Improving food security through Smallholder adoption of Sustainable Agricultural Intensification (SAI)

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Glossary and Acronyms

Aldea	Village size area
Aus	AID Australian Agency for International Development
CSOs	Civil Society Organisations
FAO	Food and Agriculture Organisation
GIZ	Deutsche Gesellschaft fur Internationale Zusammenarbeit of Germany
GMO	Genetically Modified Organisms
HYV	High Yielding Varieties
IFAD	International Food and Agricultural Development
LH	La'o Hamutuk
MAF	Ministry of Agriculture and Fishery
MC	Mercy Corps
MCIE	Ministry of Commerce, Industry and Energy
MDG	Millennium Development Goal
NGO	Non Governmental Organisations
RDTL	Republic Democratic of Timor-Leste
SAP	Structural Adjustment Programs
SoL	Seeds of Life
Suco	an area smaller than a sub-district, larger than an Aldea/village
UNTL	National University of Timor-Leste
UNTAET	United Nations Transitional Administration in East Timor
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
WB	World Bank
WV	World Vision

Chapter 1 Introduction

The global problem of food insecurity is severe, and with diminishing planetary resources and a growing human population, seems likely to intensify. While the development model used in the 20th century reduced poverty and hunger in some areas, it also contributed to widespread degradation of natural resources (and in some areas contributed to inequality). It has been argued that new approaches to food security are needed that produce more output per unit of land, improve management of natural resources and provide sustainable livelihoods to the world's 900 million smallholders (McIntyre et al. 2009). Such an approach to agriculture has been described as Sustainable Agricultural Intensification (SAI). Because SAI is knowledge-intensive and needs to be adapted to local conditions, it is not as easily adopted as more conventional practices. Consequently, strategies for adoption and scaling-up SAI need to be customised at the country level. Using Timor-Leste as a case study, this thesis examines how, and to what advantage, SAI can be scaled-up nationally. It argues that food security[1] can be improved in Timor-Leste by promoting and supporting smallholder adoption of SAI.

1.1 The Global Food Problem

The starting point for this thesis outlines the scope and character of global food insecurity; and provides a background of global response to food security in developing countries leading up to these current day debates. There are several key factors that have a significant impact on global food security that are beyond the scope of this thesis, including changing diets, resource competition from biofuels and the use of genetically modified organisms (GMOs). In recognition of their importance to the topic, brief comments are presented in Appendix B.

Worldwide, the number of undernourished people fluctuates – reaching a low of 790 million in 1995/97 (FAO 1999) and a high of 1.02 billion in 2009 (FAO 2009). Currently the figure is 805 million undernourished people, of whom more than 790 million live in the developing world (FAO 2014:12, 56). While this number is lower than in 2009, it highlights the little

[1] Agreement about the 'right to food' is enshrined in a range of international documents; each contributing to the World Food Summit (1996) definition of food security as requiring both sufficient production and economic access to food: "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 2006a:1).

progress that has been made in 20 years. There is increasing debate about what should be done.

It is generally agreed that to address world hunger, global food production needs to increase by 50% - 100% by 2050 (Royal Society 2009; Godfray et al. 2010), when the global population will reach 9 billion (McIntyre et al. 2009). Tilman et al. forecast a required increase of 100-110% in global crop demand from 2005 to 2050; adding that "This projected doubling is lower than the 176% (caloric) and 238% (protein) increases in global crop use that would occur if per capita demands of all nations in 2050 reached the 2005 levels of [rich nations]" (2011:20260-20261).

What is not agreed is the direction of agriculture to achieve this increased production (Feldman and Biggs 2012, Kiers et al. 2008, Sumberg et al. 2012) with respect to, for example, the management of natural resources (Tilman et al. 2011), the role of biotechnology (Wager 2009; Morvaridi 2012), the role of smallholder farms (Ellis 2005; Collier 2008), the focus on commoditisation (Morvaridi 2012) and the risks of private sector land acquisitions in developing countries (Cotula et al. 2009; Hall 2011).

From the 1970s the response to poverty and food insecurity was a development model that focused on economic growth (GDP), largely through trade liberalisation, and on increased food production through crop intensification relying on high yielding varieties (HYVs), fertilisers and pesticides. This agricultural approach, usually referred to as the Green Revolution (GR), successