourists:

Initial number of foreign tourists at site at one time = Weekly foreign tourist arrival rate / 2

Table 6-4. Calculated tourist arrivals per week in El Nido Municipality for 2000

Variable	Domestic Tourists	Foreign Tourists
Number of initial tourist arrivals per week	115	173
Number of initial tourists at the site at one time	57	87

The data calculated based on the 2000 tourist figure was included into the model's parameter dataset. An average annual growth rate of 12 percent was calculated utilising historical data over the 15-year time period (2000 – 2015):

Average growth rate over period = Sum of annual growth rates / Period of time

= 175 percent / 15 years

= 11.65%

The resulting plot of tourist arrivals per week and the trend projected within the model is illustrated in Figure 6.3.

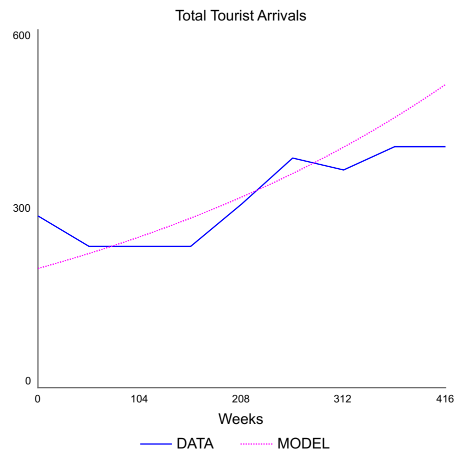


Figure 6-3. Weekly tourist arrivals in El Nido (1998 - 2017)

The graph illustrates the trend for tourist numbers utilising known data inputs (Run 2), against the model simulation of tourist numbers (Run 1).

Resulting model simulations against real situation

First the datasets were compared to observe its trend lines. The resulting testing of the trends is shown in Figure 6.2 and Figure 6.3. The model was run in the period in which known population and tourist data is known. Figure 6.2 and Figure 6.3 illustrates that when the data was input into the model and the simulations were run, the trend lines in the model simulations produce a similar trend to the real situation.

6.2 Scenario Simulation

Scenarios inform present-day decision-making by exploring different possible futures (WEF 2017) providing plausible descriptions of a possible set of events that might reasonably take place (Jarke et al 1999; Wu et al 2011). Scenarios can be forward-looking, exploring how futures might unfold from current conditions and uncertainties, however, they are not forecasts, projections, predictions or recommendations (Raskin et al 2005). Instead, scenarios are designed to stimulate thinking about possible occurrences, assumptions relating to these occurrences, possible opportunities and risks, and courses of action (Jarke et al 1999) and envisioning future pathways and accounting for critical uncertainties (Nelson et al 2010).

Scenarios are designed to explore three principal questions: (i) what will happen; (ii) what can happen, and (iii) how a specific target can be reached and reflect the probable, possible and preferable future states (van Dijk et al 2016). The scenarios outlined in this section project the probable future state of the system i.e. what can happen through assessing the food system under particular policy objectives relating to (i) economic development driven by the tourism sector and (ii) ensuring local food provisioning through agricultural and fisheries sectors.

An initial baseline scenario is used to simulate the current state of the system as per known data and local government policies. The baseline scenario is used as the reference point to examine food security outcomes when a number of 'what-if' assumptions are made. These projections are best used for planning to analyse foreseeable changes and evaluate policy shocks (van Dijk et al 2016). Three additional scenarios have been developed to explore and analyse 'what-if' assumptions based on possible policy interventions on the food system in El Nido. Linking these objectives, the four scenarios are outlined below and in Figure 6.4:

1. **Baseline or 'business as usual'**: in a world of resource-intensive consumption and economic development driven by tourism, this is a scenario assessing the current situation of high environmental cost and unsustainable food production.
2. **Policy implementation**: maintaining a tourism-focused economy, this scenario outlines a possible future based on policy implementation co-existing with high resource-intensive consumption and low prioritisation of agriculture.
3. **Resource-efficient consumption**: this scenario tests potential policy interventions aimed at prioritising agriculture, fisheries and preserving the ecosystems which underpin the food system. It assesses a resource-efficient consumption whilst still maintaining economic growth through the tourism sector.
4. **Systemic shocks**: This scenario provides a 'what if' framework if particular endogenous or exogenous shocks occur within the system. In doing so, it enables observation of how the system responds to the shock and recovery from the shock.

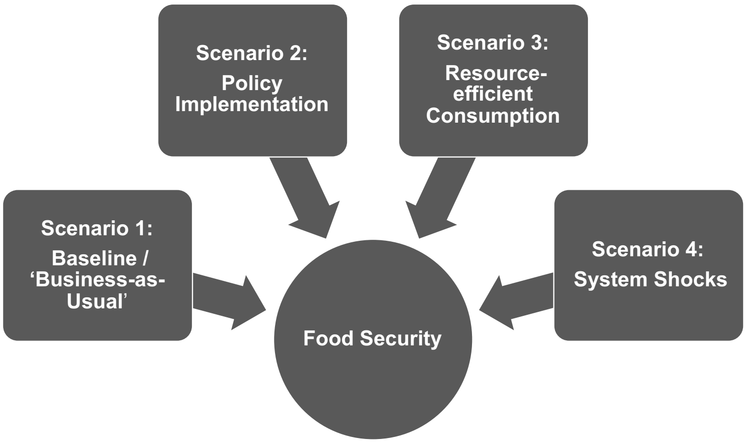


Figure 6-4. The Scenarios: Potential pathways to the future

Each of these scenarios were tested under a set of metrics pertaining to three policy objectives aimed at sustaining economic growth and preserving the local food production systems to meet the food security pillars of food availability and food access. The policy objectives are:

1. Increasing tourist numbers
2. Increasing the volume of local agricultural production
3. Increasing fish catch through sustainable fisheries management

To assess outcomes against each of the policy objectives, a set of indicator variables and adjusted variables was established (Table 6.5). The rationale and data source for the adjusted variable parameters can be viewed in Appendix B. Each of the scenarios are assessed and compared to ascertain any changes across the model parameters and the impact on the food system and food security outcomes.

Table 6-5. Scenario policy objectives, indicator variables, adjusted variables and parameters

Policy Objectives	Performance Indicators	Indicator Variable	Adjusted Variable	Scenario 1: Baseline (Business-as-Usual)		Scenario 2: Policy Implementation		Scenario 3: Resource-efficient consumption	
				Adjusted Variable	Enabled	Adjusted Variable	Enabled	Adjusted Variable	Enabled
	1. Number of tourists a. Total	Tourist population	Initial annual growth in tourist arrivals	12		14.5		12	
			Tourist arrival cap per year	700,000	✘	700,000	✘	250,000	✓
			Total tourist population allowed	375,000	✘	375,000	✘	125,000	✓
			Rooms per hotel	17		17		17	
	2. Number of tourist related jobs	Tourism plus restaurant jobs							
		Tourism income per capita							
		NPV Net Savings Site							
		Net savings effect on consumption [Poor]							
		Net savings effect on consumption [Non Poor]							
		Net savings effect on consumption [Restaurant]							
	3. Demand for food a. Demand for agricultural products. b. Demand for fisheries products	Normal meat consumption per week							
		Actual meat consumption per week							
		Normal crop consumption per week							
		Actual crop consumption per week							
		Normal weekly consumption of fish							
		Actual weekly consumption of fish							
	4. Water consumption a. Limiting effect	Surface water volume							
		Water table depth below surface							
		Effect of groundwater available on use							
		Effect of surface water available on use							
	5. Land used for urban development a. Total b. Hotels c. Houses	Total hotel area	Allowable land for hotel development	15,766		1,848		15,766	
		Total housing area	Allowable land for housing development	15,766		972		15,766	
		Total urban land area		15,766		1,848		15,766	
		Vegetated land		19,137		41,728		41,728	
		Number of houses in non mangrove area							
		Number of houses in mangrove area							
	6. Stormwater loading a. Sediment b. Nutrients (Nitrogen & Prosperous)	Pollutant concentration estuary (sediment, nitrogen and							
		Pollutant loading estuary (sediment, nitrogen and							
		Smoothed nitrogen loading from catchmen							
		Smoothed phosphorus loading from catchment							
		Smoothed sediment loading from catchment in tonnes							
	7. Septic Tank loading a. Nutrients		Septic tank pumpout frequency (Hotel)	0.5		1		1	
			Septic tank pumpout frequency (House)	0.5		0.5		0.5	
			Proportion of septic tanks pumped per pumpout (Hotel)	0.01		0.015		0.015	
			Proportion of septic tanks pumped per pumpout (House)	0.005		0.01		0.01	
			Greywater produced per hotel per week	0.5		0.6		0.6	
			Weekly grey water per HH type [Non-Poor]	0.5		0.5		0.5	
			Weekly grey water per HH type [Poor]	0.5		0.5		0.5	

Policy Objectives	Performance Indicators	Indicator Variable	Adjusted Variable	Scenario 1: Baseline (Business-as-Usual)		Scenario 2: Policy Implementation		Scenario 3: Resource-efficient consumption	
				Adjusted Variable	Enabled	Adjusted Variable	Enabled	Adjusted Variable	Enabled
Increased fish catch through sustainable fisheries management	1. Fish density (kg/hectares) a. Herbivores b. Squid c. Predators	Reef Non MPA fish density	Mooring damage rate multiplier small boat	1		1		0.75	
			Mooring damage rate multiplier large fishing boats	1		1		0.75	
			Mooring damage rate multiplier tourist boat	1		0.75		0.75	
		Seagrass fish density							
		Mangrove fish density							
		Trad fishing effort in reef	Small trad boats license limit time independent	1,552	✘	1,552	✘	1,000	✓
		Trad fishing effort in mangroves	Small trad boats license limit time independent	1,552	✘	1,552	✘	1,000	✓
		Trad fishing effort in seagrass	Small trad boats license limit time independent	1,552	✘	1,552	✘	1,000	✓
		Trad fishing effort in pelagic	Large fishing boats licence limit [pelagic boat]	292	✘	21	✓	21	✓
			Large fishing boats licence limit [squid boat]	292	✘	21	✓	21	✓
		Reef Traditional fish catch	Small trad boats license limit time independent	1,552	✘		✘	1,000	✓
			Seasonal effect on fishing effort						✓
		Seagrass Traditional fish catch	Small trad boats license limit time independent	1,552		1,552	✘	1,000	✓
		Mangrove Traditional fish catch	Small trad boats license limit time independent	1,552		1,552	✘	1,000	✓
	2. Habitats a. Reef (non MPA and MPA) b. Mangrove c. Seagrass	Number of bomb fishing boats	Actual fishing weekly survellience effort	5		10		50	
		Number of poison fishing boats	Actual fishing weekly survellience effort	5		10		50	
		Number of destructive fishing boats	Actual fishing weekly survellience effort	5		10		50	
	3. Imports	Fish imported to market	Fish mass weekly import cap		✘		✘		✓
	4. Livelihoods a. Traditional fishers b. Destructive fishers c. Income per boat (trad)	Number of traditional fishing boats	Small trad boats license limit time independent	1,552	✘	1,552	✘	1,000	✓
		Total large fishing boats pelagic plus squid	Large fishing boats licence limit [pelagic boat]	292	✘	21	✓	21	✓
			Large fishing boats licence limit [squid boat]	292	✘	21	✓	21	✓
		Fish price herbivore							
		Fish price predators							
		Fish price squid							
		Fishing jobs							
		Weekly fishing income per capita from small boats at							
	5. Habitat size and condition (carrying capacity) a. Reef (non MPA) b. Reef (MPA) c. Mangrove d. Seagrass	Reef area							
		Tourist boats (poor and non-poor)	Tourist boats license limit	277	✘	277	✘	277	✓
		Total Reef Non MPA carrying capacity	REEF percentage of reefs and reef rubble protected MPA	1.96		5		50	
		Total Reef MPA carrying capacity	REEF percentage of reefs and reef rubble protected MPA	1.96		5		50	
			Mooring damage rate multiplier tourist boat	1		0.75		0.75	
		Total mangrove carrying capacity	Mangrove restoration replanting density [Small mangrove]	100		100		125	
			Mangrove restoration replanting density [Large mangrove]	1		0		25	
			Annual mangrove restoration rate multiplier	1		1		1	
		Total seagrass carrying capacity							

Policy Objectives	Performance Indicators	Indicator Variable	Adjusted Variable	Scenario 1: Baseline (Business-as-Usual)		Scenario 2: Policy Implementation		Scenario 3: Resource-efficient consumption	
				Adjusted Variable	Enabled	Adjusted Variable	Enabled	Adjusted Variable	Enabled
Increase volume of local agricultural production	1. Land used for agriculture	Agricultural area used	Land area zoned for agriculture	31,139		6,539		15,766	
	2. Number of agricultural jobs	Total agriculture jobs							
		Agricultural income per capita							
	3. Water consumption or limitation	Total actual water use livestock							
		Total actual weekly water use crops							
	4. Yield of local production	Crop production rice	Proportion of irrigated cropland (lowland rice)	0.135		0.135		0.240	
		Crop production total							
		Livestock supply to trad market							
	5. Imports	Rice imports							
		Total crop imports including rice							
		Total meat imports							
	6. Pricing of agricultural products	Rice price at local market							
		Local price for pigs							
		Local price for cattle							

6.2.1 Scenario 1: Baseline or 'business-as-usual'

The baseline or 'business-as-usual' scenario reflects the scenario where the model is run for future periods without changing the parameters assigned for past/present conditions, as illustrated in the dynamic hypothesis' created in Chapter 5 (Figures 5.18 and 5.29), and without changes in policies or regulations. It is designed to answer the question *'Under the current situation, what are the implications for food security over the next 30 years if the El Nido Local Government continues along this path?'* (Table 6.1). This scenario explores the supply – demand juxtaposition for both the agricultural and fisheries systems. It examines the dynamics of the system in which growth is characteristic of reinforcing behaviour illustrated through: (i) growth in tourism and population; (ii) increasing demand and competition for land, for water and for natural resources; (iii) degradation of habitats and; (iv) the rise of food imports to fill the supply - demand gap brought about by declining agricultural production and fisheries catch.

Specifically, the scenario explores the state of the system in which:

- Agricultural land is limited by the amount of suitable land rather than the amount of land zoned for agriculture (refer Section 5.3.2.1).
- Enforcement of building regulations controlling the number and size of tourist developments has not been undertaken over the past ten years.
- There has been little to no establishment of waste treatment plants (sewage).
- There has been limited fisheries management to ensure fish populations and their habitats remain intake. To-date there are no restrictions in place for limiting catch either through quotas or size or limiting the number of fishing boats. Furthermore, enforcement of commercial fishing boats infringing Municipal waters has been limited (Republic Act No. 8550: The Philippine Fisheries Code of 1998).
- Establishment of Marine Protected Areas (MPAs) and Community Managed Marine Areas (CMMAs) remains low e.g. total MPAs in the Municipality total 1.96 percent (UP 2015).
- Protections on marine tourist areas to limit damage from the increased number of visitors is not implemented.
- Protection of habitats remains either unregulated or unenforced with minimal marine protected areas in place, and the illegal clearing of forests and mangroves for either land, housing construction or charcoal remains.

The results of the model simulation for Baseline Scenario (Run #1) are provided in Figures 6.7 – 6.19, with the interpretation of the model outputs occurring after week 300 due to model 'burn-in'. 'Burn-in' occurs when the selection processes programmed in the model are different from the selection processes that affect the behaviours of a particular variable (Williams et al 2017). This results in the different selection processes undergoing initial instability in model results.

The 'burn-in' is due to the model readjusting due to the uncertainty around some parameters within the model and the size of the model. The table highlights both the results illustrated as 'comparative line graphs of the simulation outputs' and the 'behaviour description'.

6.2.2 Scenario 2: Policy Implementation

Scenario 2, 'policy implementation' responds to the question '*What is the most likely future scenario if the El Nido Local Government implements the policies it has or has proposed to their fullest? What are the implications for food security over the next 35 years?* (Question 2, Table 6.1). This scenario analyses the state of the system under a set of policies and regulations currently in place or proposed for enactment. The parameters used to respond to the three policy objectives outlined in Table 6.5, are guided by: (i) mandates outlined in key national-level Acts which provide the overarching framework for the Local Government's policies on protecting the rights of municipal fishers and farmers, food security and resource protection[31], and; (ii) Local Government policies and regulations recently enacted in the Municipality (Table 6.6). Outputs of the model simulations for this scenario are viewed in Figures 6.7 – 6.19 for 'Run #2'.

[31] The Acts include: Republic Act No. 8435 Agriculture and Fisheries Modernization Act of 1997; Republic Act No. 8550 The Philippine Fisheries Code of 1998; Executive Order No 533 Adopting integrated coastal management as a national strategy to ensure sustainable development of the natural resources; Republic Act No. 7586 National Integrated Protected Areas System Act of 1992, and; Local Government Code of 1991 which provides the government with the authority to implement national and provincial legislation and establish their own regulations and ordinances.

Table 6-6. Rationale for policy parameters in Scenario 2

Area of Focus	Description of policy / regulation and relevance to the scenario	Performance Indicator Influenced
Tourism	Tourism is prioritized as the key economic activity, highlighted through the El Nido Municipal Tourist Office's tourism master plan goal to double the current tourist population within a five-year timeframe. The model simulates the trend for tourism growth using the 2016 figure of 124 000 as the baseline. Doubling the tourist numbers within a five-year timeframe from this baseline equates to a growth rate of 14.5 percent per annum.	a. Number of tourists
Protecting reef habitats	The LGU announced a set of measures designed to minimize the damage to coral reefs at the tourist sites including limiting tourist entry to marine sites (e.g. a maximum of 720 guests per day for the Big Lagoon; 360 people per day for the Small Lagoon; 144 people per day for Secret Beach) and enforcing anchorage limits (e.g. maximum of 5 boats in the anchorage area of the Big Lagoon and two boats in the Small Lagoon) (Business Mirror 2018). The model analyses this regulation through reducing the level of mooring damage at the sites to reflect the reduction in boat traffic.	a. Fish density b. Habitat size and condition
Land zoning	The Palawan Council for Sustainable Development's ECAN Resource Management Plan 2015 – 2020 is the precursor to, and influences, the Local Government's Comprehensive Land Use Plan (CLUP) which establishes land use zoning. The scenario explores what would occur if the proposed zoning areas under the ECAN 2015 – 2020 were implemented. Amendments include forested land dominating with a zoned area of 41 728 hectares with the land area for urban development proposed at 1 848 hectares (this includes commercial, tourism / commercial, industrial and light industrial, government centre, institutional and settlement) and agricultural land zoned at 6 539 hectares. The underlying assumption in the model is the allowable land for hotel development matches the land zoned for urban development, however, housing is limited to the 972 hectares zoned for settlements.	a. Land used for urban development b. Land used for agriculture
Waste treatment	The construction of a centralised sewage treatment plant to be fully operational in 2020 is underway in the Poblacion (town) area of the Municipality. The treatment plant will only incorporate the four urban barangays of Buene Suerte, Corong-corong, Maligaya and Masagana leaving 63 percent of households in the Municipality using unsanitary means of disposing of waste (ECAN 2015-2020). The model will simulate the introduction of the treatment plant by increasing the rate of septic tank pump-out frequency and the proportion of septic tanks pumped out for hotels only. The underlying assumptions include: (i) given the large percentage of households still without sewage systems, the treatment plant will not impact on the number of septic tanks for houses; (ii) all hotels will have septic tanks and be linked into the treatment plant.	a. Stormwater loading b. Septic tank loading
Fisheries management	The Philippine Fisheries Code of 1998 and local legislation of the Municipal Fishery Code of 2000 highlights the protection of the rights of municipal fisherfolk. This includes the restriction on commercial fishing boats (i.e. pelagic and squid boats larger than 3 tonnes) from entering the 15km Municipal waters zone. Currently there is no enforcement in place for fishers infringing within the municipal zone. Enforcement will be modelled by reducing the number of fishing licenses to cover only registered boats under 3 tonnes.	a. Fish density b. Livelihoods
Marine habitats (reefs)	Ordinances No 001 to 006 of 2009 stipulate the barangays of Buene Suerte, Corong-corong, Mabini, New Ibajay, Sibaltan and Villa Paz can declare Community Managed Marine Areas (CMMAs) which provide marine core zones free of human activity and creation of a buffer zone in which some 'soft' activities are allowed including tourism activities and fishing with selected gear e.g. hook and line. The ordinance is modelled through increasing the MPA area to 5 percent and decreasing the level of mooring damage from traditional fishing boats.	a. Habitats

6.2.3 Scenario 3: Resource-efficient consumption

Scenario 3, the 'resource-efficient consumption' scenario, responds to the question '*What are the implications for food security over the next 30 years (until 2050) if the El Nido Local Government implements an ideal set of policies?'* (Table 6.1). It assesses the system against intervention strategies identified in the dynamic hypothesis (Figures 6.5, 6.6) and highlighted in Table 6.7. Whilst the simulation model is not able to model all interventions indicated due to model limitations and a lack of quantitative and qualitative data on these proposed interventions, key leverage points have been identified and modeled aimed at identifying a food system whereby:

- the local food production systems are maintained with recognition of these systems as key livelihood sectors,
- environmental sustainability is prioritised, and
- the tourism sector is managed within limits to maintain a strong economy whilst limiting the sector's footprint on the environment.

In this scenario, a range of plausible interventions have been modelled against the policy objectives across a number of demographic and biophysical variables within the system. Table 6.8 provides the rationale for key policy interventions.

Results of the model simulation outputs undertaken in Scenario 3 are viewed in Figures 6.7 – 6.19 under 'Run #3'.

Table 6-7. Leverage and intervention points identified in the dynamic hypothesis

Intervention	Model Slider / Switch	Modelled (Y / N)
Tourism		
Capping the number of tourist arrivals per year	Annual tourist arrival cap	✓
Capping the total number of tourists	Total tourist population allowed	✓
Restricting the number of tourist developments built	Annual tourist arrival cap (proxy)	✓
Restricting the number of rooms allowed per tourist development	Rooms per hotel	✓
Enforcing building regulations	n/a	✗
Land Use		
Reducing the amount of land zoned for urban development	Land zoned for urban use	✓
Reducing the amount of land zoned for agriculture	Land zoned for agriculture	✓
Enforce regulations stopping illegal occupancy of land	n/a	✗
Agricultural Sector		
Improve land ownership and tenure rights	n/a	✗
Improve farm-to-market infrastructure (e.g. roads, cold storage)	n/a	✗
Improve fertiliser usage	n/a	✗
Install more irrigation systems for farming areas	Proportion of cropland irrigated	✓
Improve the use of pesticides to ensure minimal runoff impacts	n/a	✗
Introduce improved farm technologies	n/a	✗
Establish farming cooperatives to increase farm size, improve farming techniques and production	n/a	✗
Fisheries Sector		
Establish boat and licensing limits	Fishing boat license limits	✓
Establish closed fishing seasons	Seasonal effect on fishing cap	✓
Reduce the number of fishing hours per week	Fishing boat license limits (proxy)	✓
Introduce catch limits or quotas	Seasonal effect on fishing cap (proxy)	✓
	Traditional fishing boat license limits (proxy)	✓
Protection of local fishers	Fish import cap	✓
Establish marine protected areas	Percentage of protected area	✓
Establish aquaculture facilities	n/a	✗
Improve fisheries surveillance and enforcement measures	Surveillance effect	✓
Reduce the number of fishing boats	Fishing boat license limits	✓
Establish ‘protectionist’ policies e.g. capping of imports	n/a	✗
Habitats		
Introduce quotas on the number of tourist boats	Tourist boat licensing limits	✓
Enforce boat anchoring regulations	Mooring damage rate	✓
Undertaking mangrove rehabilitation and restoration programs	Mangrove restoration	✓
Undertake reforestation of forested areas and timberlands	Zoning for vegetated land (proxy)	✓

Enforcing regulations on illegal logging of forests	Zoning for vegetated land (proxy)	✓
Enforce regulations to stop illegal clearing of land	n/a	✗
Enforcing regulations on illegal cutting of mangroves	n/a	✗
Importation of building materials	n/a	✗
Establish waste management facilities	Waste management	✓
Enforce a ban on all quarrying activities	n/a	✗
Provide alternative sources for charcoal	n/a	✗

Table 6-8. Rationale for policy parameters in Scenario 3

Area of Focus	Description of policy / regulation and relevance to the scenario	Performance Indicator Influenced
Tourism	The intervention accommodates a 12 percent annual growth rate in the number of tourists entering the Municipality as per the baseline scenario, however, a 'tourist cap' limiting the number of tourist arrivals to 250 000 people per year is implemented. This figure equates to a doubling of the current tourist numbers i.e. 124 000 in 2016, in approximately seven years which is in line with current tourist policies however, it recognises a slower growth trajectory than the local government is advocating for under Scenario 2. The number of tourists in the site at any one time would equate to 50 percent of this total per week.	a. Number of tourists
	Under the baseline and policy implementation scenarios there no or little, enforcement in restricting buildings to two stories high (restricting the number of rooms available). Whilst the simulation model is unable to model the enforcement of building regulations, the scenario uses the number of rooms per hotel as the proxy for restrictions or enforcement of planning approvals and development regulations. The number of rooms remain at the average of 17 rooms per hotel based on the current average calculated from the number of hotels (incorporates resorts, hotels and lodging houses) and the number of rooms.	a. Number of tourists
Land use	The effects of land competition between urban development and agriculture is assessed through zoning restrictions. The allowable land used for hotel and housing developments remains at the current amount of land suitable for urban development – 15 766 hectares. Despite the proposed changes to the zoning by the provincial government - the Palawan Council for Sustainable Development (PCSD) - under the ECAN Resource Management Plan 2015-2020 which decreases the amount of land zoned for urban development, it is acknowledged that if tourism continues to expand and the local population continues to increase based on current trajectories, then demand for land for urban development will continue to increase.	a. Land used for urban development
	The Local Government's Comprehensive Land Use Plan 2003 – 2012 zones approximately 50 percent of the Municipal's land area as either urban or agricultural, however, the ECAN Resource Management Plan 2015 – 2020 notes that only 15 766 hectares is flat to gentle slopes and suitable for these activities. Scenario 3 explores the prioritisation of agriculture and sets the land zoned for agriculture at 15 766 hectares.	a. Land used for agriculture
	Forested or vegetated land is set to 41 728 hectares based on the proposed zoning under the ECAN Resource Management Plan 2015-2020. The increase in forested areas is used to assess impacts of sediments entering the watershed and impacting on the marine ecosystem as seen in Scenario 1 and 2.	a. Land used for urban development b. Land used for agriculture
	Consideration is given to the Agriculture and Fisheries Modernization Act of 1997 which states the State will promote the development of irrigation systems that are effective, affordable, appropriate and efficient as the basis for promoting irrigation of the lowland rice areas. The model enables the setting of the amount of land under irrigation and fertiliser. Currently, the amount of land under irrigated is 460 hectares of the lowland rice area. An intervention reflecting the prioritisation of irrigation	a. Yield of local production

	as per the Act, increases the amount of land under irrigation to 1 620 hectares which is the full area of lowland rice under cultivation. Fertilised agricultural land remains as is, as all current lowland rice fields are already fertilised.	
Waste management	The scenario sets the metrics for septic tanks for both hotels and homes as per Scenario 2 to reflect the introduction of new waste treatment facilities for the Poblacion area in 2020.	a. Stormwater loading b. Septic tank loading
Fisheries management	Scenario 3 explores a number of interventions designed to reflect the Philippine Fisheries Code of 1998 edict '*to achieve food security as the overriding consideration in the utilization, management, development conservation and protection of fishery resources in order to provide the food needs of the population'*. These include: • Limiting the number of traditional and pelagic fishing boats to 1000 and 21 respectively to reduce overfishing. Licenses for traditional fishing boats is currently at 1 552 (2015 figures). Licenses for large fishing boats (pelagics) is currently 21. The scenario assesses changes in a reduction of fishing licenses on fish catch and fish population. • The 'mooring damage rate multiplier' for both small, large boats and tourist boats is set to 0.75 to reflect the reduction in the number of fishing boats and tourist boats at marine sites. • The 'seasonal effect of fishing' is introduced to reflect the seasonal nature of fishing and as a proxy for closed fishing seasons or introducing catch quotas. • Prioritisation of habitat protection is seen in increasing the percentage of marine areas to 50 percent to analyse effects of large-scale protections on habitats and fisheries. • Surveillance effort levels are increased to 50 percent to analyse effect of improved enforcement of fisheries protection policies. • Rate of mangrove restoration is increased to analyse habitat preservation and enforcement of policies relating to the cutting of mangroves and reduction in mangrove charcoal.	a. Fish density b. Livelihoods c. Habitat size and condition d. Habitats

Figure 6-5. Agricultural food system causal loop diagram illustrating policy and management interventions

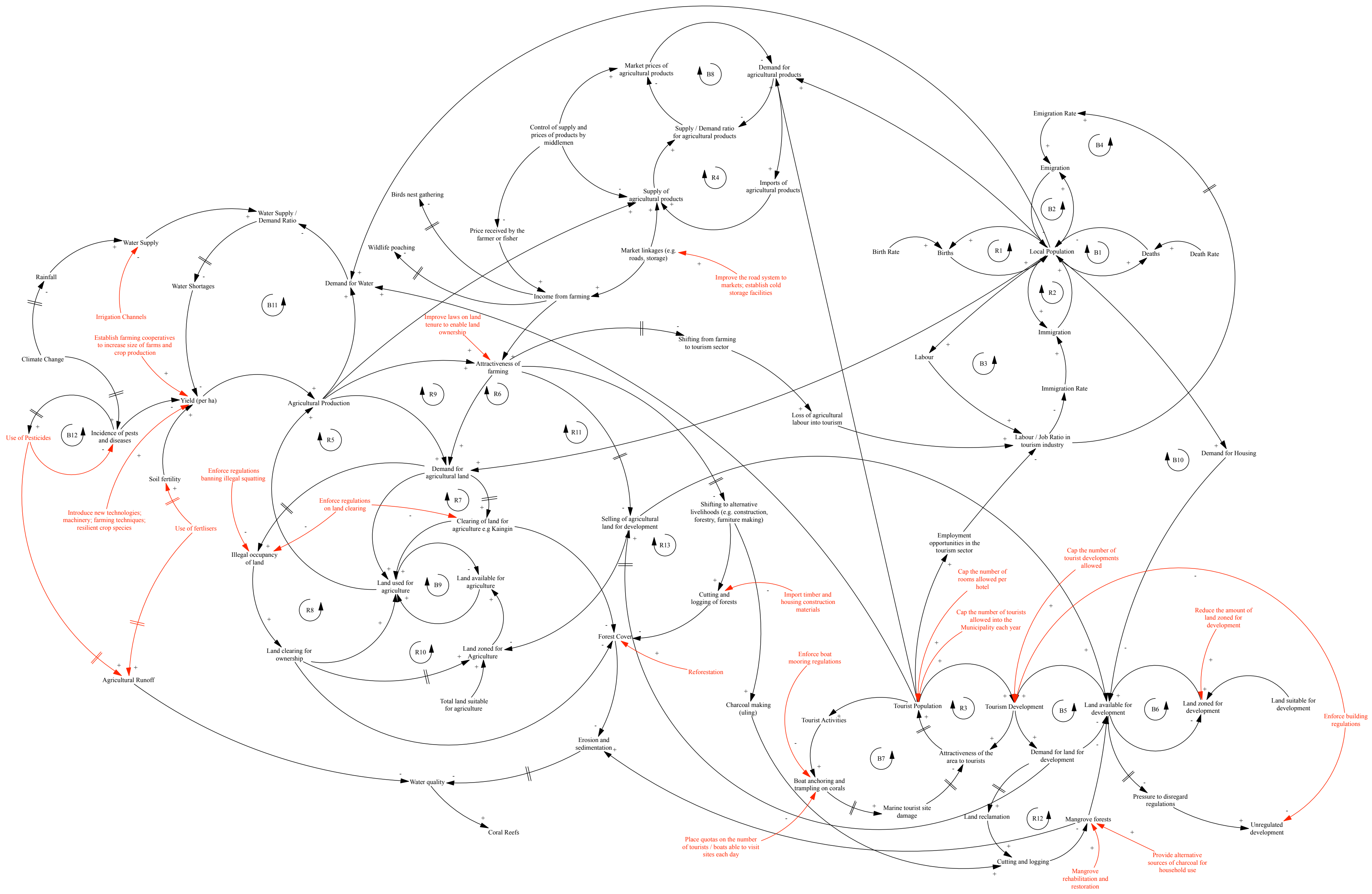
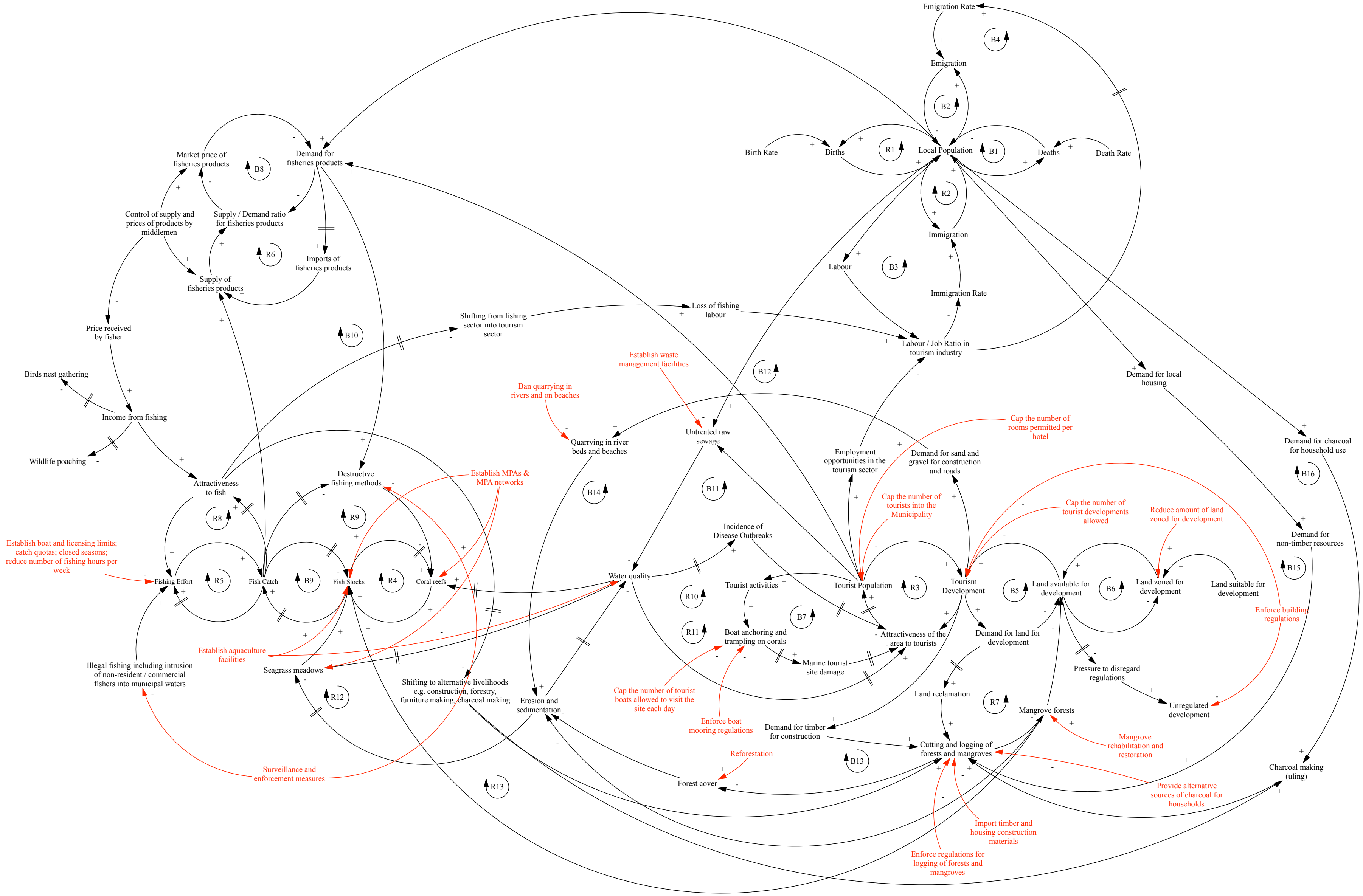


Figure 6-6. Fisheries food system causal loop diagram illustrating policy and management interventions



6.2.4 Results from the scenario model simulations

This section provides the results from the model simulations across the three scenarios – Baseline, Policy Implementation and Resource-efficient consumption. The model simulations are grouped by drivers as outlined in Chapter 5. Additional results from the simulations can be found in Annex D. The "run" corresponds with each scenario i.e. Run 1 (Baseline), Run 2 (Policy Implementation) and Run 3 (Resource-efficient consumption). Section 6.2.5 provides the discussion on the results illustrating the comparative line graphs of the simulation outputs and behaviour description.

6.2.4.1 Socio-economic drivers

The model illustrates increasing tourist numbers leading to overall exponential growth in the *tourist population* (Scenario 1 and 2), however, when the tourism cap is applied (Scenario 3), the *tourist population* increases initially until week 385 when the cap is reached, and continues in a straight trajectory at the capped rate for the remainder of the simulation period (Figure 6.7). Corresponding to the *tourist population*, an exponential increase in the *local population* is seen across all three scenarios, indicating a system whereby inputs (births and immigration) is exceeding outputs (deaths and emigration).

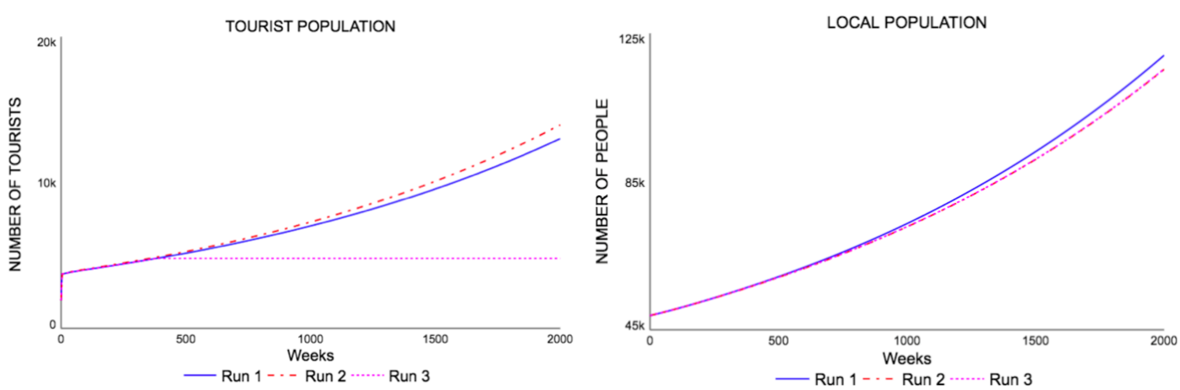


Figure 6-7. Scenario results for tourist numbers and local population

Influencing the local population, *emigration rates* exceed *immigration rates* for Scenarios 2 and 3 whilst the baseline scenario shows immigration higher than emigration (Figure 6.8). Whilst the emigration rate exceeds the immigration rate, this is not adversely impacting on the local population with growth still continuing, indicating: (i) the birth rate is offsetting any emigration, or; (ii) there remains jobs available for a large portion of the population, however, no new jobs are generated. If emigration continues to exceed immigration and the birth rate beyond 2050, the local population may start to show a declining trend.

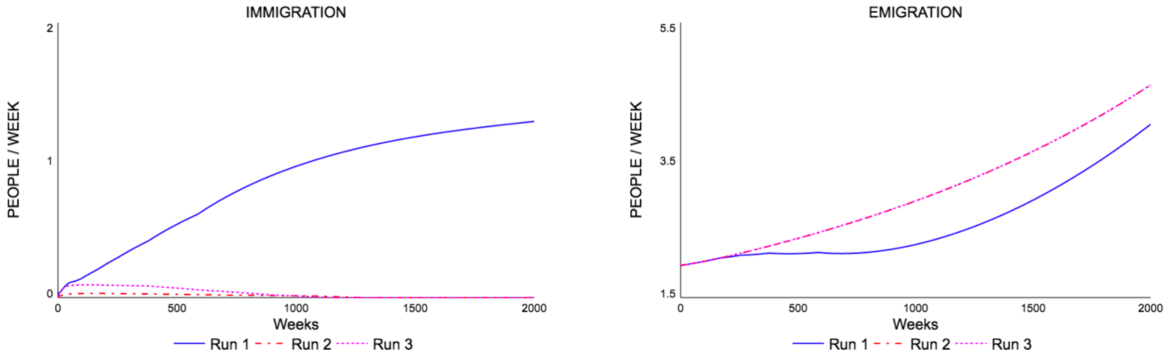


Figure 6-8. Emigration and immigration projections

In understanding what factors influence migration, the model assesses four determinants - food availability, water availability, housing availability and the labour-job ratio. Across all three scenarios, the *labour-job ratio* is identified as the most influential determinant on migration (Figure 6.9), with the trends reflecting the immigration / emigration rates.

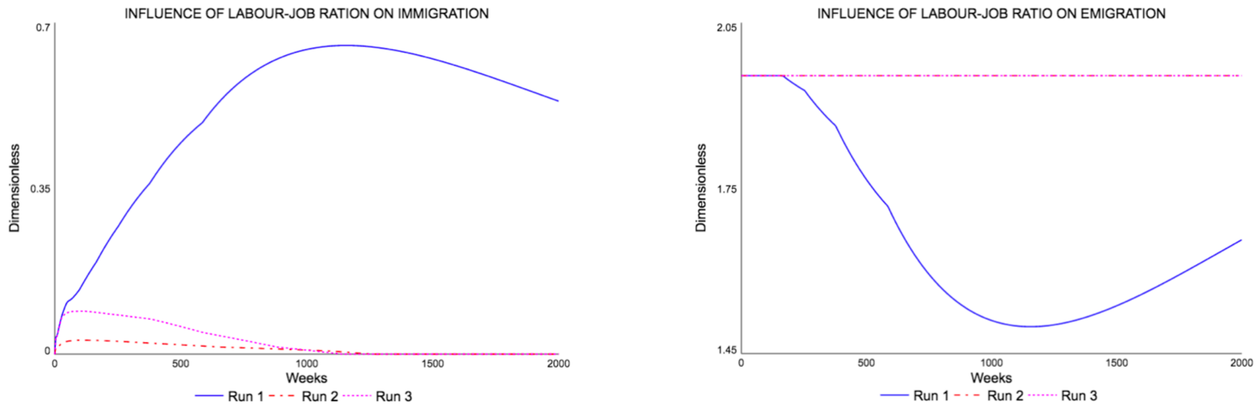


Figure 6-9. Influence of the labour-job ratio on local population

The labour-job ratio is driven by the amount of labour available versus the number of available jobs in the Municipality. Scenario 1 illustrates a system showing growth in the number of *tourism jobs* and *other jobs* due to the growth in tourism and population. Scenario 2 follows the same trend however, the number of *tourism jobs* is higher than in Scenario 1, whilst the number of *other jobs* is reflected as lower than Scenario 1. Scenario 3 shows signs of growth in *tourism jobs* until the cap on tourist numbers is reached in week 385. The number of *other jobs* continues to show growth in line with Scenarios 1 and 2 (Figure 6.10).

The trends for agricultural jobs reflect the agricultural land used, highlighting the relationship between the two variables. Whilst agricultural jobs increase over the time in Scenario 1, Scenarios 2 and 3 reveal a lower, steady trend throughout the simulation time period. Fisheries jobs shows collapse, under all three scenarios, although under Scenario 3, the collapse occurs at a later period than the previous two scenarios. The collapse of fisheries jobs reflects the model's calculation of jobs based on the job equivalency (refer Section 6.1.1)

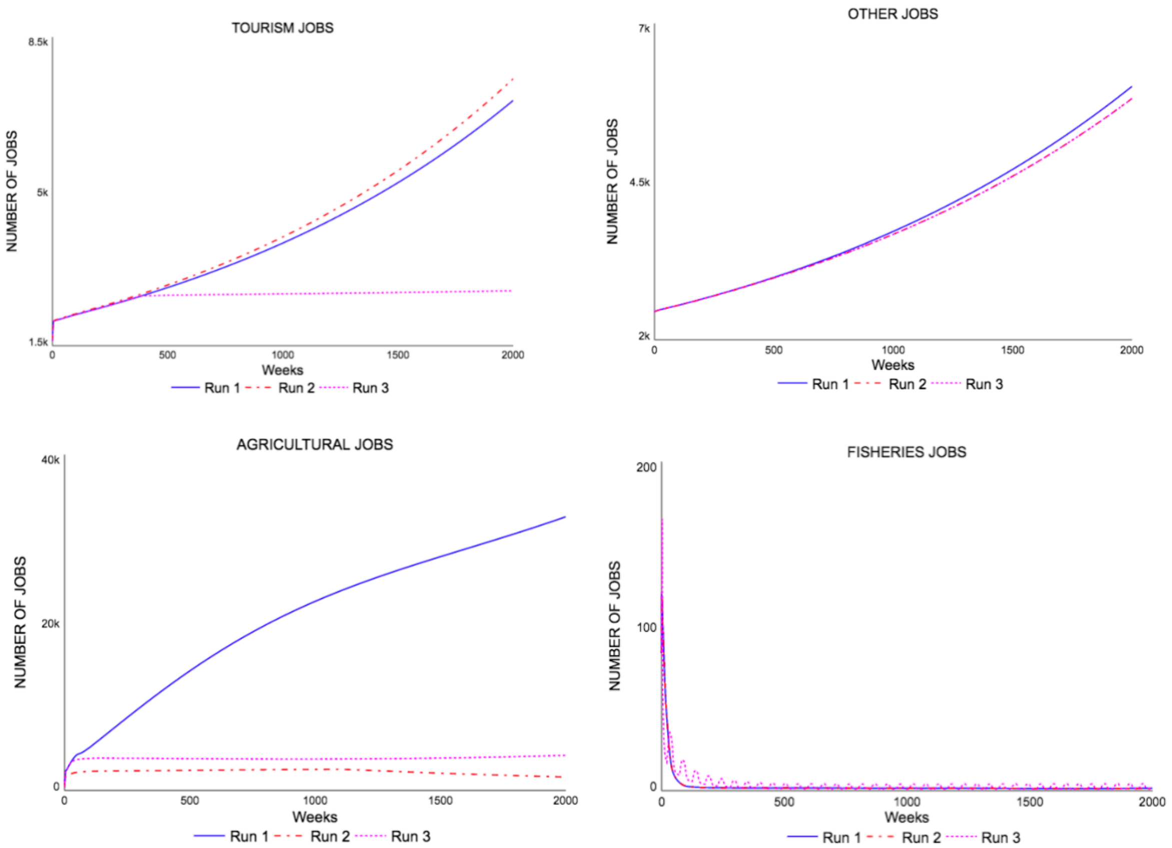


Figure 6-10. Trends for tourism, 'other', agricultural and fisheries jobs

Whilst the model simulates fisheries jobs as collapsing, the number of fishers, however, is increasing (Figure 6.11). Across all three scenarios the *number of traditional fishers* increases over the simulation time period, although the rate of increase is lower in Scenario 2 than for the other two scenarios. The *number of pelagic fishers* shows a small decline at the commencement of the period, before increasing across the time period, reflecting a shift of fishers from coastal fisheries into pelagics. Scenario 2 reflects a lower rate of increase than Scenarios 1 and 3. The *number of squid fishers* reflects the same trends as for those pelagic fishers outlined above, with an initial small decline before increasing over the simulation period.

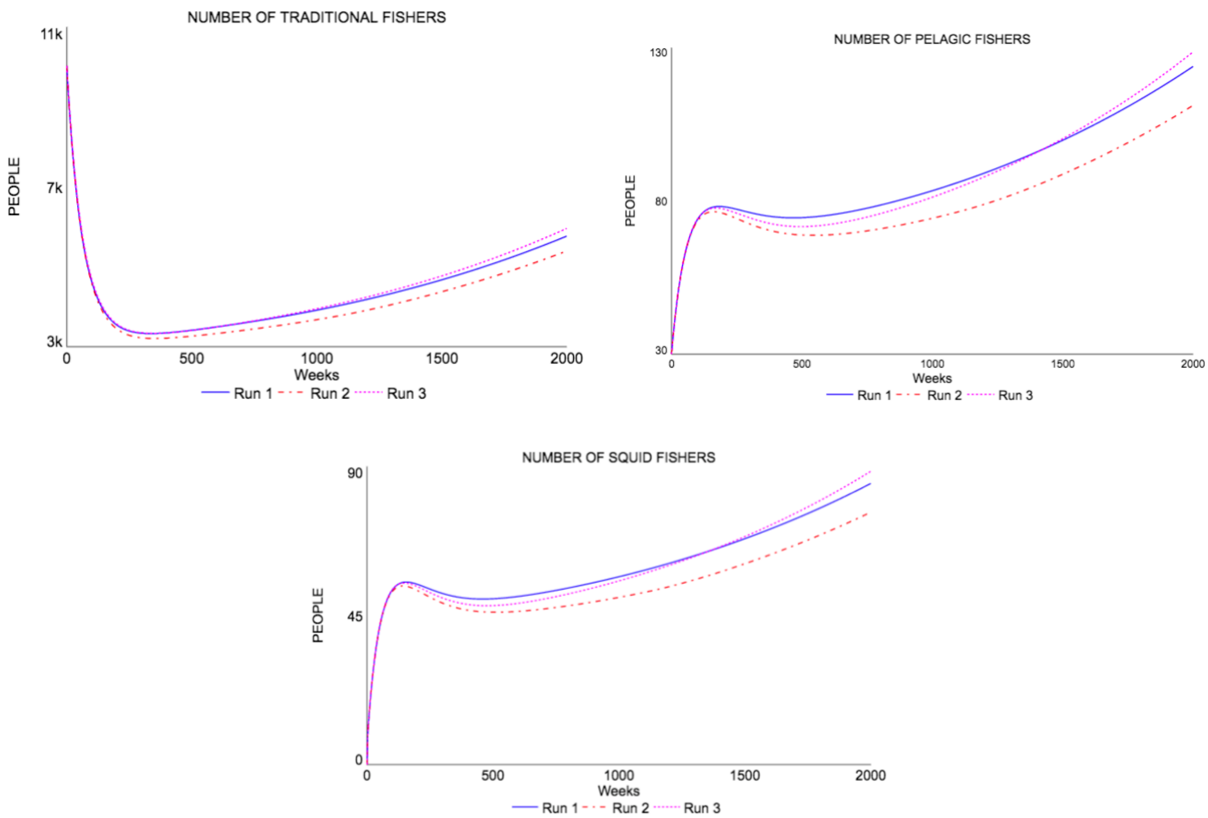


Figure 6-11. Projected fishers across traditional, pelagic and squid fisheries

6.2.4.2 Food demand

Modelling food consumption as the proxy for food demand, a review of the model's food consumption indicators highlight increasing trends for the consumption of crops, meat and fish in all three scenarios (Figure 6.12). Scenario 1 demonstrates a deviation away from the baseline levels (normal consumption per week of crops, meat and fish) as the actual consumption per week of crops, meat and fish increases at a higher rate. This could be due to food prices remaining steady (Section 6.2.4.3) and site savings increasing (Section 6.2.4.3), enabling people to have more disposable income to spend on food.

Actual crop consumption per week and actual meat consumption per week under Scenario 2 continues to deviate away from the baseline. However, the deviation is smaller than for Scenario 1. The price of food remains steady, however, whilst site savings increase, this is at a lower rate than for Scenario 1, which may be impacting upon consumption.

Scenario 3 reflects a similar trend to Scenario 2, with smaller deviations between actual and normal consumption. As food prices remain steady, the lower rates of consumption may be due to the lower level in site savings (Figure 6.17) leading to lower disposable income to be spent on food.

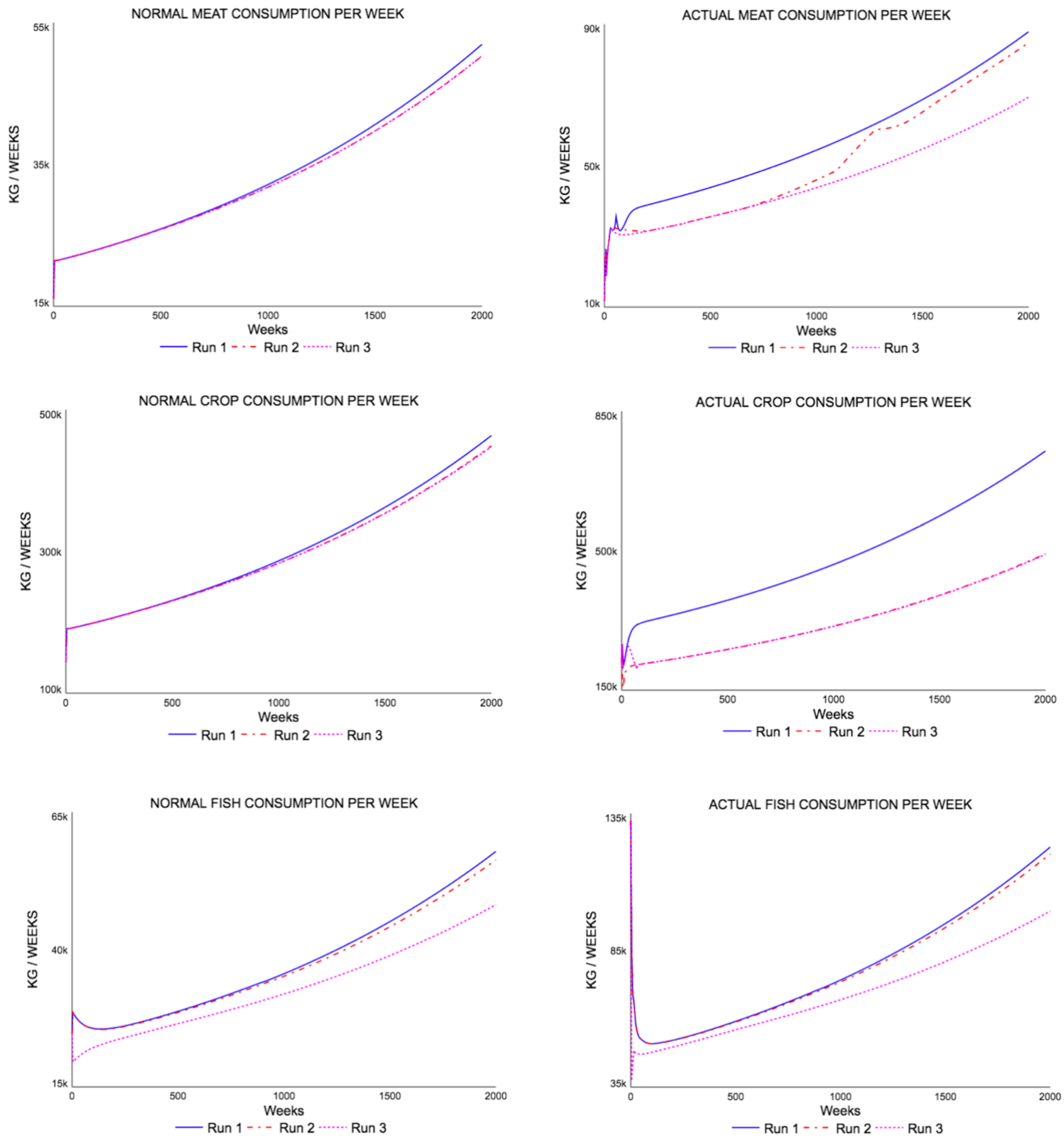


Figure 6-12. Projected food demand for meat, crops and fisheries

6.2.4.3 Food prices

The model indicates the actual *rice price at local market, cattle price at local market* and *pig price at local market* remain steady throughout the time period across Scenarios 1, 2 and 3, reflecting supply is meeting demand (Figure 6.13). Likewise, the steady trend reflecting the actual price of fish across the three scenarios for fish price (herbivores), fish price (predators) and fish price (squid) remains steady illustrating demand is being met through the importation of fish due to the low fish catch locally.

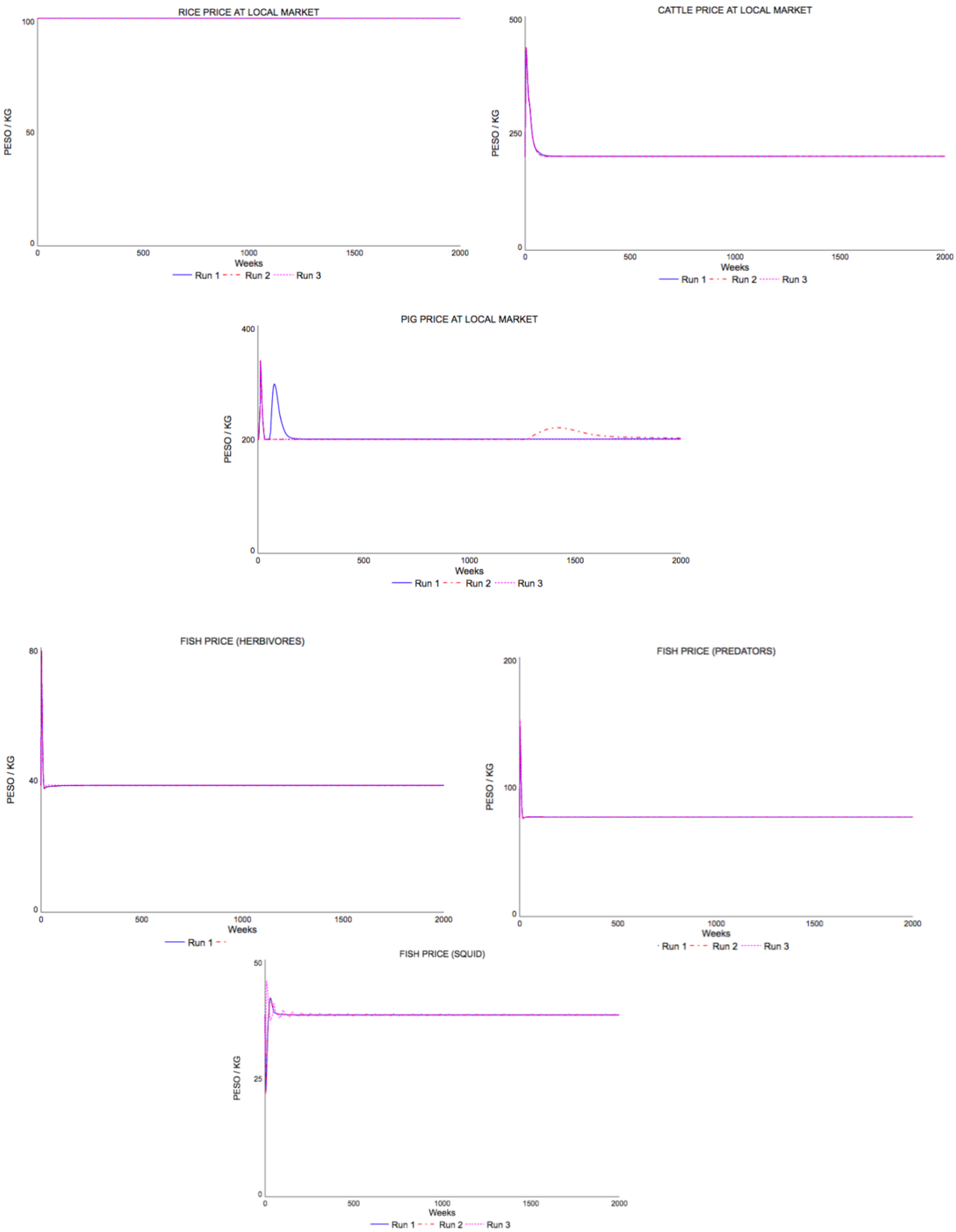


Figure 6-13. Projections for prices for rice, cattle and fish

6.2.4.4 Food supply

Food availability in El Nido is met through either agriculture or fisheries, either locally grown and caught, or imported. For agricultural production, the model simulates *agricultural land area used* increasing under Scenario 1 until reaching limits to growth or equilibrium. For Scenarios 2 and 3, the simulation reflects declines in the amount of land area used compared to Scenario 1, however, the trendline remains steady throughout the simulation period. The model shows the relationship land has on agricultural production with Scenario 1 reflecting increases in *crop production (lowland rice)* and *total crop production* (demonstrating reinforcing behaviour). Under Scenarios 2 and 3, the limitations to land are reflected in the gradual decline in these variables, with Scenario 2 showing lowland rice and total crop production reaching low levels by the end of the simulation time period (Figure 6.14).

Livestock supply to traditional market shows production or supply to the market collapsing under Scenario 1. Scenario 2 reflects growth to week 1400 before it declines, illustrating 'overshoot and collapse' behaviour. In Scenario 3, *livestock supply to traditional market* shows a growth trend in line with Scenario 2 until week 1500 whereby supply continues to increase under Scenario 3.

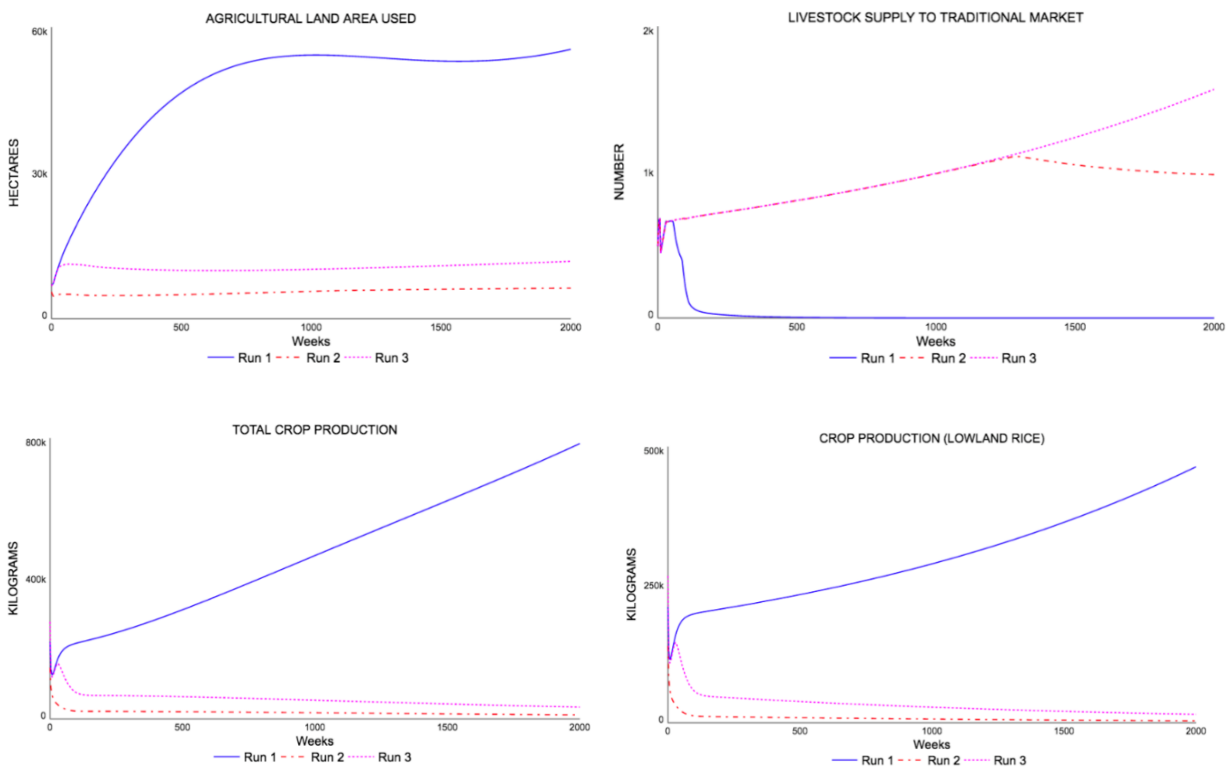


Figure 6-14. Projections for agricultural production

For fisheries, the model highlights fish catch maintaining a low but steady and consistent trend across all three scenarios for *reef traditional fish catch* (also reflecting fishing effort as seen in Annex D), although there is a small increase under Scenario 1 and 2 towards the end of the simulation's time period. *Mangrove traditional fish catch* reflects low catch with a declining trend towards the end of the simulation time period for all three scenarios, however Scenario 1 and 2 run at higher levels than Scenario 3. Across all three scenarios, *seagrass traditional fish catch* also remains low, however, Scenarios 1 and 2 reflect a small increase towards the end of the time period, similar to that seen for *reef traditional fish catch*. As with reef and mangrove fish catch, Scenario 3 for seagrass traditional fish catch remains lower than the other two scenarios (Figure 6.15).

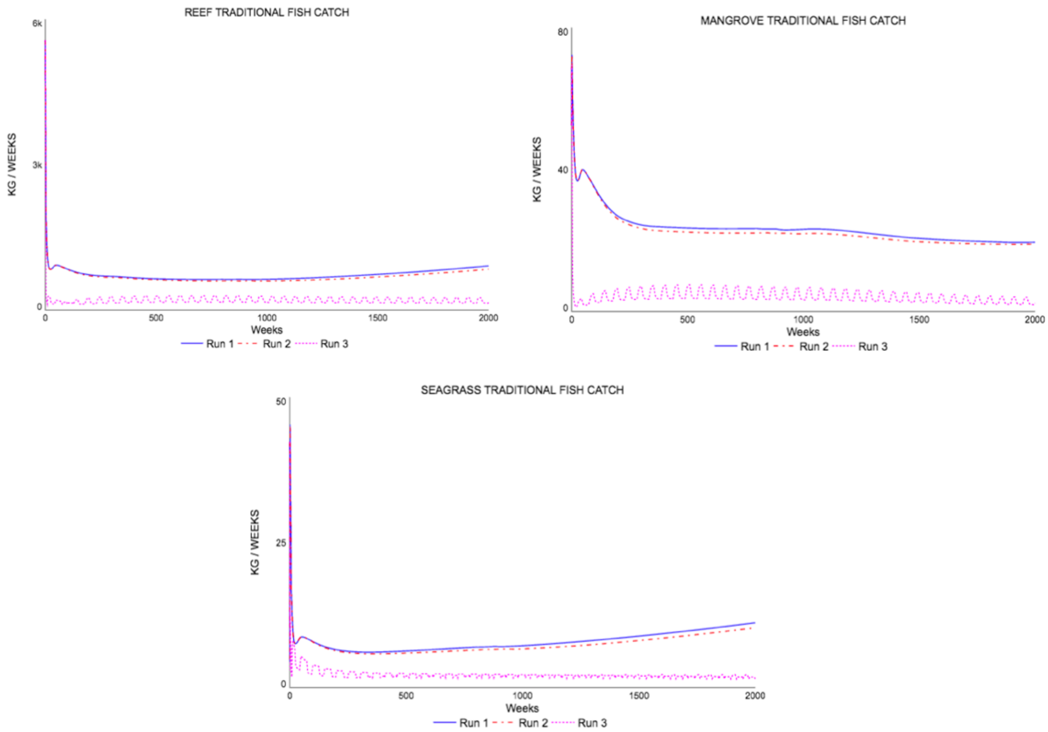


Figure 6-15. Projections for traditional fisheries

Food Imports

Food supply is further enhanced through the importation of foods. The model shows *dependency on imports* is >1 for all three scenarios however Scenario 1 highlights a higher dependency than Scenarios 2 and 3 (Figure 6.16). Highlighting food supply through imports, the model shows increases for *lowland rice imports* for Scenarios 2 and 3, with Scenario 2 showing a higher volume of imports. Under Scenario 1, *lowland rice imports* remain at zero, with the model illustrating the Municipality is producing enough rice locally to satisfy demand. *Total crop imports* across Scenarios 2 and 3 show the same trend as highlighted in imports of lowland rice, with both increasing in the simulation. *Total crop imports* for Scenario 1 also shows an increase albeit at lower volumes than experienced under the other scenarios.

The model simulates *total meat imports* under Scenario 1 as increasing at a higher rate than seen in Scenarios 2 and 3. Whilst Scenario 3 shows an increasing volume of imports this is at a lower rate than Scenario 1. Scenario 2 corresponds with Scenario 3 until week 1000 when it starts to increase exponentially.

Total fish imports increase for all three scenarios, with Scenarios 1 and 2 reflecting corresponding trends. Scenario 3 whilst showing an increasing trend across the simulation period, reflects lower levels of imports compared to the other scenarios.

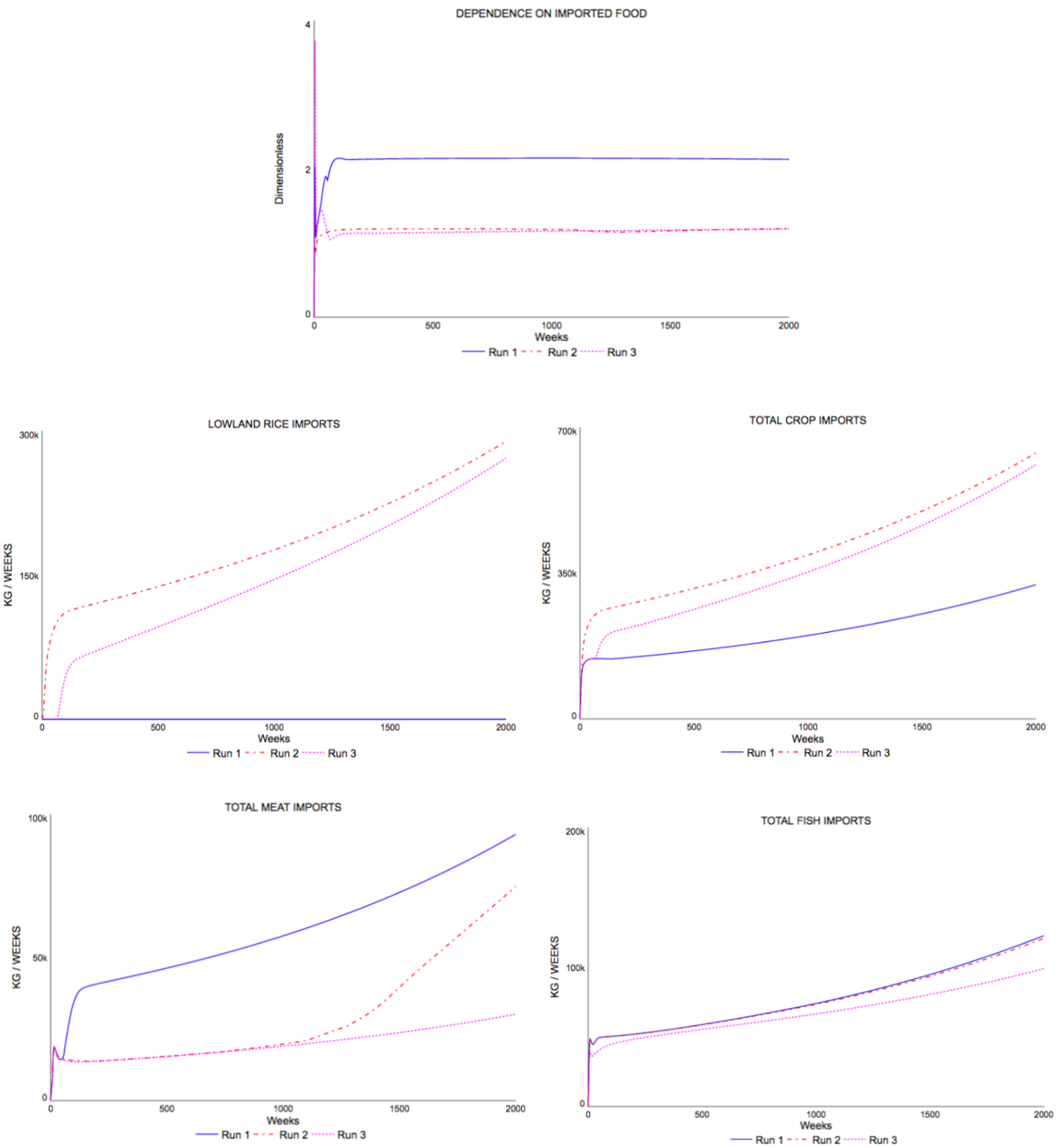


Figure 6-16. Projections illustrating dependency on food imports

6.2.4.5 Income and Savings

The growth seen in the model's simulation for tourism income per capita (Figure 6.17) corresponds with the trends for the tourist population (Figure 6.7) and the number of tourist jobs for Scenarios 1 and 2 (Figure 6.10). Scenario 3 reflects an increasing trend to approximately week 500 before income declines.

Agricultural income per capita remains at a steady trend across all three scenarios. For fisheries income per capita, the model demonstrates a system whereby inputs (effort) exceed outputs (income) as the income earnt shows a collapse in the system for all three scenarios.

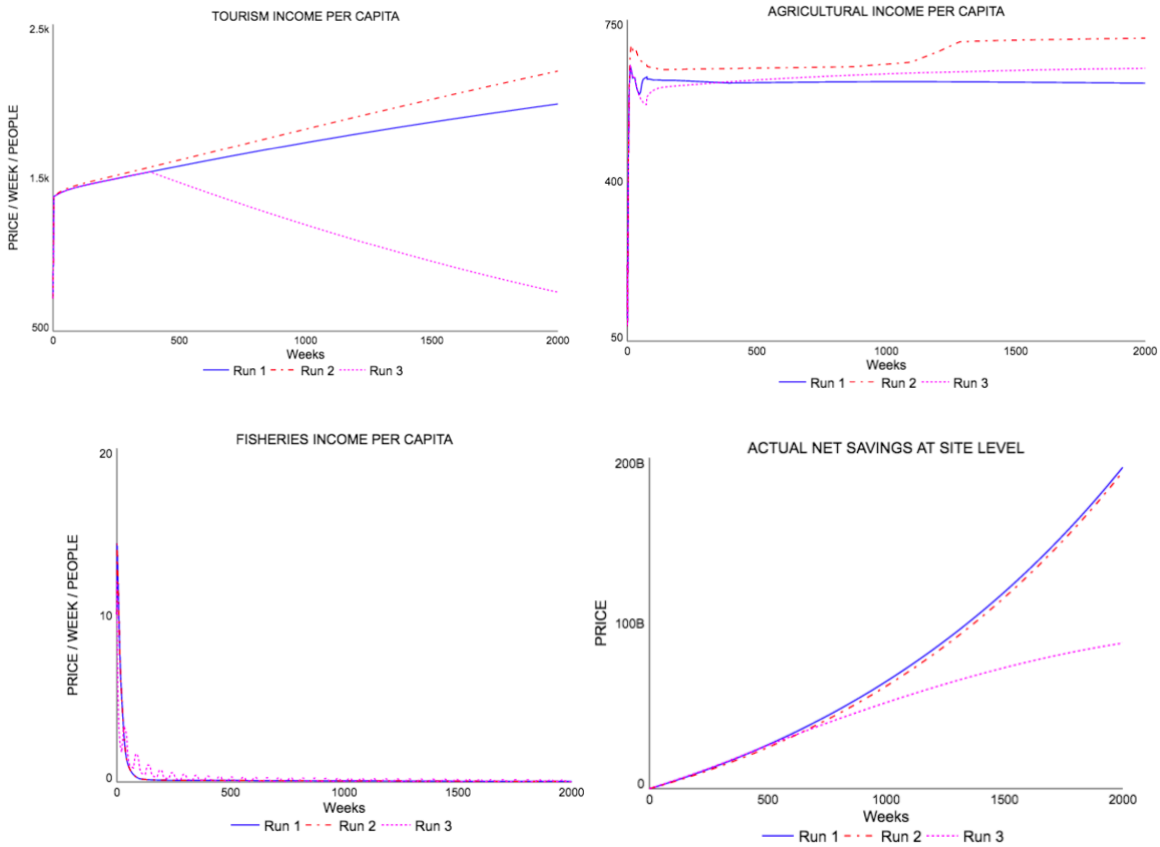


Figure 6-17. Projections for income against sectors

In Scenario 1 and 2, the actual net savings at site level increases exponentially illustrating the population in the Municipality is becoming wealthier through generated employment opportunities. Scenario 3 reveals an increasing trend, however, it remains at lower levels than the previous scenarios reflecting the cap on tourist numbers which also restricts the growth in incomes.

6.2.4.6 Demand for land

The model highlights demand for land through modelling urban land area (consisting of hotels and housing) (Figure 6.18). Under Scenario 1, the model simulates a system whereby demand for accommodation exceeds supply as the number of hotels cannot meet tourist demand. Despite total hotel area increasing exponentially, hotel capacity influences tourist arrivals as shown in the effect of hotel capacity on tourist arrivals which remains <1. Meanwhile, the number of hotels in non-mangrove areas reflects the exponential increase seen in total hotel area, whilst the number of hotels in mangrove areas declines.

Scenario 2 reveals corresponding patterns as to those viewed under Scenario 1. However, a key variation is in the effect of hotel capacity on tourist arrivals which remains at low levels (0.25) throughout the simulation period, signifying the number of hotels (or rooms available) cannot meet demand at any time throughout the simulation period. Scenario 3 shows the effects of the tourist cap intervention, with the total hotel area reaching equilibrium and remaining in that state for the simulation period, despite the overall urban land area increasing exponentially. The effects of hotel capacity on tourist arrivals reveals the supply of accommodation can meet demand with the model simulation increasing until it reaches equilibrium at week 500. The number of hotels in non-mangrove areas trends at lower levels than the previous two scenarios and remains steady, reflective of the same trend in total hotel area. The number of hotels in mangrove areas is declining at a faster rate than Scenarios 1 and 2.

The total housing area shows exponential growth across the three scenarios due to the growth in local population, with Scenario 2 progressing at a lower rate of change than Scenarios 1 and 3. The same trend is illustrated in the number of houses in mangrove areas, whilst the number of houses in non-mangrove areas also shows increasing trends for all three scenarios.

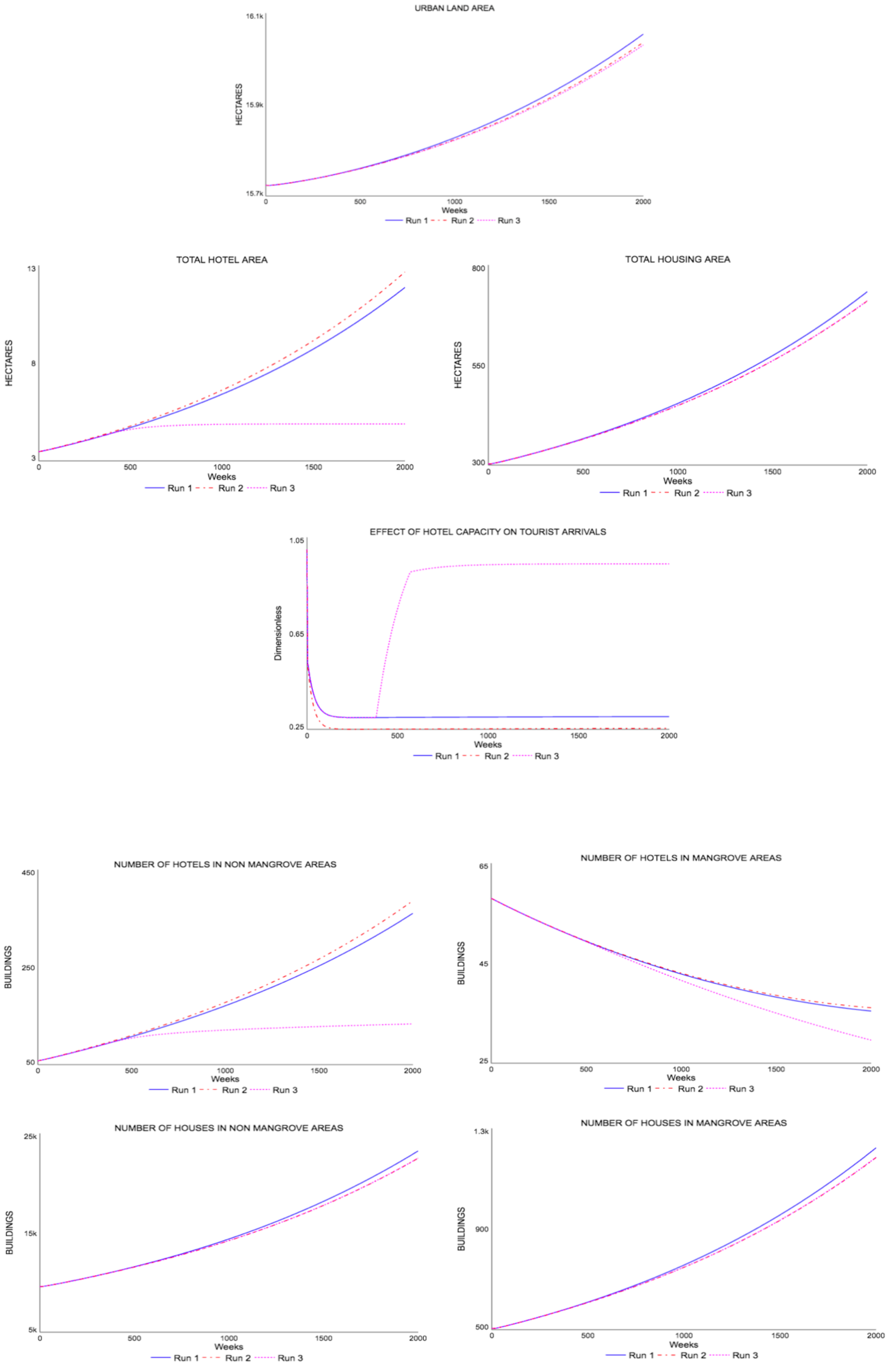


Figure 6-18. Demand for urban land for hotels and housing

6.2.4.7 Marine habitats

Total reef area under Scenarios 1 and 2 is declining, however, Scenario 3 shows a system in which total reef area remains stable (Figure 6.19). The decline in total reef area for Scenarios 1 and 2 is reflected in the decreasing trend in *carrying capacity (reef non-MPA area)* for these scenarios. Scenario 3 whilst also showing a decline, decreases over a longer time period than the other scenarios illustrating the effects of increased MPAs and surveillance. *Carrying capacity (reef MPA area)* across all three scenarios remains steady with no deviation. *Mangrove area* remains steady under all scenarios, however, there is a gradual increase over time in the amount of *converted mangrove area* for all scenarios.

The model illustrates *seagrass area* declining across all three scenarios, although Scenario 3 reflects a higher area of seagrass with a lower rate of decline. The decline in the seagrass area can be seen in the corresponding trends for seagrass area lost, which reflect exponential increases across all scenarios. Scenario 3 shows an increasing trend at lower levels than the other two scenarios. The declines are due to increased boat anchoring and sedimentation and pollutant run-off (refer Annex D).

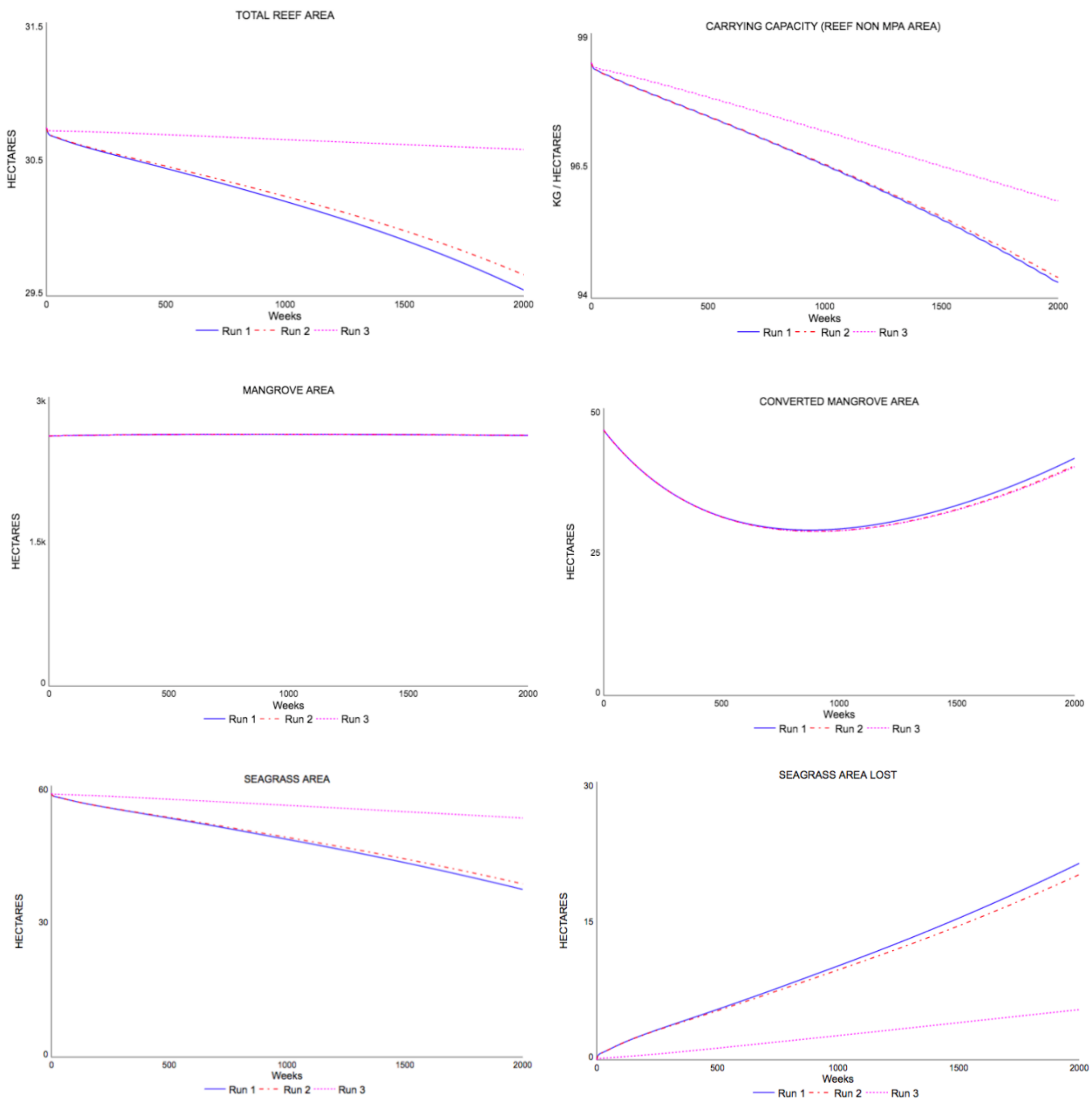


Figure 6-19. Projections for marine habitats

6.2.5 Discussion on the model simulation results

6.2.5.1 Scenario 1: Baseline or 'business-as-usual'

This scenario was undertaken to determine *'Under the current situation, what are the implications for food security over the next 30 years if the El Nido Local Government continues along this path?'* The model highlights a situation whereby the tourist and local populations will continue to grow at an exponential rate (Figure 6.7). Whilst the model illustrates emigration exceeding immigration (Figure 6.8), the local population may still continue to increase due to increases in birth rates. Immigration will also occur, and this combined with the birth rate, may offset any immediate effects felt by emigration exceeding immigration. The model highlights migration into and out of the Municipality as influenced by the labour-job ratio (Figure 6.9). If the labour-job ratio remains <1, i.e. there are excess job opportunities compared to labour availability and immigration will exceed emigration. Likewise, if the labour-job ratio increases to >1, emigration will exceed immigration.

With the growing tourist and local populations, the model highlights a situation in which demand for food is being met by both local agricultural production (Figure 6.14) and traditional fish catch (Figure 6.15), and the importation of food (Figure 6.16). Modelling food consumption as the proxy for food demand, a review of the model's food consumption graphs highlights parallel trends between those of *tourism population* and *local population* (Figure 6.7) and the consumption of crops, meat and fish (Figure 6.12). Whilst the tourist and local population influences actual consumption per week of crops, meat and fish, other influences including the stability in food prices (Figure 6.13), growth in incomes and increased wealth at the site level (Figure 6.17), impact upon consumption.

El Nido has historically relied upon the local agricultural and fisheries sectors to meet the food and livelihood needs of the Municipality's local population. Whilst the agricultural sector shows growth in crop production (lowland rice) and total crop production (Figure 6.14), this is not enough to meet the demands of the population, with imports of crops and meat increasing to meet the gap between demand and supply (Figure 6.16). In meeting the demand for fish, the fisheries sector shows an inability to provide enough fish from local stocks and is reliant on fish imports to fill the gap (Figure 6.16). In particular, the low levels of fish catch, declining fish density and degraded habitats (Figures 6.15 and 6.19) reveal a system under pressure. Furthermore, the increase in fishers (Annex D) combined with the low fish catch, signifies a fisheries system experiencing overfishing. The declines across the fisheries variables occurs very early in the timeline and reflects an overshoot and collapse of the system brought about by the erosion of the carrying capacity of the system, creating negative feedback limiting growth (Sterman 2000).

A number of pressures on the food system affecting the ability to produce enough agricultural and fisheries produce are highlighted by the model. The increased growth in tourist and local populations (Figure 6.7), and the rising demand for land for hotels and housing (Figure 6.18) leads to not only competition with the agricultural sector for available land, but also creates flow-on impacts downstream. The model demonstrates the impacts of tourism and housing development through modelling pollutant concentrates and loading into the system (Annex D). As outlined in Chapter 5, the food system is heavily impacted upon by: pollutants from urban waste generated from increasing tourist numbers and local population and poor waste management controls; runoff from increased fertiliser use in farming and; the degradation of terrestrial habitats brought about by the cutting and logging of forests and mangrove forests to generate farming land in the uplands and land for housing in the mangrove coastal areas, for timber and non-timber resource use and which leads to increased erosion and sedimentation.

The decline of subsistence food sources and the increase in imports to provide for the tourist population and local population's needs as illustrated in the simulations, can impact on the ability of the people to access food as if people do not have sufficient income to purchase food. Whilst food availability is met, the ability to economically procure food closely correlates to entitlements or income (FAO 2006). The ability to access food is not only reliant upon food availability and income, but also on pricing of food and whether this remains within the reach of the population to procure. The model demonstrates a situation whether people are spending more (>1) or less (<1) on food (fish, crops, meat) through the *actual net savings at site level* variable. In the Baseline Scenario, the *actual net savings at site level* increases demonstrating people are spending more on food (Figure 6.17).

In determining food price trends, the model utilises the actual value to calculate the expected pricing stream, rather than future values based on the inclusion of inflation rates. The model indicates agricultural and fisheries food prices i.e. *rice price at local market*, *cattle price at local market*, *pig price at local market* and *fish price (herbivores, predators and squid)* remain steady, reaching equilibrium levels (Figure 6.13) - indicating current supply is meeting demand due to the importation of food.

As habitats continue to erode without increased policy interventions and enforcement and continue to decline, a portion of the local population are moving away from these traditional livelihoods into tourism or tourism-related industries to take advantage of higher wages, thus shifting towards a dependence on a single-sector economy for income generation (Figure 6.10). However, for others in the Municipality the shift into other employment is more difficult due to lack of education or skills, and therefore they are caught in a vicious cycle of continuing to attempt a livelihood from declining resources. For many in the Municipality, they still remain under the poverty and food thresholds (Section 4.7), thereby signifying a potential lack of access to food in the future.

Box 6.1. Key findings from the Baseline Scenario

Key findings from the model simulations for the Baseline Scenario include:

- Tourist numbers and local population show strong and continued growth
- Demand for food is intensifying and is increasingly met by imports
- People are spending more of their income on food
- Increases in incomes are leading to higher levels of consumption of food
- Fisheries remain in decline due to overfishing and degradation of habitats
- Rising demand for urban land for hotels and housing is leading to increased competition with the agricultural sector
- Increased tourist numbers and local population is leading to an increase in pollutants

6.2.5.2 Scenario 2: Policy Implementation

The Policy Implementation scenario responds to '*What is the most likely future scenario if the El Nido Local Government implements the policies it has or has proposed to their fullest? What are the implications for food security over the next 35 years?* (Table 6.1). Within this scenario, policies and regulations pertaining to land use, habitat protection, fisheries management and waste management were tested within the model and compared to the Baseline Scenario responses. The model simulations demonstrate that whilst the implementation of a set of policies outlined in Table 6.5 increase tourism and tourism-related livelihoods and income, these measures impact adversely on the local agricultural production and do little to improve the fisheries sector and supporting marine ecosystems.

The model illustrates exponential growth in the *tourist population* and *local population* (Figure 6.7) and again shows the influence of immigration and emigration on the local population similar to the Baseline Scenario. However, in this scenario, outputs exceed inputs within the system, that is, *emigration* exceeds *immigration*, with the model showing *emigration* increasing whilst *immigration* declines substantially compared to the Baseline Scenario (Figure 6.8). The *labour-job ratio* continues to remain the most influencing effect on migration, with immigration <1 and emigration >1 (Figure 6.9), demonstrating declining job opportunities and excess labour, which could be linked to lower numbers of agricultural and fisheries jobs (Figure 6.10).

As per the Baseline Scenario, the tourist and local populations continue to drive demand for food, land and water resources. Food consumption continues to deviate away from the baseline consumption patterns (i.e. normal consumption per week), with *actual crop consumption per week* and *actual meat consumption per week*, showing the largest deviations, illustrating both increases in the population and a possible shift in consumption patterns. *Actual fish consumption per week* runs parallel to the Baseline Scenario, showing an increasing trend, however, the deviation away from the baseline consumption patterns is at lower levels than for crops and meat, highlighting possible high consumption rates for fish at the baseline level, and a shift in consumption patterns towards meat products (Figure 6.12).

The reduction in the amount of land available for agricultural use (Figure 6.14) and low fish catch (Figure 6.15) shifts food production away from the local sector towards a reliance on imports (Figure 6.16). As the amount of *agricultural land area used* declines from the Baseline Scenario level due to re-zoning, a ‘limits to growth’ scenario is reached immediately impacting upon *crop production (lowland rice)* and *total crop production* (Figure 6.14). *Livestock supply to the traditional market*, however, shows growth to week 1400 before it declines (Figure 6.14) – reflecting an ‘overshoot and collapse’ behaviour (Sterman 2000). This pattern reflects a situation whereby the lack of available land is influencing the selling of livestock rather than price which remains steady (Figure 6.13). However, once all available livestock has been sold at market without replenishing stock, the supply of livestock reflects a decline commencing at week 1400.

As with the Baseline Scenario, the flow-on effects of increased growth in the tourist population and local population (e.g. overfishing and habitat degradation) continue to affect the ecosystem underpinning the fisheries food system, albeit at a lower rate than experienced under the Baseline Scenario. Simulations for the fisheries sector reveal overfishing still occurs under Scenario 2 with low and declining fish catch across reefs and mangroves, whilst increasing slightly in seagrass habitats (Figure 6.15). Fish density is reliant on the health of the marine ecosystems to maintain healthy stocks (refer Section 5.4.1). Despite the reduction in farming caused by declines in agricultural land, the introduction of an improved waste management system and increased zoning for forests, there still remains higher levels of pollutants entering and exiting the system as seen under the Baseline Scenario – all of which impact onto the marine ecosystem (Figure 6.19). As a result, exponential declines for the *total reef area* and subsequently *carrying capacity (reef non-MPA area*) continues despite small intervention measures, signaling the habitat is losing its ability to maintain a healthy fish population.

Whilst food availability is met through imports (Figure 6.16), food access is still determined by the ability of people to procure food. Whilst income levels for *tourism income per capita* remain high (Figure 6.17), many of the population remains employed outside of the tourism sector and do not benefit from tourism income. The majority of the population in El Nido continues to remain in low-income earning positions such as agriculture and fisheries (refer Table 4.5) and remain under the poverty and food threshold (refer Table 4.6). Whilst the model simulates *agricultural income per capita* remaining steady reflecting the Baseline Scenario trend, *fisheries income per capita* collapses as fish catch declines (Figure 6.17). The model illustrates a system whereby actual food prices for rice, meat and fish remain steady as supply meets demand (Figure 6.13), people are still spending a larger amount of their income on food, as demonstrated with the *actual net savings at site level* (Figure 6.17). For future prospects, as prices rise this may lead to difficulties with a large portion of the population unable to procure agricultural and fisheries products if their income does not increase in line with price rises. Furthermore, as the land and marine ecosystems continue to degrade, their ability to produce or catch food for either income or subsistence becomes limited.

Box 6.2. Key findings from the Policy Implementation Scenario

Key findings from the model simulations for the Policy Implementation scenario include:

- Policy implementation focusing on tourism adversely impacts on local agricultural and fisheries sectors
- Tourist numbers and local population show continued growth
- Demand for food continues to increase and is met by imports
- Shift in consumption patterns towards meat products
- People continue to spend more of their income on food

6.2.5.3 Scenario 3: Resource-efficient Consumption

In responding to the question '*what are the implications for food security over the next 30 years (until 2050) if the El Nido Local Government implements an ideal set of policies?'* Scenario 3 explored a series of interventions across the agricultural, fisheries and tourism sectors. The resulting model simulations illustrate a system which despite the series of interventions aimed at moving the system back towards equilibrium and reversing declines across the agriculture and fisheries sectors, will require an integrated series of stronger interventions in order to reverse the declines being experienced. However, further analysis outside the scope of this study, would be required to determine whether stronger interventions will bring the system back into some balance between meeting the population's needs, improving local food production and ensuring environmental protections.

As seen in the model simulations, despite limitations placed on tourist arrivals, the local population continues to grow exponentially (Figure 6.7), despite emigration outpacing immigration (Figure 6.8). This may be a reflection of the birth rate exceeding the death rate rather than migration factors dominating population growth. The *labour-job ratio* is again the key influencing factor, with labour availability exceeding the number of job opportunities (Figure 6.9). Whilst opportunities are still available in *tourist jobs* and *other jobs*, job losses are experienced across the agricultural and fisheries sector (Figure 6.10). *Agricultural job* losses are exacerbated by declining agricultural land area and low production levels (Figure 6.14), whilst the decline in *fisheries jobs* is intensified by increases in the number of fishers (Annex D) and declines in fish catch and fish density.

Whilst consumption levels of food remain at lower levels than the Baseline and Policy Implementation Scenarios (Scenarios 1 and 2), food demand remains on an upward trajectory. This is reflected in the deviation of *actual consumption per week for crops, meat and fish* away from the baseline i.e. normal consumption per week (Figure 6.12). However, to meet this food demand, the local production systems are not able to produce enough to satisfy demand (Figure 6.14 and 6.15). The amount of *agricultural land area used* remains at significantly lower levels than Scenario 1, although at higher levels than Scenario 2 (Figure 6.14), and this has repercussions on the yield of lowland rice and crops, and how much livestock is produced. The model simulates declines for both *crop production (lowland rice)* and *total crop production*, whilst *livestock supply to traditional markets* shows exponential growth as farmers continue to sell off livestock due to land limitations (Figure 6.14).

With low yields of crops, livestock production and fish catch (refer below) from local sources, demand for food remains heavily *dependent on imports* to fill the demand – supply gap. *Lowland rice imports* and *total crop imports* show exponential increases as demand increases and local supply declines, whilst *total meat imports* and *total fish* *imports* also show increasing trends but at a lower trajectory than for lowland rice and crops (Figure 6.16).

Food sourced through the local fisheries sector also shows declining or collapsing trends under Scenario 3. In this scenario, policy interventions relating to seasonal catch and quotas, licensing and habitat protection were implemented, and the results of these interventions are reflected in the graphs for fish catch, fish density and carrying capacity, fishing boats and fishing effort, and habitats simulations. *Reef traditional fish catch, mangrove traditional fish catch,* and *seagrass traditional fish catch* all demonstrate oscillating behaviour (Figure 6.15), illustrating the impacts of the 'seasonal effect of fishing' switch in the model's interface, regulating fishing effort and fish catch leading to peaks and troughs reflecting seasonal fishing effects or closed fishing seasons. With this protectionist intervention in place, fish catch is lower than under Scenarios 1 and 2 and shows a declining trend across the simulation period.

The fisheries management interventions implemented in Scenario 3 (Table 6.5) also impact upon traditional fishing effort and fishing boats – illustrating the effects of the 'seasonal effect on fishing' switch used to reduce fishing effort in out-of-season and implement catch quotas. As seasonal effects, increased surveillance and an increase in marine protected areas are implemented, fishers move away from coastal fisheries to pelagics – as evidenced by the increase in *traditional fishing effort in pelagics* and the decline in *traditional fishing effort on reefs, traditional fishing effort in mangroves* and *traditional fishing effort in seagrass* (refer Annex D).

Likewise, limits to the number of boat licenses, increased surveillance and MPAs leading to a shift in fishers moving away from coastal fisheries to pelagics is also evident in the model simulations for fishing boats (refer Annex D). The number of *traditional fishing boats* remains lower than the previous two scenarios, whilst *large fishing boats (pelagics and squid)*, show an increasing trend running parallel with Scenario 1. Simulations for *destructive fishing boats* also shows a similar upwardly increasing trend, although the number of destructive fishing boats is at lower levels than for Scenarios 1 and 2 thus illustrating the effects of increased surveillance effort on bomb and poison fishing. Previous patterns of fishers shifting entirely away from traditional fishing into tourism remains strong, with the model highlighting *tourist boats* increasing until the cap on boat licenses is reached and it remains steady.

The effects of implementing the fisheries management interventions is also reflected across the model's simulations for marine habitats, subsequently demonstrating flow-on effects to fish density and habitat carrying capacity. With the *total reef area* increasing from the previous scenarios, this increases the *carrying capacity (reef non-MPA area)* which in turn improves the *reef non-MPA fish density* (refer Annex D). Whilst the overall trends for these variables remain as declining, the interventions demonstrate improvement over Scenarios 1 and 2. The greatest flow-on effects of the interventions are seen with reefs, with the simulations for mangrove and seagrass habitats[32] remaining the same as Scenario 1 and 2 outputs (Figure 6.19) with the exception of a rise in *seagrass area*. The rise in *seagrass area* and reduction in *seagrass area lost* is a reflection of the decreased mooring damage of fishing and tourist boats, caused by limitations to the number of boats allowed in the area (refer Annex D).

The effects of the intervention on tourist numbers can be seen across a number of the variables, in particular those relating to tourism developments. Whilst *urban land area* remains at the same level as previous scenarios, the effects of the tourist cap is reflected in the decline in *total hotel area*, as the supply of hotels is able to meet demand from week 500 onwards, as reflected in the *effect of hotel capacity on tourist arrivals* (Figure 6.18). The decline in hotel demand is also seen in the lower trend for *number of hotels in non-mangrove areas* and in the decreasing rate in *number of hotels in mangrove areas* above those in Scenarios 1 and 2 (Figure 6.18). As less hotels are required to meet tourist demand, less hotels are being built in these areas. Demand for local housing remains high however, as the *local population* continues to increase (Figure 6.7) and this is reflected with an exponential increase in the *total housing area*. For local housing, the model illustrates the connection between local population growth, total housing area and where the houses are constructed, reflecting no change from previous scenarios as the *number of houses in non-mangrove areas* and the *number of houses in mangrove areas*, continue to show increases (Figure 6.18).

Furthermore, the impact of an increasing local population with minimal building and waste management regulations or controls, is reflected in the model through increased levels of pollutants entering and exiting the system. *Pollution concentration estuary (sediment)*

[32] The one exception is the simulation for seagrass area which shows increases above Scenarios 1 and 2, and seagrass area lost which also reflects improvements under Scenario 3.

continues to increase and reflects higher levels than evidenced under Scenario 1 and 2. These patterns are also reflected in the *pollutant loading from catchment into estuary area (sediments)* and *smoothed sediment loading from catchment* (refer Annex D). The increase is due to increased sedimentation from forest and mangrove clearing for housing as seen in the growth in housing construction in both non-mangrove and mangrove areas increases (Figure 6.18) and continued farming practices overusing fertilisers and pesticides. The increase in the level of sediments and pollutants is reflected back on the marine ecosystem health as *reef non-MPA fish density, mangrove fish density* and *carrying capacity (reef non-MPA area)* continues to decline (refer Annex D).

Lastly, demand and competition for water resources from the agricultural and urban sectors continue to reflect high levels of groundwater extraction, despite tourism related interventions and lower levels of agricultural activity. The model simulates an exponential growth trend for levels of water demand and extraction, albeit at lower levels than previous scenarios, as illustrated in the graph *water table depth below surface* (refer Annex D).

As with the previous two scenarios, whilst food availability remains stable due to the dependence on imports, the ability of people to economically access food remains reliant on people's ability to pay, exerting pressure on income generation. The model highlights several situations in terms of the reliance on income generation from the three key sectors – tourism, agriculture and fisheries. Reflecting the restrictions on tourist numbers, which in turn restricts the number of *tourist jobs* (Figure 6.10), *tourism income per capita* shows an 'overshoot and collapse' behaviour, with income declining exponentially from week 500 as growth in the tourism sector halts (Figure 6.17). *Agricultural income per capita* remains steady at rates higher than under Scenario 1 but lower than Scenario 2, and as with previous scenarios, *fisheries income per capita* collapses (Figure 6.17). Whilst people are spending less of their income on food (as demonstrated through the *actual net savings at site level*, the simulation still reflects an increasing trend for food spending, just at lower levels than in the previous scenarios (Figure 6.17).

Overall, whilst the interventions under Scenario 3 impact positively in some areas (i.e. water demand, marine habitats, tourism development), in the key areas relating to improving local food production and maintaining livelihoods, the interventions fail to ensure a sustainable level over the simulation period, and both the production of food and income generation from key employment sectors decline. In summary, fisheries and agricultural production still remain on a downward trajectory, and the limitations to tourism growth impact on economic growth in the Municipality restricting the local population's ability to access food.

Box 6.3. Key findings from the Resource Efficient Consumption Scenario

Key findings from the model simulations for the Resource Efficient Consumption scenario include:

- Interventions do significantly improve local food production and maintain livelihoods
- Local population continues to grow despite emigration outpacing immigration
- Food demand continues on an upward trajectory, although at lower levels than previous scenarios
- Local agricultural production and fish catch declines, and food demand is met by imports
- Despite a number of fisheries interventions, fish catch continues to show declines however, illegal fishing shows an increase
- Jobs and incomes across tourism, agriculture and fisheries sectors are declining and people are now spending less of their income on food

6.3 Assessing the food system under shocks

Scenario 4 assesses how resilient the food system in El Nido is to shocks under the three scenarios – Baseline, Policy Implementation and Resource-efficient consumption. The shocks tested in the model simulation are outlined below.

A. A decline in tourist numbers

The shock simulates a future collapse of tourist numbers and the effects on the local population, food consumption and tourism development. The shock simulates tourism dropping to 5 percent of current value (across all three scenarios) and commences in year 5 (i.e. 52 weeks * 5) and stops at the end of the 12-month period (52 weeks) later. At the end of the 'shock' period, the annual tourist growth rate returns to the previous rate i.e. 12 percent (Scenarios 1 and 3) and 14.5 percent (Scenario 2). The 'shock' reflects the sensitive nature of tourism and is reflective of external influences on the tourism industry which impact at the local level such as security concerns, a global financial crisis or the attraction of El Nido as a tourist destination diminishing and travelers moving elsewhere.

B. A decline in the volume of local agricultural production

The model simulates a decline in rainfall leading to drought conditions. A rainfall reduction metric was used to simulate a drought. The rainfall reduction percentage set for the shock is the magnitude of the drought. For example, the shock is set to 95 percent rainfall reduction, simulating rainfall is 95 percent less than normal. The timing of the shock is determined by the 'drought start week'. In this simulation the 'drought start week' commences in year 5 and continues for a 12-month period. The start and end period correspond with the tourism shock. The shock simulates the effect of a reduction in rainfall on crop production and surface water volume.

C. A decline in food imports

The model simulates a 50 percent reduction of current imports under the Baseline Scenario for crop and meat imports, whilst fish imports are capped at 200kg per week. The cap is set across the life of the simulation period and reflects pressures on external market sources through turning on the 'import cap' switch in the interface. This shock explores the impacts of an external policy intervention which requires the food producing areas to meet the food demands of local population first prior to any exports. The likelihood of such an event arose from discussions with the El Nido Agricultural Technical Officer (El Nido MAO 2017), in which local food shortages were highlighted as occurring in one of the key supply areas to El Nido Municipality - Taytay, situated to the south of El Nido, due large volumes of food being exported rather than meeting local requirements first.

6.3.1 Results of the model simulation against shocks

The shocks were run across all three scenarios i.e. Baseline, Policy Implementation and Resource-efficient consumption, and simulate the effect of a scenario whereby all three shocks are tested simultaneously within each of the three scenarios. Results of the model simulations for Scenario 4 are outlined below with the discussion of the results in Section 6.5.2.

6.3.1.1 Socio-economic drivers

Under the shocks, the model simulates the decrease in tourist numbers (5 percent of current value). The *tourism population* increases to week 260 (five-year mark) before declining to just above zero levels for all three scenarios (Figure 6.20). The simulation shows at the end of the 12-month shock period, tourism numbers increase over the time period reflecting s-shaped growth behaviour across all three scenarios. Scenario 2 reveals the number of tourists increasing at a faster rate than the other scenarios due to the higher annual tourist rate i.e. 14.5 percent. The model simulation highlights the relationship between tourism and local population (Chapter 5) illustrating declines across all three scenarios. The system behaviour in Scenario 1 and 3 reflects goal seeking behaviour as limits are reached with population decline. Scenario 1 reveals less impact from the tourism decline than Scenario 2 and 3.

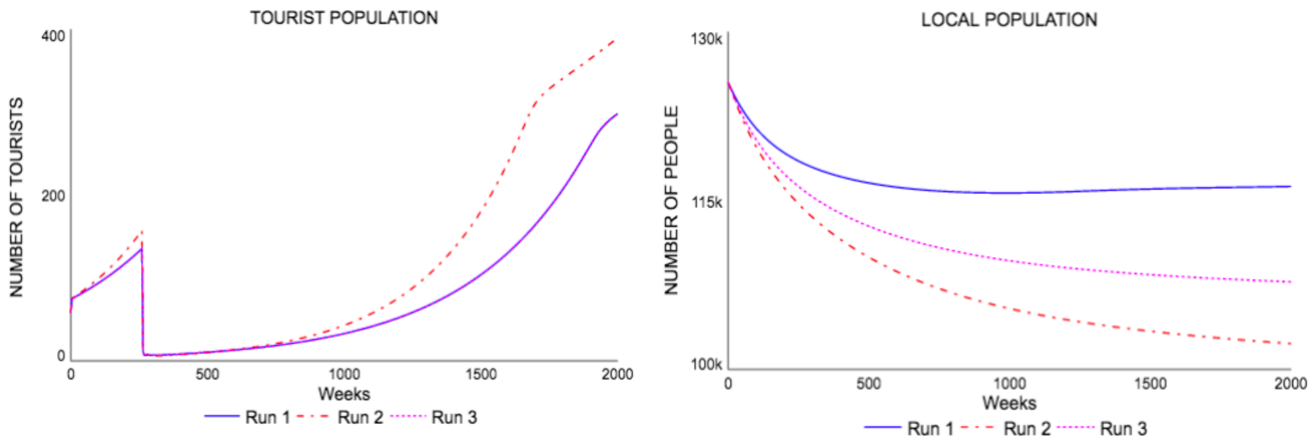


Figure 6-20. Projections for tourist numbers and local population under the system shocks

The declines in the local population is reflected in migration rates, with each scenario illustrating the emigration rate exceeding the immigration rate (across all scenarios the immigration rate remains at zero) (Figure 6.21). The increased level of emigration compared to the scenarios in Section 6.3, is due to a fall in food availability.

The simulations under Scenarios 1, 2 and 3 demonstrate the most influential effect on immigration and emigration is food availability (Figure 6.22). This is evidenced in the declines of actual consumption per week for crops, meat and fish whereby it is lower than the baseline levels (Figure 6.25), declining crop production, livestock and fish catch which remains unaffected by the shocks (Figures 6.27 and 6.28), and restricted imports (Figure 6.29).

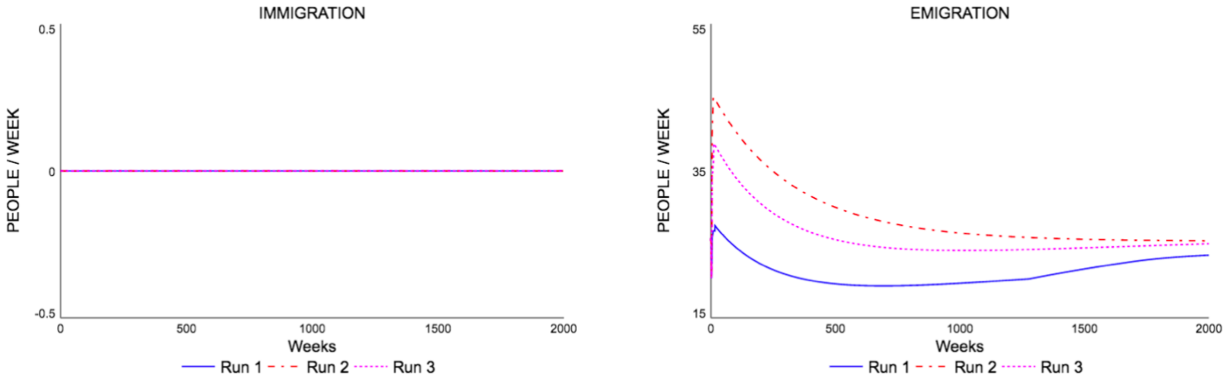


Figure 6-21. Migration trends under the system shocks

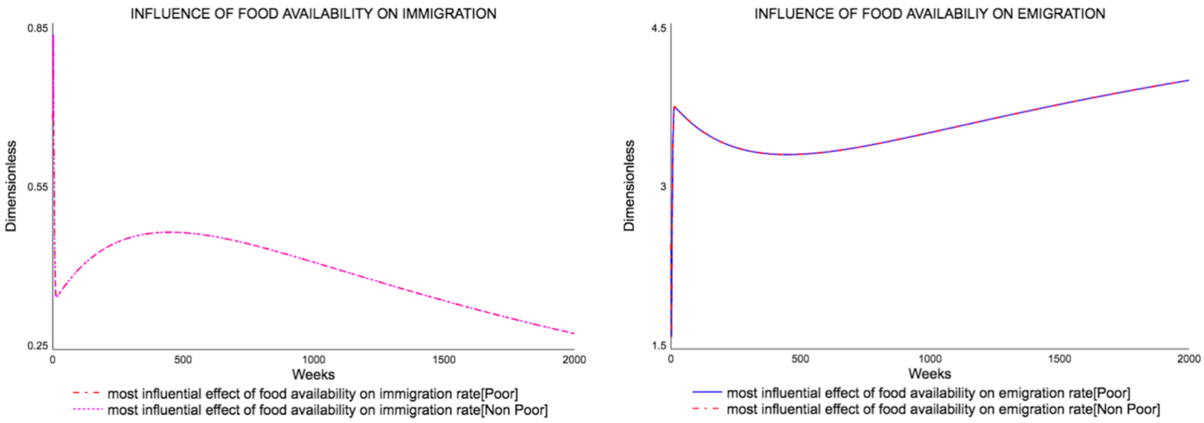


Figure 6-22. Influence of food availability on immigration and emigration under the system shocks

6.3.1.2 Jobs and Income generation

Tourism jobs and *tourism income per capita*, closely reflect the tourist population trend (Figure 6.23), demonstrating the relationship between these variables. Both variables illustrate the impacts of the fall in tourist numbers in year 5 with declines followed by slow increases across the simulation period. In the tourism income per capita graph, Scenario 2 reveals behaviour of overshoot and collapse – increasing before it starts to decline in week 1700. This behaviour is also mirrored in Scenario 1 and 3, but at a later time in the simulation period.

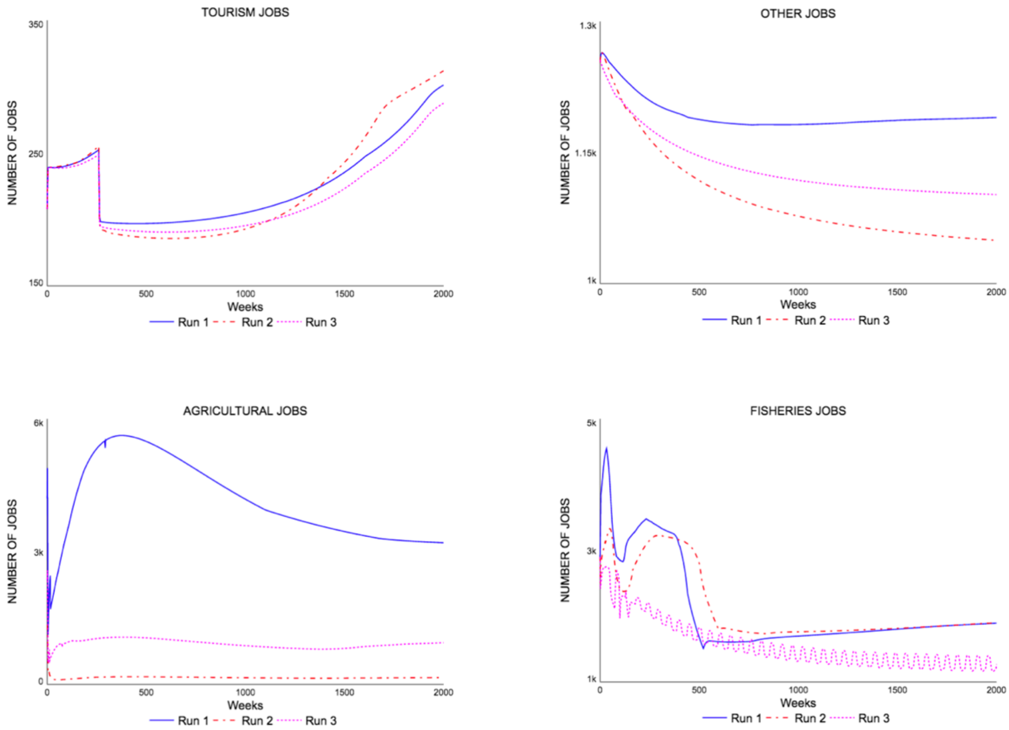


Figure 6-23. Projections for jobs across sectors under the system shocks

Declines in agricultural land are influencing the number of agricultural jobs available, which in turn, effects the amount of income earnt from the sector. *Agricultural jobs* under Scenario 1 demonstrates systems behaviour of overshoot and collapse as the number of jobs increases quickly to week 400 before declining over the remainder of the simulation period. In Scenarios 2 and 3*, agricultural jobs* remain steady albeit at lower levels than Scenario 1, with Scenario 2 showing the least number of jobs available (Figure 6.23). As *agricultural jobs* decline, this has flow-on effects onto the generation of income with *agricultural income per capita* declining across all scenarios (Figure 6.24).

Fisheries jobs and *fisheries income per capita* reflect declining trends across all three scenarios (Figure 6.23 and 6.24), reflective of declining fish catch (Figure 6.28).

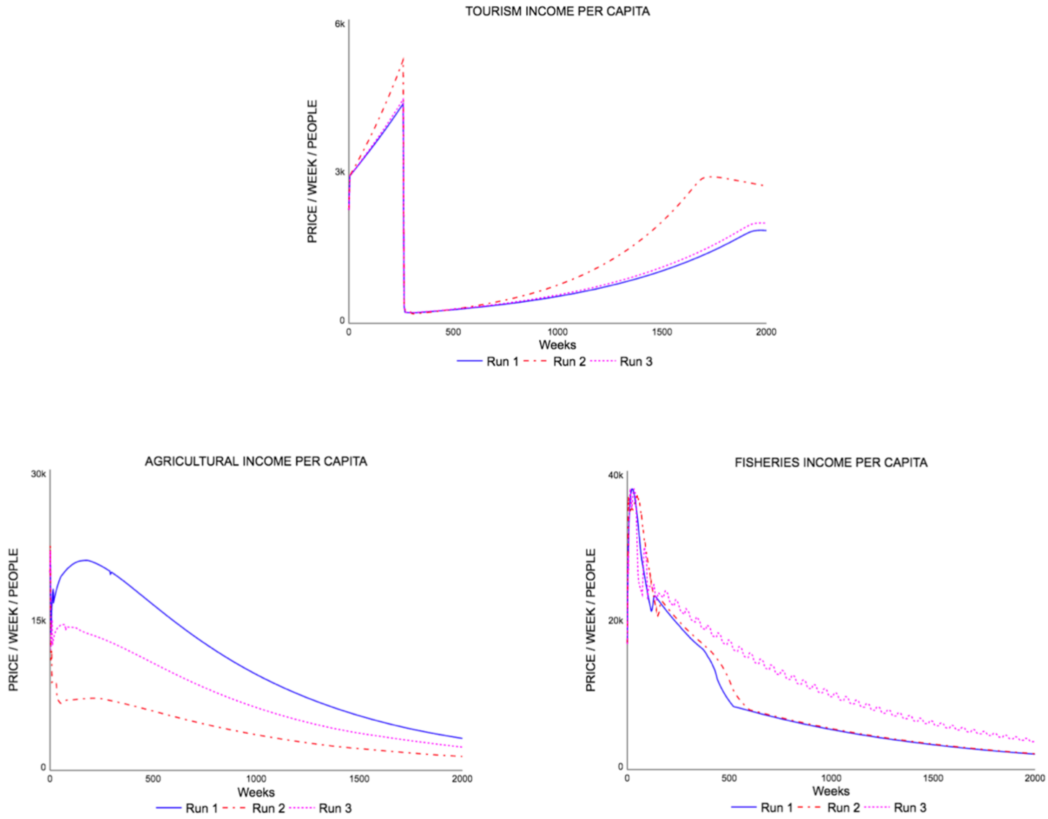


Figure 6-24. Income projections across sectors under the system shocks

6.3.1.3 Food Demand

For all food groups (i.e. crop, meat and fish) under Scenario 1, the actual consumption per week runs below the baseline i.e. normal consumption per week. In Scenario 1, *actual crop consumption per week, meat consumption per week* and *fish consumption per week* all remain under the baseline rate. *Actual crop consumption per week* shows a declining trend across the simulation period, whilst *actual meat consumption per week* remains steady. *Actual fish consumption per week* however reveals a collapse throughout the time period (Figure 6.25). The actual consumption per week is affected by lower population and tourism numbers, import caps, increases in price and declining income.

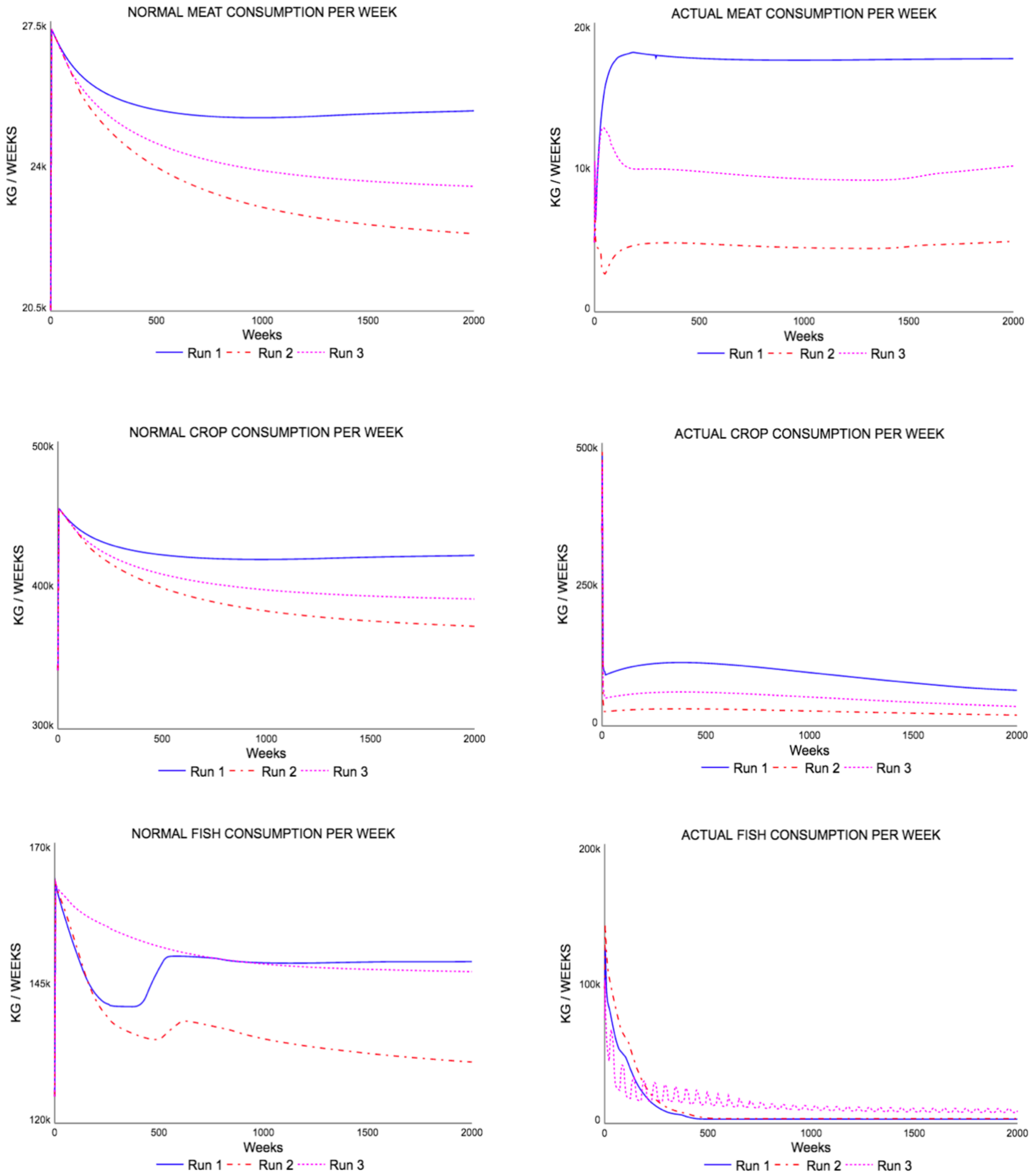


Figure 6-25. Consumption projections for meat, crops and fish under the system shocks

6.3.1.4 Food Prices

The decline in local production and limits to the amount of food imported, affect the prices of food. The model simulation shows the actual price for rice, cattle and fish, all increasing to varying degrees across all three scenarios. This may be due to the supply from local production and imports unable to meet the demand, thus driving the price higher. Across all scenarios, pig price at local market shows a collapse. It is unknown what may have led to this collapse and it may be an anomaly in the model (Figure 6.26).

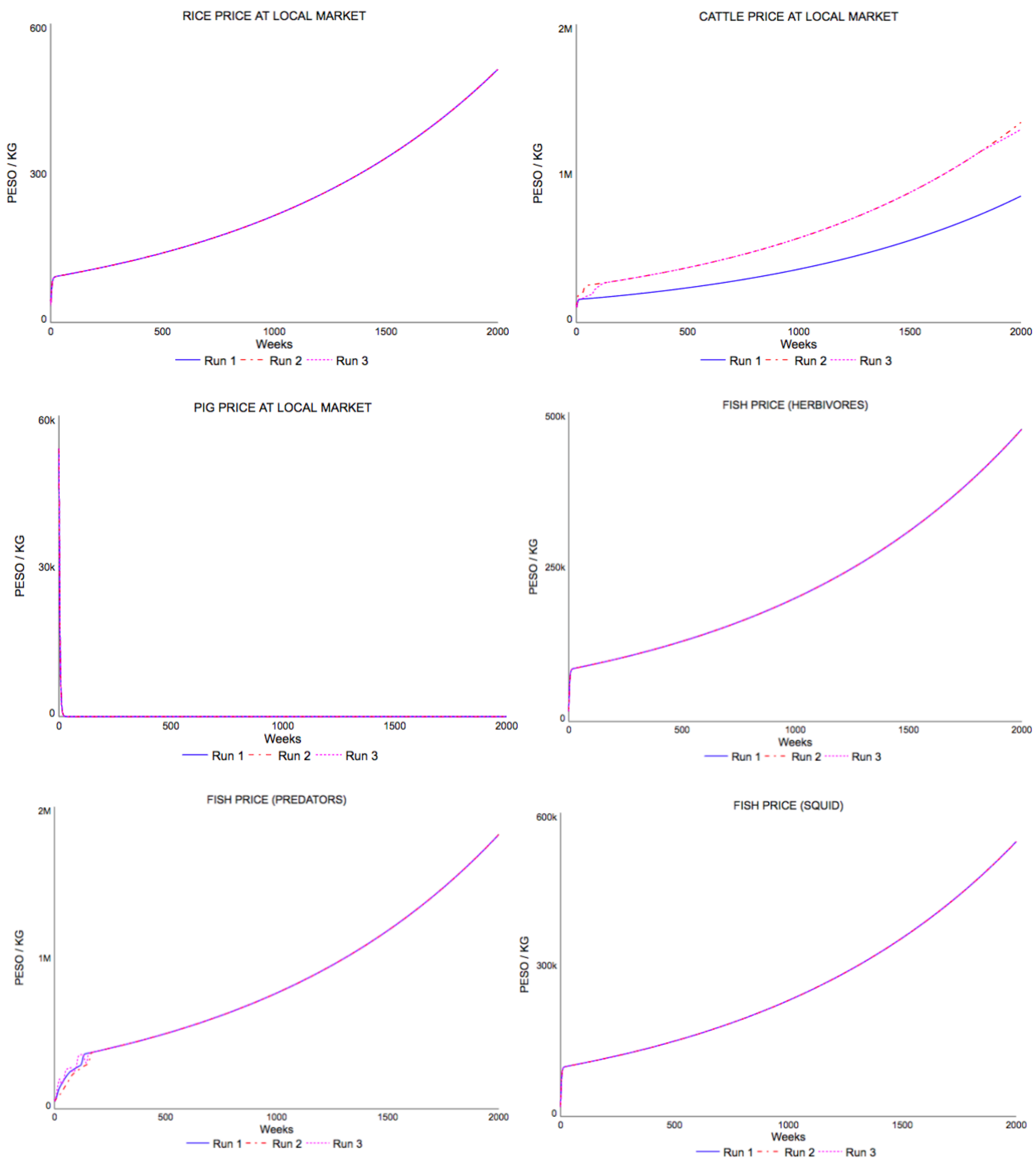


Figure 6-26. Projections for food prices under the system shocks

6.3.1.5 Food Supply

The simulations reveal little evidence the reduction in rainfall is a key influencer on agricultural yield, possibly due to the short time period in which drought is experienced. Rather, agricultural land area used appears to be the key influencer on production with crop yield declining across all three scenarios. Scenario 2 shows lower levels of yield for crop production (lowland rice) and total crop production than the other scenarios. Livestock supply to traditional market remains steady across all three scenarios, again with

Scenario 2 illustrating the lowest levels of supply, reflecting the reductions in land availability (Figure 6.27). Traditional fisheries catch remains on a declining trend, with the exception being traditional mangrove and seagrass fisheries under Scenario 3, illustrating the increase in MPA area moves fishers to fish other habitats (Figure 6.28).

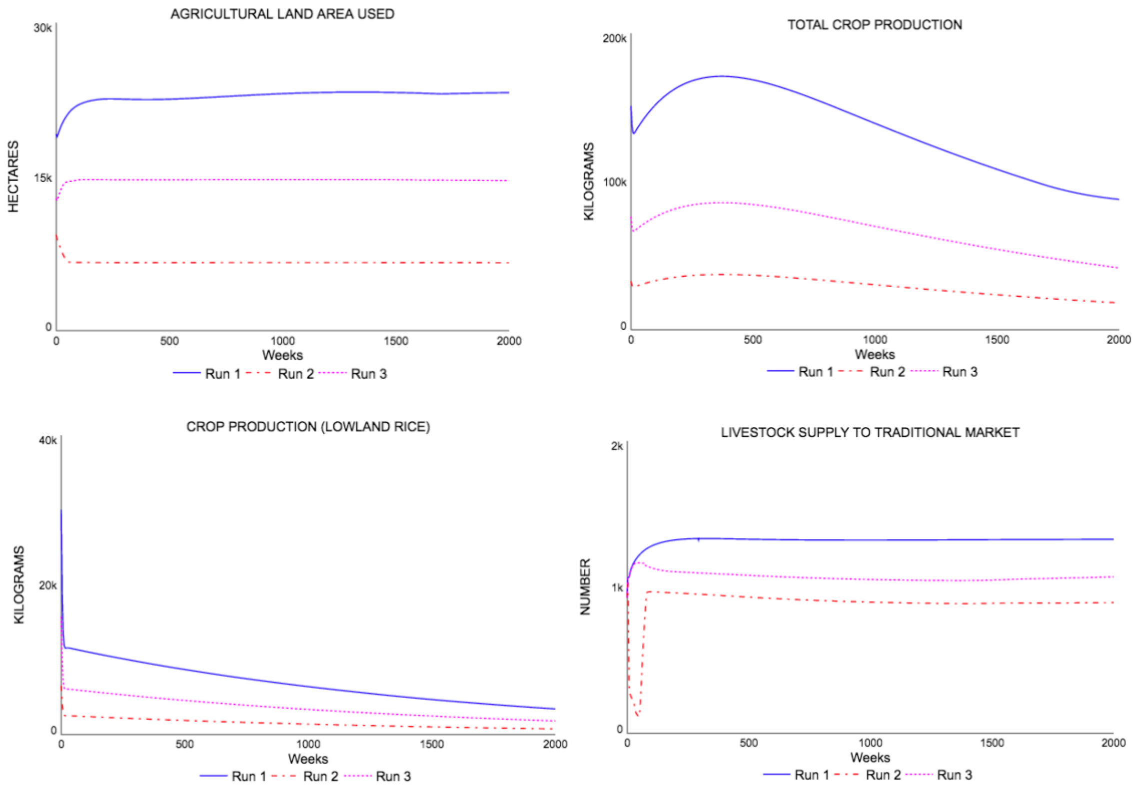


Figure 6-27. Projections for agricultural production under the system shocks

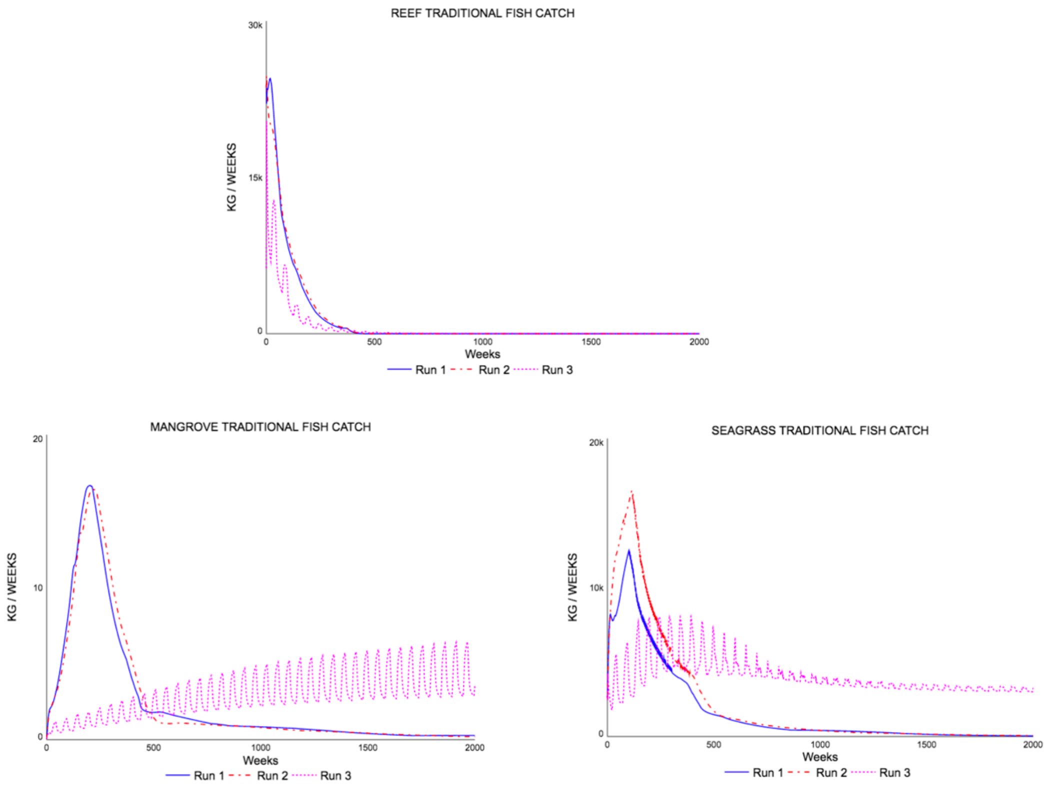


Figure 6-28. Projections for fisheries catch under the system shocks

6.3.1.6 Food Imports

Capping crop and meat imports at 50 percent of the Baseline value, and fish imports at 200kg per week, reveals a system in which the limit is immediately reached. Dependence on imports remains at equilibrium under Scenario 1. However, under Scenario 2 and 3 the dependence shows signs of increasing with Scenario 2 reflecting the highest dependency. Under Scenario 1, lowland rice imports show a small increase whilst total crop imports show an increasing trend. Total meat imports remain steady, having reached equilibrium, as does total fish imports (Figure 6.29).

Scenario 2 highlights a slow decline in lowland rice imports, total crop imports and total meat imports before it levels off. Total fish imports reflect it reaching equilibrium as per Scenario 1 and 3. Scenario 3 corresponds to the previous two scenarios, with lowland rice imports and total crop imports showing a slow decrease before levelling off. Total meat imports decline slowly over the simulation period (Figure 6.29).

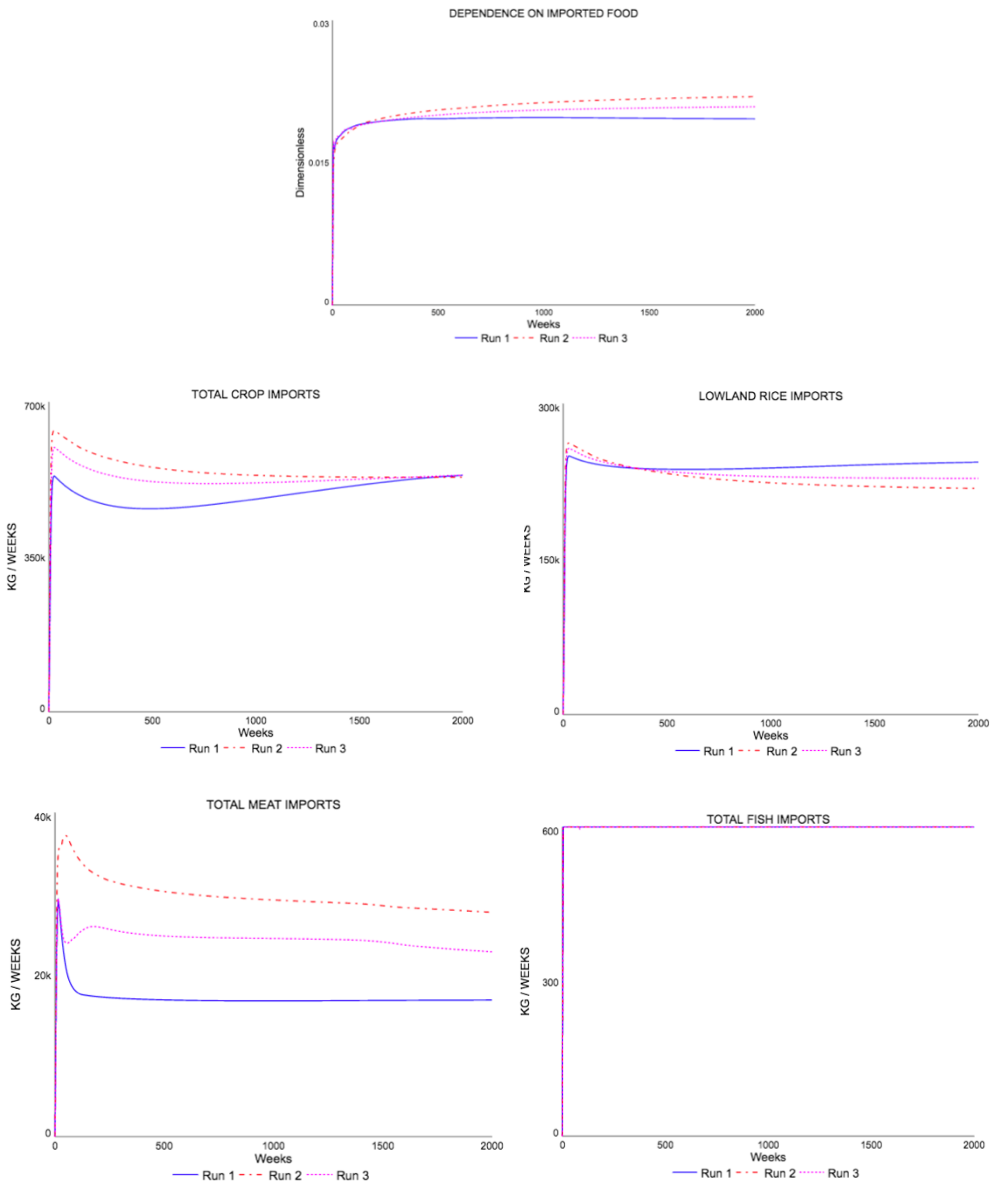


Figure 6-29. Projections for food imports under the system shocks

6.3.1.7 Demand for land

Whilst tourism affects the local population and food consumption, it also has impacts on the demand for land leading to tourism development. The amount of urban land reflects the zoning levels outlined in Table 6.5 and remains steady across the simulation (Figure 6.30). However, under the tourism shock, the effect of hotel capacity on tourist arrivals reveals supply is meeting demand (when equilibrium is met) until week 1650 (Scenario 2) and week 1870 (Scenarios 1 and 3) when demand for accommodation reaches levels above the supply of hotels. The total hotel area reflects the supply of accommodation meeting demand as it highlights a decline for all scenarios until week 1650 (Scenario 2) and week 1870 (Scenarios 1 and 3) when it reverses and starts to increase. The trends shown in the number of hotels in non-mangrove areas also reflect this pattern as the number of hotels in mangrove areas reflects an exponential decline (Figure 6.30).

6.3.1.8 Marine Habitats

Under all three scenarios, *total reef area* remains low, with Scenario 3 highlighting the impacts of increased areas of MPAs and enforcement, whilst Scenarios 1 and 2 show the largest declines (Figure 6.31) before levelling off. *Mangrove area* shows a small increase over the simulation period for all scenarios, however, *seagrass area* continues to show declines under all three scenarios (Figure 6.32).

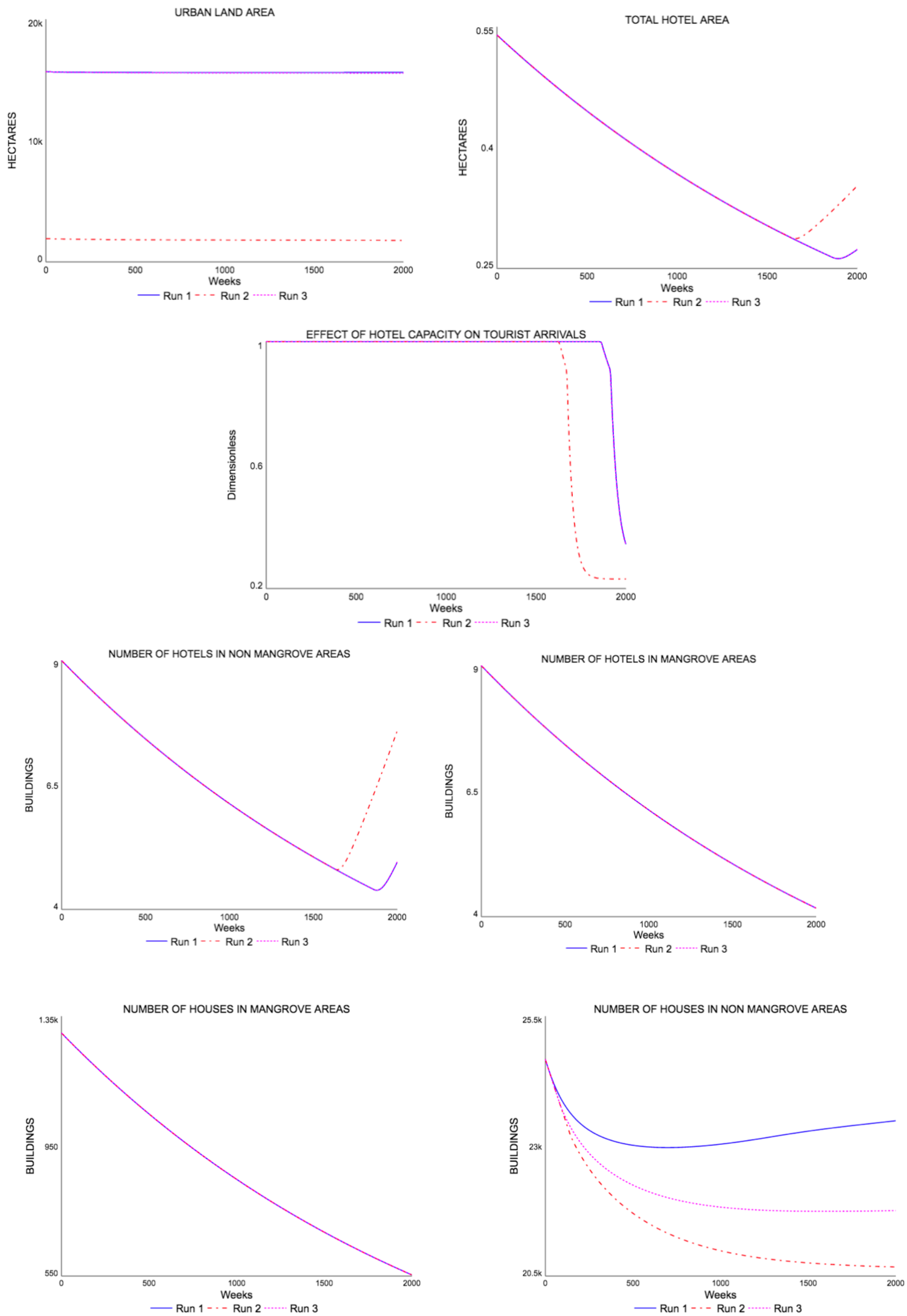


Figure 6-30. Projections for urban land use under the system shocks

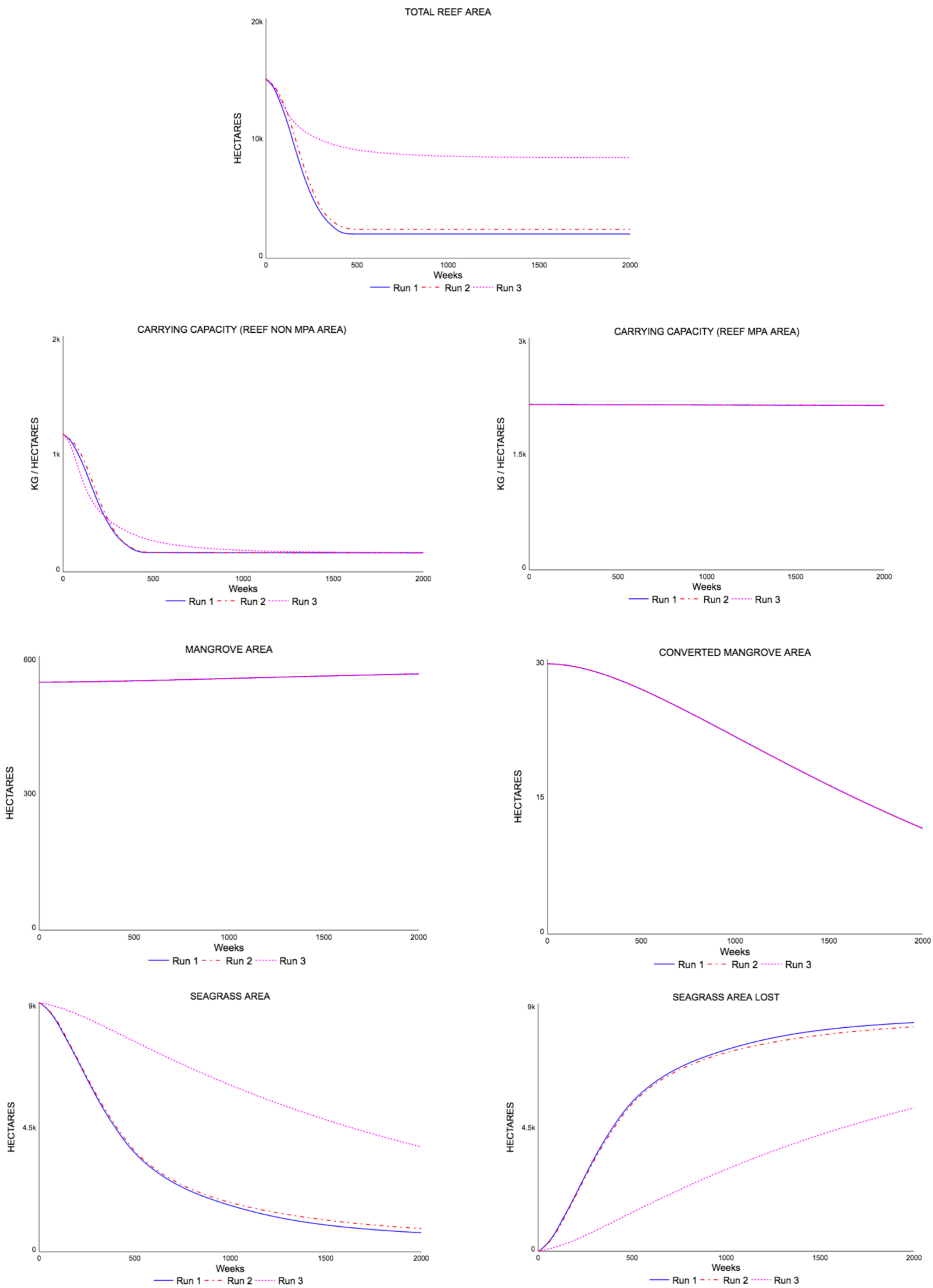


Figure 6-31. Projections for marine habitats under the system shocks

6.3.2 Discussion on the model simulation results

Scenario 4 inserted three shocks into the food system model reflecting declines in tourist numbers, rainfall and imports to assess the impacts upon food consumption, agricultural production, the supply of food and food pricing. Through inserting these shocks, the results are used to analyse RQ3 "*How resilient is food security in El Nido to shocks under the previous three sets of scenarios?*" The resultant model simulations demonstrate a food system with varying degrees of resilience to the shocks.

The decline in tourist numbers in year five (week 260) impacts upon the social-economic drivers of the food system with tourism sector related variables i.e. *tourist population, tourism jobs, tourism income per capita* and *tourism developments* quickly affected by the fall in tourist numbers (Figure 6.20, 6.23, 6.24 and 6.30). Whilst the system shows initial declines followed by increases in growth post-shock, this is more a result of the input of a consistent annual tourism growth rate of 12 percent (Scenario 1 and 3) and 14.5 percent (Scenario 2), rather than a sign of resilience in the system (Figure 6.20). In the event of shocks which befall the tourism industry, it is unlikely tourism growth would return at the same initial levels following such a decline and would be more closely aligned to a longer period of time in which tourist numbers remained low, followed by a slower build up before it reaches the initial annual growth rate.

The variables reflecting the least resilience to the decline in tourist numbers are *tourism jobs*, *tourism income per capita, total hotel area* and *number of hotels in non-mangrove areas*. *Tourism income per capita* demonstrates overshoot and collapse behaviour – declining in week 260 as the shock enters the system, and subsequently increasing until week 1750 (Scenario 2) and week 1900 (Scenarios 1 and 3) before it reaches the limit and accordingly begins to decline (Figure 6.24). Tourism development also reflects less resilience as the trends for *total hotel area* and *number of hotels in non-mangrove areas* display exponential decay until week 1650 (Scenario 2) and week 1890 (Scenarios 1 and 3), before they reflect a turnaround and start to show signs of increase (Figure 6.30).

Under this shock, *local population* illustrates a declining trend across all scenarios, although the highlighted trends are not as sharp or sudden as those viewed for the tourist population (Figure 6.20). Overall, the population remains at higher levels and recovers faster under Scenario 1 whilst Scenario 2 displays the greatest decline in population with no recovery over the simulation period. Whilst migration continues to have an influence on the local population (Figure 6.21), unlike in the previous model simulations for the scenarios outlined in Section 6.3, the most influential factor on migration is that of food availability (Figure 6.22).

With the tourist and local population declining, food demand falls across all scenarios with *actual consumption per week for crops, meat and fish* dropping below the baseline (i.e. normal consumption per week) (Figure 6.25). Fish consumption shows the highest vulnerability to the change, with actual consumption per week declining to almost zero levels across the three scenarios. In terms of the highest rates of consumption, Scenario 3 showed the least deviation between *actual crop consumption per week* and *actual fish consumption per week*, with Scenario 1 displaying the least deviation in *actual meat consumption per week*.

Food demand (even with a reduced tourist and local population) is met through local agricultural and fisheries production or through imports. Whilst the shock of rainfall reduction for 12 months does not affect the overall production of crops and livestock, the decline in the amount of land available for agricultural use does impact on yield (Figure 6.27). *Crop production (lowland rice)* and *total crop production* decline across the simulation period for all three scenarios. However, Scenario 1 reflects a stronger resilience than Scenario 2 to the change in land availability with a higher yield. Livestock supply remains steady across all scenarios, although the levels remain low reflecting a lack of available grazing land. As agricultural land declines, farmers sell more of their cattle rather than retaining stock.

Whilst the *dependence on imported food* has reduced from the levels demonstrated under the initial Scenarios 1, 2 and 3, there still remains a reliance on imports to fill the demand-supply gap. Under the shock the reduction in the amount of imports into the Municipality is reflected in lower levels of *lowland rice imports, total crop imports, total meat imports* and *total fish imports*. Furthermore, the simulations reveal the import limit is reached at the commencement of the time period and remains steady throughout the period. Scenario 2 reflects the strongest dependency for crop and meat imports, whilst Scenario 1 is more dependent upon *lowland rice imports* under the system shocks. All scenarios remain equally dependent upon fish imports, reflective of the continued decline in the fisheries sector across all three scenarios (Figure 6.29).

As with all the scenarios, whilst food availability is met largely through imports supplemented by some local agricultural production, economic access to food will remain largely dependent upon food pricing and the ability to procure food through income generation. The model simulates *rice price at local market, cattle price at local market* and *fish price at local market* all showing exponential growth under all scenarios (Figure 6.26). However, *pig price at local market* shows collapse (Figure 6.26). For rice, cattle and fish the increase in price is due to declining volumes of produce reaching the market from both local production and imports. With increasing prices, the importance of income is reflected, although this too shows signs of decline across *agricultural income per capita* (Figure 6.24). The importance of tourism continues as seen in *tourism income per capita* (Figure 6.24). The simulation reveals a recovery period from the loss of tourists in week 260 however, it then peaks and shows signs of decline in week 1700 (Scenario 2) and week 1980 for Scenarios 1 and 3.

In summary, whilst the study on impacts of shocks on the food system was limited, it has illustrated the El Nido food system has a low resilience to: (i) declines in the tourism sector which has flow-on effects onto the employment sector and income generation and: (ii) a decline in food imports which are required to meet demand as local production declines. Furthermore, the scenario highlighted the vulnerabilities within the food system and the ineffectiveness of the policy interventions under Scenarios 2 and 3 as food availability declines leading to an increase in emigration.

Box 6.4. Key findings for System Shocks scenario

Key findings from the model simulations for assessing the food system under system shocks include:

- Local population shows declines but tends to recover faster than tourist numbers
- Food availability becomes the key determinant or influencer on migration
- Food demand declines due to the declining population
- Fish consumption declines across all three scenarios
- Crop production declines across all three scenarios
- There remains a reliance on imports to meet food demand
- Economic access is challenged by increasing food prices due to a lack of local food production

7 Discussion

This chapter discusses the findings of the assessment of the local food system in the El Nido Municipality and whether it can achieve the food security pillars of availability and access. It also identifies wider implications of these findings for enacting policy and practical actions for local food systems. It concludes with some reflections on the research approach undertaken for addressing the research problem.

7.1 Findings of the food system assessment

The dynamic hypothesis (Chapter 5) and the simulation modelling and analysis (Chapter 6), present the food system in El Nido, including a range of plausible futures without assigning probabilities to the outcomes (Reilly and Willenbockel 2010). In particular, they highlight a food system which: (i) has reached a state of irreversibility, and; (ii) remains vulnerable to disturbances and lacks the resilience or capacity to continue providing a function over time. The model simulations across the three scenarios highlight a food system in which there is no 'best case' scenario as each intervention leads to feedbacks within the system which move it towards an alternative state which may not be desirable to the government or the population. Furthermore, with the insertion of exogenous shocks into the food system, the vulnerability and lack of resilience is further highlighted, as the system fails to return to its previous state in achieving a sustainable food system.

7.1.1 Irreversibility of the food system

The analysis of the model simulation outcomes for each of the three scenarios – Baseline or Business-as-Usual (Scenario 1), Policy Implementation (Scenario 2) and Resource-efficient consumption (Scenario 3) – highlight a system which has reached its 'tipping point'. Tipping points are critical thresholds offering various timescales of onset and impact, and are processes of 'discontinuous, and at times disruptive, change' (O'Riordan et al. 2013). In the case of the El Nido food system, the tipping point is leading to a state of irreversibility (The Global Food Security Programme 2017). Despite interventions directed at reversing declining food production, the system is unable to swing back towards a state of equilibrium whereby economic growth through tourism generation can sustainably co-exist with local food production whilst still retaining ecosystem health.

Food systems must be able to continue to deliver food security outcomes under increasing social-economic and environmental change drivers (Ericksen 2008b; Tendall et al. 2015). As the food system responds to these drivers, the scenarios highlight a system facing food security issues, declining food self-sufficiency and income inequality (Otsuka 2013). The local food system is moving away from the traditional agricultural and fisheries sectors which provided both food and employment to the population (Section 4.4), and is becoming reliant on a single sector economy, namely tourism, to promote economic growth (Section 4.3) and by doing so, provide incomes for the population with which to access food. The growing or catching of food within the local system is no longer the priority and the system has become reliant on food imports to meet food demand from the growing tourist and local populations.

This ‘irreversibility’ of the local food system to support food availability and access is highlighted in El Nido as no one scenario presented reveals an approach in which the food system can achieve a ‘whole-of-system’ food security outcome in the face of pressures facing it as outlined in Section 5.1, whilst not harming the social and biophysical environment (van Wijk 2014). For example, the achievement of food availability through agricultural production and fisheries catch reveals declines across all scenarios. For lowland rice and crop production, the two scenarios with policy interventions – Scenarios 2 and 3 – highlight declining yields linked to policies signifying reductions in the area zoned for agricultural use. Furthermore, even though Scenario 1 reveals increased yields of lowland rice and crops, this is due to the model utilising the higher zoning area of agricultural land (i.e. 31 139 hectares (PCSDS 2003)). This zoning policy is not realistic given the geographical limitations with only 19 percent of land suitable for agricultural and urban use (PCI 2006) (Section 5.3.2.1). An additional challenge for agricultural production will be increasing demand for water between the agricultural sector and the urban sector. Despite an increase in irrigation under Scenario 3, yields still remain low. As demand for land and water increase, prioritisation will be given to the urban sector, particularly tourist developments evidenced by the declines in agricultural land versus the exponential increases in urban land area. As land area declines, farming input costs increase and rates of return decline, it therefore becomes more attractive to the farmer to sell land rather than retain it (Section 5.3.2.1).

Within the fisheries sector two factors are affecting the decline and collapse of fisheries: (i) habitat degradation, and; (ii) overfishing. Habitats underpinning fisheries are in decline, particularly reef habitats which reveal exponential decay in Scenarios 1 and 2. Even when interventions of increasing marine protected areas are incorporated (Scenario 3), the simulation only shows increases compared to the previous two scenarios, rather than any real change in reef health – as evidenced by the continued decline in reef carrying capacity and fish density. Additionally, mangrove and seagrass areas remain under threat with the area of converted mangroves slowly increasing and seagrass area lost showing exponential increases across all scenarios.

Secondly, overfishing contributes to the ecosystem health decline and low fish catch (Table 6.8). The number of fishing boats[33] and actual fishers in the system increase across all scenarios putting further pressure on a declining resource. Furthermore, interventions including increasing surveillance, limiting boat licenses and increasing MPAs, lead to impacts elsewhere in the system. This is evidenced through the model simulations which show increases in these interventions cause a shift away from traditional fishing into destructive fishing, thereby placing further pressure on fisheries. Despite the number of fishers increasing, the simulations reveal collapses across the number of *fisheries jobs* and *fisheries income per capita*. This reveals a system which can no longer sustain fishers, nor are income levels obtained from fishing sufficient to sustain their livelihood.

The food system is unable to achieve food availability through local agricultural production or fisheries catch alone and is reliant upon imports to fill the food demand – supply gap under all scenarios. The model simulations for all three scenarios reveal a food system which has a dependency on imported food >1 with Scenario 1 revealing the highest dependency. With the exception of lowland rice imports under Scenario 1, all scenarios reveal a system heavily reliant upon the importation of rice, crops, meat and fish to fulfil food demand.

Even with food availability being met by imports, the vulnerability within the food system is highlighted through variances in economic access to food. Dependency upon imports can lead to food access issues particularly if food prices increase and / or jobs decline and income levels fall. The model simulations reflect a situation whereby food prices remain steady having reached equilibrium i.e. supply is meeting demand. The challenge will be to ensure the local population can retain a steady source of income through employment creation to procure food. Whilst tourism jobs remain on an upward trajectory, the income per capita generated from this sector also remains on a similar trajectory. The population becomes wealthier (as evidenced in increases in net site savings) and this improves

[33] The exception to this increasing trend is Scenario 3, in which the number of traditional fishing boats is capped. However, the number of large fishing boats and destructive fishing boats increases across all scenarios.

economic access to food. However, when limits to tourist numbers are implemented, as shown under Scenario 3, the number of jobs is also limited. This in turn leads to an exponential decline in the *tourism income per capita* and a decline in net site savings.

Whilst tourism generates wealth, for those in agricultural and fisheries jobs, income generated is not as high as for those employed in the tourism sector. Agricultural jobs remain low under Scenarios 2 and 3, and fisheries jobs collapse under all scenarios. The per capita income generated from these activities reflects the same trends. If the net site savings is reflecting the tourism sector, it could be surmised, there are sections of the population who still remain limited in their ability to economically procure food and remain vulnerable to high food prices and income declines.

To conclude, all scenarios reveal a prioritisation of tourism over the local production systems, leading to further environmental degradation and demand for natural resources. The rise in both tourist population and local population drives increased food demand with all scenarios revealing actual food consumption per week rising above the baseline levels. This demand is met through local food production and imports. Furthermore, the growth in the tourism and local populations highlights the importance of the tourism and domestic employment sectors in driving income per capita trends, and in turn, enabling a large portion of the population to purchase food. The ability to purchase food, however, is becoming increasingly critical as the local agricultural and fisheries systems decline or collapse (leading to declines not only in income generation but also in self-sufficiency), and the Municipality becomes heavily dependent upon imports. In many cases, the system shows continued behaviours of exponential decay or overshoot and collapse. When the results of the scenarios are analysed (Section 6.3), it becomes evident the tipping point has been reached and the system continues to decline despite the policy interventions examined within the scenarios. There is little doubt a state of irreversibility within the food system has been reached.

7.1.2 A resilient food system?

'*The greatest constant of modern times is change*' (Sterman 2000, pp 3). Food systems need to deliver food security outcomes and continue to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances (Ericksen 2008a; Tendall et al 2015; Allen and Prosperi 2016). The model simulations under Scenario 4 'system shocks' (Section 6.3.1) reveal the El Nido food system is vulnerable to disturbances and highlights a lack of resilience within the food system as the food security pillars of food availability and food access cannot be met in a holistic manner and continue to provide sufficient and accessible food under increasing social-economic and environmental change drivers.

Both the dynamic hypothesis (Section 5.2) and the scenario simulations (Section 6.2.4) reveal a system dominated by the interdependent drivers of tourism and population growth. As the tourism sector grows the local population also increases. However, as demonstrated under Scenario 4, whilst all scenarios show recovery against the tourist population following the 12-month decline in tourist numbers in year 5, the flow-on effects reveal a reduction in local population and declines in the employment sector and income generation across all three scenarios. Additionally, declining livelihood opportunities and the loss of food availability, is leading to declining population numbers driven by emigration. Whilst the rate of recovery is higher in Scenario 1 and 3, the levels of population do not reach the same pre-shock levels. Furthermore, this has implications within the employment sector which sees domestic jobs (i.e. other jobs) also decline. However, the largest change to the local population is brought about by the lack of food availability within the Municipality when faced with disturbances in the system.

Crop and lowland rice production decline across all scenarios, with lowland rice production almost reaching zero under Scenarios 2 and 3. All scenarios highlight the supply of livestock to market as steady, revealing a system in which there is a continuous supply as farmers sell livestock. The key influencer on crop production in the system is land availability. As demonstrated in Scenario 1, as available land remains high, production shows increasing trends. However, with lower limits set for Scenario 2 and 3, production is reduced.

Despite interventions implemented for the fisheries sector, the sector continues to show declines and collapse under the system shocks. Traditional fish catch across reefs, mangroves and seagrass collapse, with fish density on reefs and seagrass, also shows declining trends due to loss of reef and seagrass areas and therefore the ability to sustain fish populations, particularly on reefs as the carrying capacity declines. Whilst *mangrove traditional fish catch,* and *seagrass traditional fish catch* show signs of increase under Scenario 3, this is caused by moving the pressure from one fishery to another. Over time, these fisheries will not be able to sustain demand and declines will also occur. This is evidenced by declines in *seagrass fish density* across all scenarios, with Scenario 3 sustaining longer-term decline. As local agricultural production declines with fish catch declining to zero levels, dependency on imports to meet food demand remains high and the volume of imported rice, crops, meat and fish recording high and consistently steady trends.

The losses in agricultural production and fish catch translate into declines across both agricultural and fisheries jobs, with little resilience within the system to rebuild these employment sectors. The analysis of fisheries jobs under Scenario 4 (Section 6.3.1.2) reveals: (a) higher job numbers than seen in the scenario outcomes and; (b) a slower decline in the number of jobs compared to the previous scenarios. However, this shift in the trend pattern is reflecting the overall fall in the number of tourist boats (i.e. fishers returning to fishing), the higher number of fishers (refer Annex C) and the higher prices received for fish (Figure 6.26). Importantly, the shift in job numbers is reflected in the income per capita trends. For example, over the simulation time period, tourist income per capita shows overshoot and collapse and agricultural income per capita reflects declines across all scenarios. Whilst fisheries income per capita does show declining trends, it does increase when compared to the collapse experienced under the previous scenarios, suggesting this increase in income levels may be due to the increase in fish price received by the fisher.

With continued decline in local production and increased imports, pressure on the system to continue to provide both sufficient and accessible food can be seen in the simulations outlining the most influencing effect on migration. Here, food availability can be seen as the largest influencing factor – meaning there is either: (i) not enough food in the system for the population, or (ii) people cannot access the food available. The model simulations under Scenario 4 reveal a system of exponential increase in food prices for rice, cattle and fish. As income levels fall and prices rise, the ability to access food becomes more challenging. In particular, the net savings at site level highlights exponential increases for all scenarios, revealing people are expending higher levels of their income on food. As prices continue to increase, the ability to obtain food becomes more difficult.

In summary, whilst in some areas the system is able to respond and adapt to the changes, the system still lacks the capacity to provide sufficient and accessible food for the population. Whilst food availability continues to be met through imports, access to food is restricted to those in the population who have the ability to generate an income and procure food. With food prices increasing exponentially due to supply shortfalls, the ability of people to access and procure food will be restricted, as evidenced by food availability being the most influencing effect on migration (Figure 6.22). `

7.1.3 Policy implications for local government

Given the current state of the food system and the lack of improvement through a number of policy interventions under the scenarios (Chapter 6), the local government will need to determine its long-term goals prior to major changes. The local government has the mandate to implement ordinances and regulations within these frameworks aimed at ensuring economic growth, food security and poverty alleviation, supplementary livelihoods, improved incomes for fishers and farmers, and the sustainable development of coastal and marine resources. However, as demonstrated in the scenarios, current policies of the local government are not going far enough in preserving the local food system or generating supplementary livelihoods and incomes for farmers and fishers.

Many of the current regulations designed to promote tourism to increase economic growth and promote tourism-related livelihoods, act to the detriment of the natural environment and the traditional livelihood sectors of the farmers and fishers in the municipality. As traditional livelihoods become less attractive, farmers and fishers move away from these sectors into either tourism (particularly fishers who convert their boats into tour boats), construction, forestry or alternative destructive livelihoods such as illegal cutting of forests and mangroves for household use, and wildlife poaching (Chapters 5, 6).

The rapid rise of the tourism sector has brought with it many challenges. Whilst economic growth is necessary for alleviating poverty and reducing hunger and malnutrition and is critical for increasing employment and incomes (FAO 2015), in El Nido, the Municipality has seen economic growth occur too quickly. It has been unable to keep pace and create and implement policies which enable both sustainable development through tourism and conservation of the natural environment to support local fishing and farming. Moreover, many in the Municipality particularly in the rural barangays, have not benefitted from the growth brought about by tourism and still remain under the poverty and food threshold (Table 4.6). Added to this are other factors including the *pakasan* or *padrino*[34] system

[34] Traditional value system whereby one asserts political pressure or gains favour through family affiliation or friendship

which has led to the non-enforcement of regulations (e.g. building construction codes, illegal forestry), leading to further pressures on the system.

Given the challenges facing the food system and demonstrated in Chapter 6, any new policy regulations to improve the local food system must be undertaken in the context of trade-offs that exist among different objectives and use the trade-off curves to identify win-win or ‘almost-win-almost-win’ outcomes. Implementing future policies aimed at bringing the sectors back to more of an equilibrium, and reducing poverty and hunger in the Municipality, may also be detrimental as unforeseen feedbacks may occur which are outside the scope of this research.

To improve food systems, Pretty et al 2003, HLPE (2009), Beddington et al (2012), ADB (2012), OECD (2013), World Bank (2015) and Townsend et al (2016) amongst others, all advocate for a combination of short and long-term, economic and social, macro and structural, and global, regional and national policies to promote food security and reduce poverty and hunger. However, for many of the policies promoted in the literature[35] there are a number of suppositions: (i) many of the strategies are focused at the macro or global level. Whilst some of these strategies can be brought down and implemented at the local level, other strategies are more challenging given local political, economic and social environments; (ii) there is a marked bias towards the agricultural system which fails to take into account the importance of fisheries as a key food and livelihood sector for many communities.

Whether or not these strategies could be applied in the El Nido context would need firstly the strategies to be clearly defined and able to be integrated into already existing legislation and policies. Secondly, strategies would need to be tested within the system’s framework to ascertain if the interventions would meet the combined goals of sustainable food systems, habitat conservation and economic growth.

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[35] E.g. Integrated food security and sustainable agriculture into global and national policies; increasing global investment in agriculture and food systems; providing food-based safety nets; enhancing and sustainably; intensifying agricultural productivity; promoting rural development; defining property rights; improving the efficiency of natural resource use; reshape food access and consumption patterns, and; reduce loss and waste in food systems.

7.2 Reflections on the research approach

This section turns to reflecting on the overall thesis research, in particular, the research approach, policy implications of the findings and the limitations of the research. Significant features of the research approach discussed include: (i) the nature of complexity within the food system and; (ii) the linear approach to the food system framework.

7.2.1 Complexity of the food system

Food systems are complex adaptive systems (Clancy 2013) of which food security is an essential outcome (Ericksen 2008a; Liverman and Kapadia 2010; Ingram 2011). Given the complexity of this local food system, a particular challenge for this study has been the trade-off between assessing the food system as a whole and focusing in detail on particular components or outcomes of the food system.

As a complex adaptive system, this local food system consists of nested hierarchies, multiplicity of cross-scale interactions and feedback loops between different hierarchical levels implying a high degree of complexity and non-linear behaviour (Rammel et al. 2007). As this system is sufficiently complex, it may not be practical or perhaps even possible to know the details of each local interaction (Lansing 2003). The study highlighted a number of factors relating to the issue of complexity and the challenges in being able to undertake a 'whole-of-system' analysis:

1. **Complexity of the local food system**: Given the multifaceted nature of the food system and the many dimensions residing within it, it became too complex for the research to focus across the local food system in its entirety in terms of assessing the food security elements (i.e. activities, outcomes and social and environmental welfare), the drivers, interactions and the feedbacks generated. The study therefore, only focused on analysing the problem of food insecurity through the food availability and food access lens. However, whilst this enables a more detailed study into those components of the system, it cannot account for the cross-interactions and feedbacks which occur between these components and agents not examined, or feedbacks generated from interactions between agents not examined and how these feedbacks might impact on the components examined. Furthermore, when interventions are interposed into the system to test the system's resilience to change, the responses may not be as realistic as when other

components or feedbacks are added. There are therefore limitations in the scope and a true, overall picture of the food system is not able to be obtained.

2. **Simplification of the system was undertaken at the commencement of the approach**: The first step following the problem articulation was the development of the dynamic hypothesis. This was undertaken using causal loop diagrams which in themselves, utilised aggregated information (Chapter 5). Causal loop diagrams are designed to communicate the central feedback structure of the dynamic hypothesis and are not intended to be descriptions for the model at the detailed level (Sterman 2000). Having too many local interactions and detailed information on each interaction incorporated into the causal loop diagrams would make it difficult to ascertain the overall feedback structure and interactions. As Sterman (2000, p.166) notes '*modelling is the art of simplification*'. Therefore, the structure of the dynamic hypothesis was simplified to ensure the central feedback structure was highlighted.

3. **Data limitations**: There was a scarcity of historical data for the El Nido case study site and an inability to access relevant data from data custodians. This impacted on the ability of the model to be able to develop simulations with a high degree of certainty and to use the tool for predictive purposes. Given these limitations, this study has used the model as a tool for understanding system structure versus system behaviour and not a model for prediction.

4. **Model limitations**: The simulation model utilised to assess the dynamic hypothesis outlined in Chapter 5, was not designed to capture all elements of the food system. For example, it is not possible to incorporate all elements highlighted in the dynamic hypothesis into the model if it is not able to be converted into stocks and flows. Furthermore, whilst the model itself is detailed and complex, there still remains a large amount of information not incorporated into the design e.g. physical access to food via roads and storage, water usage and storage, climate change, soil fertility, pests and diseases (refer Section 6.1.1).

Given the complexity of the food system, Chapter 1 of this study highlights the 'siloed' approach to food system agents or components as a challenge. However, upon reflection, given the complexity of the system, it is not possible to research, analyse and understand the whole food system within the confines of this one research thesis. However, several advantages arise in the refined approach used including: (a) the ability to undertake a more detailed analysis on specific areas of the food system and to test the system under multiple scenarios; (b) enabled an analysis of the system using system methods and modelling feedbacks which are important within the food system framework (Section 2.3.1); (c) the ability to apply the theoretical knowledge into a real-life situation as was the case with El Nido, and; (d) enabled interactions with communities and government to take place focusing specifically on their areas of interest and to gain their input and gauge their level of understanding of the system.

7.2.2 Mapping vulnerability and resilience in the food system is not a linear process

The food system framework developed by Ericksen (2008a) (refer Section 2.3.1) provides the diagrammatical approach to understanding the food system incorporating interactions between global environmental change and social-economic drivers as key influencers on food system activities and outcomes. However, whilst the framework provides an overarching conceptual model to assist in understanding and assessing the local food system, it does not highlight the constantly changing, non-static (Liu et al. 2007) structure of the food system.

The linearity of the food system framework restricts the understanding that food systems as dynamic systems (refer Section 2.3). It implies the subsequent modelling of the system is a linear sequence of steps (Sterman 2000), rather than a constantly evolving process, and detracts from the complexity of the interlinkages and interactions of these drivers and activities at various scales and levels (Gerber 2014). In this manner, the systems dynamics approach and in particular, the development of the causal loop diagrams in this study enabled a framework of the local food system to be developed which moved beyond the linear approach. In particular, it captured the changing patterns of interaction, modes of interaction and the capacity to include links to and feedbacks with other system outcomes (Hammond and Dube 2012).

The overall food system crosses multiple levels and systems (Hammond and Dube 2012) and strongly shaped by interactions between agents, and exogenous and endogenous forces in which they change and reorganise their component parts to adapt themselves to the problems posed by their surroundings (Holland 1992). This can be seen through the development of the causal loop diagrams for the agricultural and fisheries systems in El

Nido (Chapter 5). Furthermore, local interactions can produce nonlinear effects (Lansing 2003).

Food systems need to be able to adapt and meet the challenge of providing access to food for the growing population without diminishing the environment upon which the system relies. The addition of the vulnerability, resilience and adaptive capacity concepts into this framework (Section 2.3.3, Figure 2.4), further embedded the food system framework approach into the study. However, the linearity of these functions and their interactions remains. Vulnerability can occur at any interaction between variables, or within the feedbacks of the system (refer Figure 5.18, 5.29). Furthermore, each interaction can cause a reaction elsewhere in the system which raises or reduces that particular agent's vulnerability to further disruptions. Likewise, resilience is about the capacity of the system to absorb and adapt to changes and adjust to shocks (Adger et al. 2005; Toth et al. 2016). This too can be tested at various scales and across various agents and interactions and should not be restricted to a direct and unwavering relationship between variables.

8 Conclusions

Assessing the food security outcomes within a food system is complex and multidimensional and so requires a dynamic approach. It requires a holistic approach to understand and analyse the many drivers, activities, interactions and feedbacks within the system as outlined in Chapter 2. Whilst much of the analysis and proposed solutions are aimed at the global level rather than at the local level (Chapter 2), understanding and implementing interventions and practical solutions is vital in addressing food insecurity at the localised level, whereby the loss of food availability, access, utility and stability is most felt. Hence the research problem addressed in this thesis is: '*to assess the performance of a local food system over time, and its ability to continue to function effectively to meet food security outcomes'*.

8.1 Addressing the research questions

The research problem was addressed through three research questions (Table 8.1) that were presented in Chapter 1. This section summarises the findings regarding these questions.

Table 8-1. Research questions and chapters in which they were addressed

Research question		Where it is addressed
1.	What are the factors contributing towards food security globally and in Southeast Asia in particular?	Chapter 1, 2, 4
2.	What are the dynamics affecting food security in a southeast Asian community?	Chapters 5, 6
3.	What scenarios would affect the ability of local communities to produce and procure food?	Chapters 6, 7

<u>Research question 1</u>: What are the factors contributing towards food security globally and in Southeast Asia in particular?

Food security is an outcome of the food system (Ericksen 2008; Ingram 2011) and exists when *"all people at all times have physical or economic access to sufficient, safe and nutritious food to meet all their dietary needs and food preferences for an active and healthy life*" (FAO 2006). There are four pillars used to measure a populations', household or individual's level of food security – availability, access, utilisation and stability (Chapter 2).

There are a range of factors contributing towards food insecurity, whether it is at the global, regional, national or local levels. These range from macro to micro level and result in failures of households achieving availability, access and utilisation of food (Ericksen 2008b; Barrett and Lentz 2015). Within the El Nido Municipality food availability is influenced by production failures, seasonal shortages, climate change impacts, and resource constraints (Devereux et al. 2008; Walqvist et al. 2009). Food access is impacted upon by price spikes, unemployment, loss of livelihoods (Barrett 2010), inaccessible markets and poverty (Vermuelen et al. 2011; Barrett and Lentz 2015). All of these factors influence the local population's ability to access food under various circumstances and are explored to varying degrees in developing the dynamic hypothesis for the problem of food insecurity (Chapter 5) and in assessing the local food system's ability to continue to meet the food security pillars (Chapter 6).

<u>Research question 2</u>: What are the dynamics affecting food security in a Southeast Asian community?

Food systems encompass a number of activities which give rise to a number of outcomes including food security outcomes, socioeconomic issues and conditions, and to the environment, and all have feedbacks to the food system drivers (Ericksen 2008a; Ingram 2011) (Chapters 2, 5). Utilising a systems dynamics methodology to determine the dynamics affecting the food system at the case study site (Chapter 3), the research identified two socio-economic drivers – tourism and population – as the key influencers on the local food system (Chapter 5).

The growth in tourism and population has led to increased food demand and increased demand for land, water and natural resources (Chapters 5, 6). In turn, these interactions have led to a number of environmental and socioeconomic feedbacks (e.g. limits to land and water, competition for land and water between agricultural and urban sectors, degradation of habitats, loss of fish stocks, reduced water quality, loss of livelihoods and incomes) within the food system which have impacted upon the ability of the system to continue to meet food demand through local agricultural and fisheries systems (Chapters 5, 6).

The loss of, and limitations to, the amount of land available and suitable for agricultural purposes due to geographical limits, lack of land tenure and selling of agricultural land, is exacerbated by poor soils, pests and diseases and low technologies all leading to low yields for both crops and livestock (Chapters 5, 6). Furthermore, the activities on terrestrial habitats i.e. poor farming practices, logging of forests and mangroves for urban development and agricultural purposes, and the lack of waste management facilities, is impacting downstream with pollutants entering the marine ecosystem, resulting in declining water quality and a loss of habitat supporting fisheries. Along with overfishing and poor fisheries management, this has led to a significant decline in fish populations (Chapters 5, 6).

With declining local production systems, increased food demand and changes in food diets influenced by the tourist population and local population, the food system is shifting from one which was previously dominated by the local agricultural and fisheries sectors, to one which is heavily reliant on food imports to meet food demand (Chapters 5, 6).

Research question 3: What scenarios would affect the ability of local communities to produce and procure food?

Four scenarios were modelled to ascertain the influences on the ability of the local community to meet food security outcomes (Chapter 6). The 'business-as-usual' scenario simulated the current situation of high tourism and population growth, high employment in the tourism and tourism-related sectors, declining natural resources and, declining agricultural production and fish catch. Two scenarios were modelled implementing policy interventions: (i) the ‘policy implementation and enforcement’ scenario reflecting current and proposed local and provincial government policies with prioritisation on tourism growth, and (ii) the ‘resource-efficient consumption’ scenario reflecting these policies in addition to further interventions aimed at improving the local production systems whilst still retaining economic growth. The fourth scenario – ‘system shocks’ – modelled three shocks against the policy objectives.

The model simulations reveal a food system in which no one scenario displays an overall ‘whole-of-system’ improvement or sustainability across the food system, enabling the local communities to effectively produce and procure food. The various policy interventions under the scenarios, whilst improving some areas of the system, had effects on other areas of the system, which at times were adverse. For example, in Scenario 3, the interventions of increased surveillance and MPAs and limiting fishing boat licenses, whilst improving the total reef area and reducing traditional fishing, led to an increase in traditional fishing effort in mangroves and pelagics. Similarly, the limit to tourist numbers led to economic impacts with a decline in tourist jobs and tourism income per capita.

Under all three scenarios, the model simulations reveal increasing food consumption for crops, meat and fish which cannot be met by local production alone. As local agricultural yields and fisheries catch decline or collapse, the gap in demand – supply is increasingly met by imports. Furthermore, all scenarios highlight a system which is increasingly moving away from agriculture and fisheries as dominant employment sectors and becoming increasingly reliant upon tourism growth to maintain economic growth – a factor which is evidenced through the jobs and income simulation graphs.

When the system shocks are included into the scenarios as seen in Scenario 4, the simulations reveal further pressure on the food system to be able to provide food for the tourist and local populations. The shocks highlight a system which is vulnerable and lacks resilience as the loss of tourism leads to declines in jobs and income generated; agricultural production continues to show declining trends and; traditional fisheries catch collapses under all scenarios. The system remains reliant on imports however, the volume is constrained by the cap placed on imports. The ability to procure food is impeded by the tourism sector displaying overshoot and collapse behaviour, and all other employment sectors are also declining. Incomes per capita also decline reflecting the employment situation, reducing the purchasing power of the local communities. As food prices increase, the inability to grow or access food drives people to emigrate from the municipality.

Given the lack of resilience within the system to either respond or adapt effectively to the changes brought about by the policy interventions analysed in this study (Scenarios 2 & 3), different measures would need to be undertaken to ensure the food system can continue to ensure the population can produce and procure food. This is an area for future research. The challenge lies in identifying a number of policies beyond those identified and tested in these scenarios, and which would be able to be implemented effectively within the political, social and environmental elements of the El Nido system. To do this would require *"… transformational changes in governance, management and the use of our natural resources that are underpinned by enabling political, social and economic conditions*" (Neufeldt et al 2013).

8.2 Contributions of this research

a. Systems approach

The research found that undertaking a systems approach through the use of Ericken's (2008) food system framework and the systems dynamics methodology provided a number of advantages: (i) it enabled the complexity to be addressed in a holistic approach integrating the coupled human and natural system; (ii) it provided a process and mechanism to assess the interconnectedness and interdependencies across components, sectors and feedbacks which are present in both human and natural systems (Liverman and Kapadia 2010; Ingram 2011; Misselhorn et al. 2012) (Chapter 3) and; (iii) it enabled a closer understanding of how the food system is organised within the municipality (Chapter 5). Overall, the systems approach using both the food system framework and the systems dynamics method, provided for a more simplified approach to be undertaken to what is a complex problem.

b. Local food system

With much of the food security debate at the global level, there has been less focus upon the impacts of population growth, changing economies, habitat loss and declining agricultural and fisheries systems at the local level. This research has provided multiple insights into a local food system. Firstly, the research has moved the study beyond a single sector or activity to assessing the interactions across drivers, activities and outcomes within the local food system. Secondly, it captures multiple production systems – agriculture, fisheries and the impacts of their decline – in assessing the system. This is particularly important given that many local communities, particularly those in coastal areas, are heavily reliant on both agricultural and fisheries systems to provide for food and livelihood needs. Thirdly, the research focuses on socio-economic and ecological dimensions of the food insecurity problem through gaining an understanding of the interactions between these dimensions and how they influence and impact upon each other. Lastly, the research at the local level considers livelihoods within the food insecurity problem, highlighting the importance of livelihoods and access to food as key barriers to becoming food secure for these communities.

8.3 Future research needs

The study highlights the rapid decline in a local food system, and the irreversibility of this decline if policy interventions aimed at preserving local food production are not implemented quickly and effectively. Furthermore, it emphasises the need to undertake a systems approach when developing and implementing any intervention.

A range of future research needs have emerged from this study including: (1) exploring additional, more detailed scenarios and their implications on local food systems; (2) exploring in more detail the impact of shocks on the system; (3) undertaking further case studies for comparison; (4) further investigations against all food security pillars.

1. **Additional policy intervention and scenario testing**

Whilst this study sought to test policy interventions identified during the community participatory workshops, literature reviews and formal and semi-structured interviews, substantial opportunities still remain to identify and test further interventions. Whilst a number of global strategies have been put forth in the literature these could be further examined and defined for the local level and tested within the simulation model. Further investigation into the local and provincial legislation and policies could also provide further possible interventions to be tested.

Furthermore, additional scenarios could be explored including: (i) a more detailed analysis of the demand and supply of food in the municipality, particularly the role of imports in food availability; (ii) the role of alternative food sources in the food system e.g. wild food; (iii) a more detailed analysis of the fisheries sector and the impacts this will have on both food supply and livelihoods in the municipality and; (iv) future impacts of climate change on the agricultural and fisheries sectors.

2. **Additional exploration of system shocks**

This study focused upon three shocks; declining tourist numbers, declining agricultural production and a reduction on imports. However, there are a number of areas in the impact of shocks could be examined including: (i) the shocks were undertaken as 'one-off' shocks with the assumption the system would return to 'business as usual' following the shock. Further study could focus upon the impact of repeated shocks over the simulation period and the impacts on the food system e.g. tourism downturns across the 35 year timeframe; (ii) climate changes shocks (e.g. typhoons, bleaching events, floods) and the impacts these may have on agricultural and fisheries systems and; (iii) economic shocks including high food prices, impacts of supply controlled by the 'middlemen', losses of income.

3. **Further case study investigations on local food systems**

The research has conducted a study into a single case study of El Nido, Palawan. However, there is substantial opportunity to apply the conceptual framework and methodology in further case study investigations in other locations. This could lead to opportunities to test and enhance the approach and findings of this research through comparative studies.

4. **Further investigations on impacts on all food security pillars**

Whilst this research focused on food availability and economic access within the local food system due to the limitations of the approach, there remains substantial opportunity to further explore the dynamics within the food system assessing impacts on the food security outcomes of physical access, utilisation and stability. More detailed exploration of the system assessing the drivers, interactions and subsequent feedbacks on these pillars would add value to the study and provide a more comprehensive understanding and assessment of a local food system.

8.4 Conclusion

In conclusion, this study has assessed the performance of a local food system and achieved an improved understanding of the dynamics, interactions and feedbacks which affect food security at the local level. The approach undertaken enabled a rigorous analysis to be undertaken of the El Nido Municipality's food system and provides the basis for further assessment and evaluation to be undertaken. This study has resulted in several conclusions.

The local food system is in decline and requires strong interventions to be implemented immediately if agriculture and fisheries remain priorities. The policy interventions modelled under this study are not enough on their own to reverse the cycle of decline, particularly in relation to fisheries. Integrated policies, specifically targeting improved agricultural techniques and yield to be implemented. Furthermore, fisheries management requires a long-term outlook aimed at rebuilding both the marine habitat and fish stocks if the Municipality wishes to retain a fisheries sector. This will require decision-making which may be looked upon unfavourably by large sectors of the community.

Tourism will remain as the key influencing driver on the system. The simulations reveal a system increasingly reliant upon tourism as the lynchpin for economic growth. However, given the precarious nature of the tourism sector, the government will need to build growth and employment in other sectors to ensure long-term resilience against any sectoral downturns. Furthermore, the government needs to ensure development guidelines are being met, and waste management facilities improve, to preserve the environment.

Local agricultural and fisheries production remain in decline and alternatives beyond tourism will be needed to sustain the local rural communities which do not have access to benefit from the tourism sector. Whilst tourism benefits the urban barangays, it does not flow onto populations in the rural barangays who remain reliant on agriculture and fisheries to sustain them for food and incomes. There needs to be long-term strategies and schemes developed to assist these rural communities to either continue in their occupations or be able to generate income through other mechanisms.

The natural environment requires protection. The natural environment in El Nido underpins not only the food system, but it also supports the tourism sector. It is currently suffering degradation from human activities which is undermining its ability to continue to provide ecosystem services. Without a healthy environment both the food system and tourism will decline.

The study has found the El Nido food system is facing a number of pressures and has reached its tipping point. Whilst the study assessed some policy interventions within the scenarios, it found the interventions were not effective in reversing or halting falling agricultural production, declining fish catch and habitat degradation. Without a platform of sound, integrated policy interventions designed to prioritise and strengthen the local production systems, conserve the natural resource base and build in safety nets to provide support to local communities during downturns, the system will continue to decline and be unable to provide for a food secure future for the local communities.

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Appendices

Appendix A: Ethical clearance for research involving human participants

THE UNIVERSITY OF QUEENSLAND

Institutional Human Research Ethics Approval

Project Title:	Capturing Coral Reef and Related Ecosystem Services (CCRES) Project - 16/02/2016 - AMENDMENT
Chief Investigator:	Prof Peter Mumby, Dr Carl Smith, Melanie King
Supervisor:	Dr Carl Smith, Prof Peter Mumby, John Pickering
Co-Investigator(s):	Prof Tom Baldock, Dr Dave Callaghan, Dr Behnan Shabani, Prof Andrew Griffith, Dr Russell Richards, Mr Siham Taruc, Dr Alice Rogers, Mr Nicholas Wolff, Prof Matthew Sanders, Mr John Pickering, A/Prof Damian Hine, A/Prof Kim Bryceson, Dr David Parker, Dr Sue McAvoy, Dr Anya Phelan, Mr Erik Simmons, Mr Abdi Tunggal Priyanto, Dr Nils Krueck, Ms Lisda Haryani
School(s):	Biological Sciences; SAFS; Business; Civil Engineering; Psychology; Centre for Biodiversity and Conservation Science
Approval Number:	2015000582
Granting Agency/Degree:	The World Bank; Global Environment Facility; UQ
Duration:	31st December 2018

Comments/Conditions:

Note: if this approval is for amendments to an already approved protocol for which a UQ Clinical Trials Protection/Insurance Form was originally submitted, then the researchers must directly notify the UQ Insurance Office of any changes to that Form and Participant Information Sheets & Consent Forms as a result of the amendments, before action.

Name of responsible Committee:
Behavioural & Social Sciences Ethical Review Committee
This project complies with the provisions contained in the *National Statement on Ethical Conduct in Human Research* and complies with the regulations governing experimentation on humans.

Name of Ethics Committee representative:
Associate Professor Elizabeth MacKinlay
Acting Chairperson
Behavioural & Social Sciences Ethical Review Committee

Signature Liz MacKinlay Date 18/2/16

Appendix B: Scenario policy parameters- rationale and data source

Policy Objectives	Performance Indicators	Adjusted Variable	Unit of Measure used for 'Adjusted Variable'	Rationale & Data Source for adjusted variable metrics		
				Scenario 1	Scenario 2	Scenario 3
Increase tourist numbers	1. Number of tourists a. Total	n/a	No. of people	2015 population figures (Source: Philippines Statistical Authority)	2015 population figures (Source: Philippines Statistical Authority)	n/a
		Initial annual growth in tourist arrivals	Percentage	Growth rate over 1998-2016 period (Source: El Nido Municipal Tourism Office)	Based on El Nido LGU tourism policy to double numbers in five years (Source: El Nido Municipal Tourism Office)	Growth rate over 1998-2016 period (Source: El Nido Municipal Tourism Office)
		Tourist arrival cap per year	No. of tourists	Government policy of no caps (Source: El Nido Local Government Unit)	There is no policy to cap tourist numbers (Source: El Nido LGU)	Based on cap on tourist numbers to regulate tourism impacts
		Total tourist population allowed	No. of tourists	Government policy of no caps (Source: El Nido Local Government Unit)	There is no policy to cap tourist numbers (El Nido LGU)	Based on cap on tourist numbers to regulate tourism impacts
		Rooms per hotel		Calculated on available data for hotels and number of rooms (Source: Tripadvis	Calculated on available data for hotels and number of rooms (Source: Tripadvisor)	Calculated on available data (Source: Tripadvisor)
	2. Number of tourist related jobs					
	3. Demand for food a. Demand for agricultural products. b. Demand for fisheries products					
	4. Water consumption a. Limiting effect					
	5. Land used for urban development a. Total b. Hotels c. Houses	Allowable land for hotel development	Hectares	Zoning for urban development (Source: Comprehensive Land Use Plan 2003-20	Proposed tourism/commercial land use zoning (Source: ECAN RMP 2015-2020)	Land suitable for agricultural and urban use (Source: ECAN RMP 2015-2020)
		Allowable land for housing development	Hectares	Zoning for urban development (Source: Comprehensive Land Use Plan 2003-20	Proposed settlement land use zoning (Source: ECAN RMP 2015-2020)	Land suitable for agricultural and urban use (Source: ECAN RMP 2015-2020)
			Hectares	Zoning for urban development (Source: Comprehensive Land Use Plan 2003-20	Proposed total urban land use zoning (Source: ECAN RMP 2015-2020)	Land suitable for agricultural and urban use (Source: ECAN RMP 2015-2020)
			Hectares	Current land under forest (Source: ECAN RMP 2015-2020)	Proposed forested land use zoning (Source: ECAN RMP 2015-2020)	Proposed forested land use zoning (Source: ECAN RMP 2015-2020)
	6. Stormwater loading a. Sediment b. Nutrients (Nitrogen & Prosperous)					
	7. Septic Tank loading a. Nutrients	Septic tank pumpout frequency (Hotel)	This slider can be used to adjust the frequency that septic tanks are pumped out. If this slider is set to 1 then the pump out frequency is once every week.	Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)
		Septic tank pumpout frequency (House)		Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)
		Proportion of septic tanks pumped per pumpout	This slider enables the fraction (0 - 1) of septic tanks that are in the site to be adjusted	Assumption in model (Source: Expert elicitation)	Based on an assumption all new hotels will link into waste treatment facility	Based on an assumption all new hotels will link into waste treatment facility
		Proportion of septic tanks pumped per pumpout		Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)
		Greywater produced per hotel per week	This slider enables the greywater (cubic metres) that is produced each week by a single poor household to be adjusted.	Assumption in model (Source: Expert elicitation)	Based on assumption the increase in number of hotels will increase greywater	Assumption in model (Source: Expert elicitation)
		Weekly grey water per HH type [Non-Poor]		Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	
		Weekly grey water per HH type [Poor]		Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	Based on assumption the increase in number of hotels will increase greywater

Policy Objectives	Performance Indicators	Adjusted Variable	Unit of Measure used for 'Adjusted Variable'	Rationale & Data Source for adjusted variable metrics		
				Scenario 1	Scenario 2	Scenario 3
Increase volume of local agricultural production	1. Land used for agriculture	Land area zoned for agriculture	Hectares	Zoning for agricultural land (Source: Comprehensive Land Use Plan 2003-2012)	Proposed agricultural land use zoning (Source: ECAN RMP 2015-2020)	Land suitable for agricultural and urban use (Source: ECAN RMP 2015-2020)
	2. Number of agricultural jobs					
	3. Water consumption or limitation					
	4. Yield of local production	Proportion of irrigated cropland (lowland rice)	Hectares	Land under irrigation in 2017 (Source: El Nido Municipal Agricultural Office)	Land under irrigation in 2017 (Source: El Nido Municipal Agricultural Office)	Based on all lowland rice area under irrigation
	5. Imports					
	6. Pricing of agricultural products					

Policy Objectives	Performance Indicators	Adjusted Variable	Unit of Measure used for 'Adjusted Variable'	Rationale & Data Source for adjusted variable metrics		
				Scenario 1	Scenario 2	Scenario 3
Increased fish catch through sustainable fisheries management	1. Fish density (kg/hectares) a. Herbivores b. Squid c. Predators	Mooring damage rate multiplier small boat	This slider assigns a multiplying effect to the damage rate caused by small fishing boats on reef and seagrass habitats. If the slider is set to a value < 1 (slider moved left of the center) then damage rate is reduced. If the slider is set to a value > 1 (slider moved right of center) then the damage rate is increased.	Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	Based on reduction in small boat fishing licenses in model & increased surveillance
		Mooring damage rate multiplier large fishing boats		Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	Based on reduction in small boat fishing licenses in model & increased surveillance
		Mooring damage rate multiplier tourist boat		Assumption in model (Source: Expert elicitation)	LGU policy to reduce number of boats in tourist sites (Source: Business Mirror)	LGU policy to reduce number of boats in tourist sites (Source: Business Mirror)
		Small trad boats license limit time independent	No. of boat licenses	Number of boats registered in 2015 (Source: Office of the Provincial Agricultur	Number of boats registered in 2015 (Source: Office of the Provincial Agriculturist)	Proposal of scenario to reduce licenses to rebuild fisheries
		Small trad boats license limit time independent	No. of boat licenses	Number of boats registered in 2015 (Source: Office of the Provincial Agricultur	Number of boats registered in 2015 (Source: Office of the Provincial Agriculturist)	Proposal of scenario to reduce licenses to rebuild fisheries
		Small trad boats license limit time independent	No. of boat licenses	Number of boats registered in 2015 (Source: Office of the Provincial Agricultur	Number of boats registered in 2015 (Source: Office of the Provincial Agriculturist)	Proposal of scenario to reduce licenses to rebuild fisheries
		Large fishing boats licence limit [pelagic boat]	No. of boat licenses	Commercial boats home-based in Palawan in 2017 (Source: Marina PEO Data)	Number of boats <3 tonne in 2017 classified as Municipal boats (Source: Marina PEO Da	Number of boats <3 tonne in 2017 classified as Municipal boats (Source: Marina PEO D
		Large fishing boats licence limit [squid boat]	No. of boat licenses	Commercial boats home-based in Palawan in 2017 (Source: Marina PEO Data)	Number of boats <3 tonne in 2017 classified as Municipal boats (Source: Marina PEO Da	Number of boats <3 tonne in 2017 classified as Municipal boats (Source: Marina PEO D
		Small trad boats license limit time independent	No. of boat licenses	Number of boats registered in 2015 (Source: Office of the Provincial Agricultur	Number of boats registered in 2015 (Source: Office of the Provincial Agriculturist)	Proposal of scenario to reduce licenses to rebuild fisheries
		Small trad boats license limit time independent	No. of boat licenses	Number of boats registered in 2015 (Source: Office of the Provincial Agricultur	Number of boats registered in 2015 (Source: Office of the Provincial Agriculturist)	Proposal of scenario to reduce licenses to rebuild fisheries
		Small trad boats license limit time independent	No. of boat licenses	Number of boats registered in 2015 (Source: Office of the Provincial Agricultur	Number of boats registered in 2015 (Source: Office of the Provincial Agriculturist)	Proposal of scenario to reduce licenses to rebuild fisheries
	2. Habitats a. Reef (non MPA and MPA) b. Mangrove c. Seagrass	Actual fishing weekly survellience effort	This slider sets the effect (0 - 100%) that surveillance has on destructive fishing activity.	Assumption in model (Source: Field observations)	Assumption in model (Source: Field observations)	Proposal of scenario to increase surveillance to rebuild fisheries
		Actual fishing weekly survellience effort		Assumption in model (Source: Field observations)	Assumption in model (Source: Field observations)	Proposal of scenario to increase surveillance to rebuild fisheries
		Actual fishing weekly survellience effort		Assumption in model (Source: Field observations)	Assumption in model (Source: Field observations)	Proposal of scenario to increase surveillance to rebuild fisheries
	3. Imports	Fish mass weekly import cap				
	4. Livelihoods a. Traditional fishers b. Destructive fishers c. Income per boat (trad)	Small trad boats license limit time independent	No. of boat licenses	Number of boats registered in 2015 (Source: Office of the Provincial Agricultur	Number of boats registered in 2015 (Source: Office of the Provincial Agriculturist)	Proposal of scenario to reduce licenses to rebuild fisheries
		Large fishing boats licence limit [pelagic boat]	No. of boat licenses	Commercial boats home-based in Palawan in 2017 (Source: Marina PEO Data)	Number of boats <3 tonne in 2017 classified as Municipal boats (Source: Marina PEO Da	Number of boats <3 tonne in 2017 classified as Municipal boats (Source: Marina PEO D
		Large fishing boats licence limit [squid boat]	No. of boat licenses	Commercial boats home-based in Palawan in 2017 (Source: Marina PEO Data)	Number of boats <3 tonne in 2017 classified as Municipal boats (Source: Marina PEO Da	Number of boats <3 tonne in 2017 classified as Municipal boats (Source: Marina PEO D
	5. Habitat size and condition (carrying capacity) a. Reef (non MPA) b. Reef (MPA) c. Mangrove d. Seagrass					
		Tourist boats license limit	No. of tourist boat licenses	Number of boats registered in 2015 (Source: ECAN RMP 2015-2020)	Number of boats registered in 2015 (Source: ECAN 2015-2020)	Number of boats registered in 2015 (Source: ECAN 2015-2020)
		REEF percentage of reefs and reef rubble protected	Percentage	Percentage of MPA in Municipal waters (Source: ECAN RMP 2015-2020)	Increase percentage of CMMPA in Municipal waters (Source: LGU Ordinance No 001-006	Proposal of scenario to increase area of MPA to rebuild fisheries
		REEF percentage of reefs and reef rubble protected	Percentage	Percentage of MPA in Municipal waters (Source: ECAN RMP 2015-2020)	Increase percentage of CMMPA in Municipal waters (Source: LGU Ordinance No 001-006	Proposal of scenario to increase area of MPA to rebuild fisheries
		Mooring damage rate multiplier tourist boat	As above	Assumption in model (Source: Expert elicitation)	LGU policy to reduce number of boats in tourist sites (Source: Business Mirror)	LGU policy to reduce number of boats in tourist sites (Source: Business Mirror)
		Mangrove restoration replanting density [Small mangrove]	This slider sets the density (mangroves per hectare) that 'Small' and 'Large' mangroves are planted during restoration in of recovered mangrove areas.	Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	Proposal of scenario to increase mangrove restoration to improve fisheries & runoff
		Mangrove restoration replanting density [Large mangrove]		Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	Proposal of scenario to increase mangrove restoration to improve fisheries & runoff
		Annual mangrove restoration rate multiplier	This slider assigns a multiplying effect to the restoration density of 'Small' and 'Large' mangroves specified in the two other sliders in this sub-control panel.	Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)	Assumption in model (Source: Expert elicitation)

Annex C: Semi-structured interview protocol matrix

Script prior to interview

I'd like to thank you for being willing to participate in the interview aspect of my study.

[Provide an overview of my study]

[Ask interviewee what language they are comfortable speaking in]

My study seeks to understand food security and the food system in El Nido. During our interview today I will be asking you about your thoughts on food security in your barangay. These questions will be about agriculture and fisheries production and how households access food.

[Review aspects of the consent form and seek consent for the conversation to be recorded as notes]

If yes: Thank you. Please let me know if at any point you are not comfortable answering a question.

If no: Thank you for letting me know. I will not take notes of this conversation.

Before we begin the interview, do you have any questions? [Discuss questions]

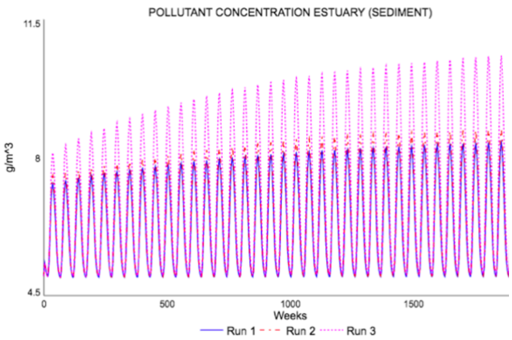
If any questions (or other questions) arise at any point in this study, you can feel free to ask them at any time. I would be more than happy to answer your questions.

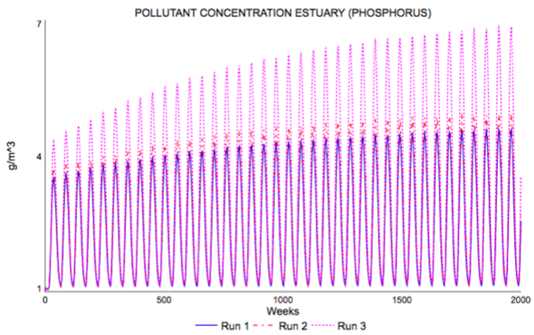
Research Question	Interview Questions
Research Question 1: What are the factors contributing towards food security globally and in Southeast Asia in particular? a. What is food security? b. What is the current state of food security at the global and regional level? c. How does this translate to the local context?	*To begin this interview, I would like to ask you some questions on food security in your barangay* • What do you understand about food insecurity? • Is food insecurity a problem in your barangay? *Follow up:* • Do you have access to enough food to feed households? • What is the main source of food in the barangay i.e. what do people eat the most of? *(what else?)* *End of interview question:* • What do you think people in the barangay will be eating over the next 5-10 years? Where is the possible source of food?
Research Question 2: What are the dynamics affecting food security in a southeast Asian community? a. What are the social-ecological drivers affecting a community's food system and its behaviour over time? b. What are the interactions and feedback loops between these drivers within a local community that explain the behaviour over time?	• What is the main source of food in the barangay i.e. what do people eat the most of? *(what else?)* *Follow up:* • What are your crops and how many rotations a year do you do? • For the food eaten here in the barangay, where does it come from? • Is your priority for eating your own crops / catch or do you wish to sell more? • If the crops have failed or there is no fish what happens? • If you do not get good prices for your crops or fish what do you do? • Why do crops fail or why do you not get a good price? • Do you use gleaning to gather food? What sort of food? Who does the gleaning? What do they glean? Is it seasonal? Do you eat it or sell or both? • Is fishing increasing or decreasing in the barangay? Are you finding it harder or easier to catch fish? What sort of fish are you catching? Has size or type of fish changed? • What do you see as the biggest threats to food production or buying food (i.e. food security) in their barangay? Why? *Follow up:* • What do you feel could be done to alleviate these threats? • What do you see will be the future of agricultural production and / or fisheries?

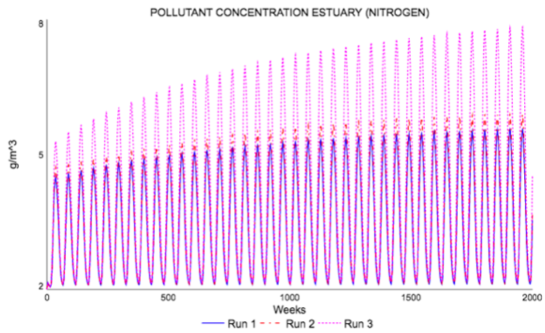
Annex D: Additional model simulations

Pollutant Concentrations

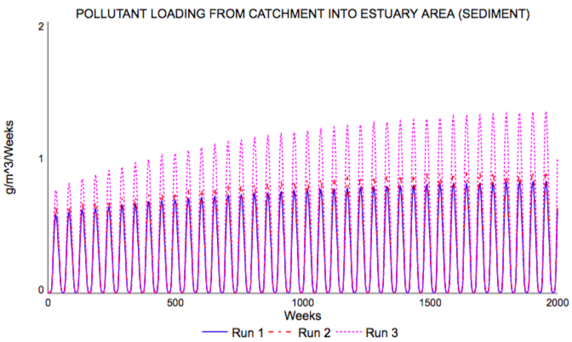
The model highlights the effect rainfall has on the levels of pollutants entering the system from waste and agricultural activities through the oscillating trends seen for the *pollutant concentration estuary (sediment, phosphorous and nitrogen)* across the scenarios. Overall, Scenario 3 demonstrates the highest levels of pollutant concentration with an increase over the simulation period. The increase in pollutant concentration may be due to increased levels of surface water volume.

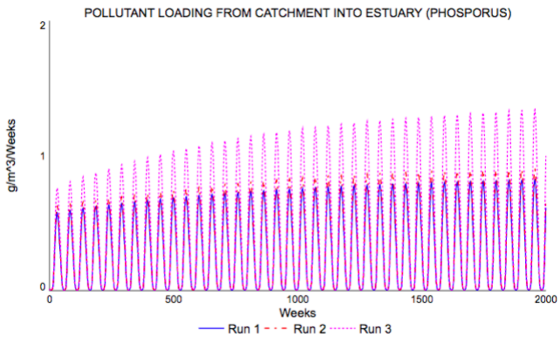


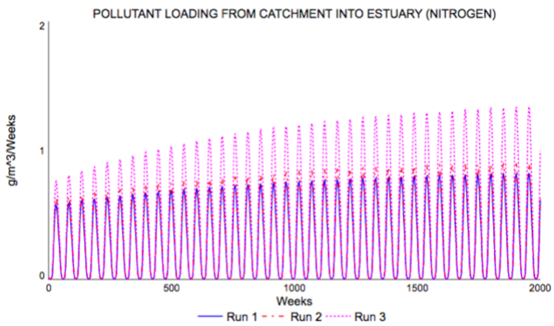




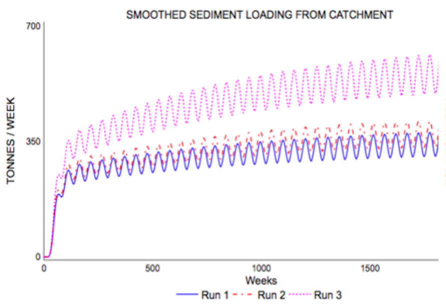
The same trends can be seen in the pollutant loading from catchment into estuary (sediment, phosphorous and nitrogen) with Scenarios 1 and 2 corresponding to each other with a gradually increasing trend, and Scenario 3 showing the larger rate of increase over the time period due to increased levels of surface water volume.

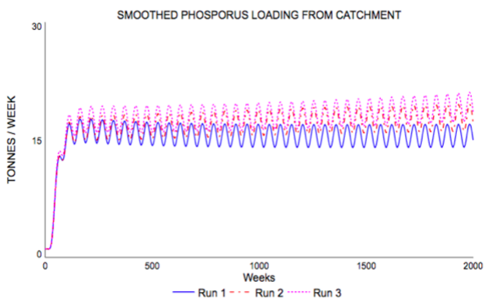


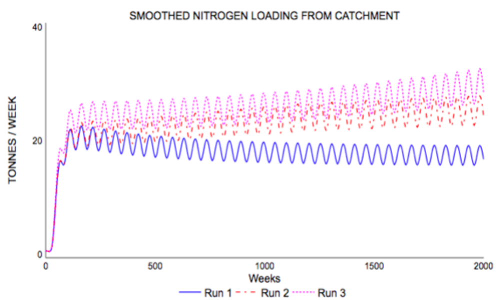




For the *smoothed sediment loading from catchment* all scenarios show increases with Scenario 3 showing higher levels than Scenarios 1 and 2 which correspond closely to each other. The *smoothed phosphorous loading from catchment* highlights a parallel trend across the three scenarios, with Scenario 1 showing lower levels than Scenarios 2 and 3. Lastly, the *smoothed nitrogen loading from catchment* shows levels under Scenario 1 declining slowly over the period, whilst the levels under Scenarios 2 and 3 increase, with Scenario 3 showing the highest levels of loading due to the increased surface water volume.



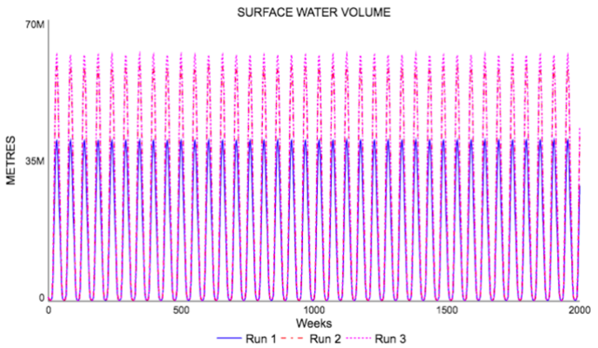


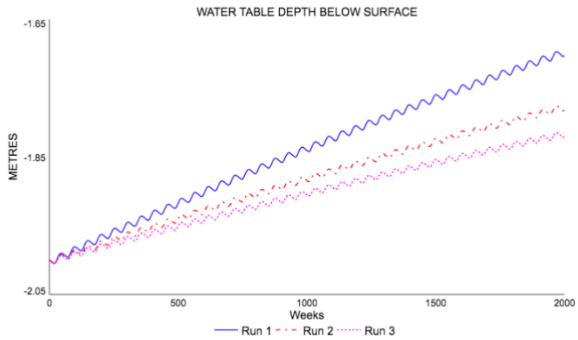


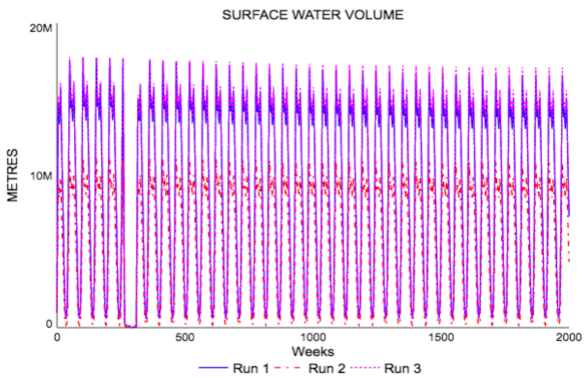
Surface Water and Groundwater

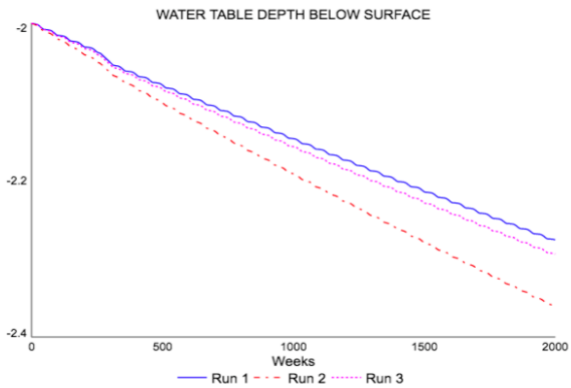
In simulating water demand, the model reveals an oscillating trend for *surface water volume* due to the effects of seasonal rainfall across all scenarios. Higher volumes of surface water are achieved under Scenarios 2 and 3. The simulations for groundwater extraction highlight increases for all three scenarios as the *water table depth below surface* declines as more groundwater is extracted.

Scenario 1 demonstrates a higher level of extraction, whilst Scenario 3 reveals the lowest extraction levels.



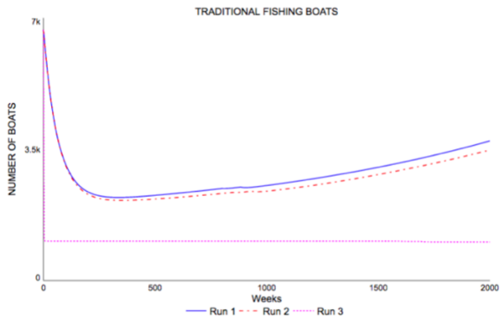


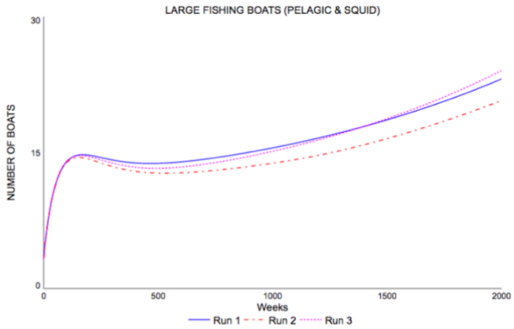


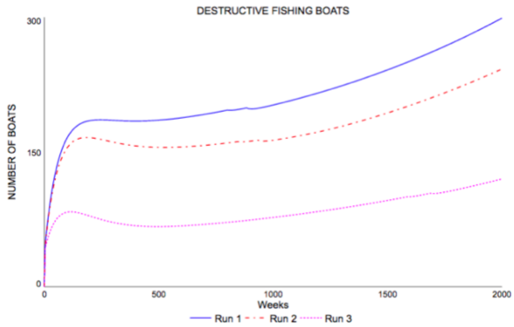


Fishing Boats

The number of *traditional fishing boats* reflects increasing trends for Scenarios 1 and 2, whilst the number of boats under Scenario 3 remains steady due to the licensing caps. *Large fishing boats (pelagic and squid)* reveals corresponding trend patterns across all three scenarios, as there is an increase in the number of boats over the simulation period. However, Scenario 2 reveals a lower number of boats compared to the other two scenarios, possibly due to licensing caps or a shift into tourist boats. Lastly, *destructive fishing boats* shows a gradual increase under the three scenarios, with Scenario 1 illustrating a higher level of destructive fishing than Scenarios 2 and 3, with Scenario 3 revealing the lowest number of destructive fishing boats due to increased surveillance effort.







Fishing Effort

The model emphasises a steady trend for *traditional fishing effort on reefs* for all scenarios, however overall, Scenario 3 reflects lower trends. Scenarios 1 and 2 illustrate a steady trend pattern, with Scenario 3 running parallel at a lower rate and showing oscillating behaviour due to the 'closed season' switch. *Traditional fishing effort in mangroves* is modelled as a steady trend declining slowly across the time period. As with fishing effort on reefs, Scenario 3 runs parallel to Scenarios 1 and 2 but at a lower rate of fishing effort. The model highlights *traditional fishing effort in seagrass* as the same trend as traditional fishing effort in reefs, with all scenarios holding steady with a small increase across the simulation period. *Traditional fishing effort in pelagics*, demonstrates similar trends for all scenarios, with a steady trend across the time period.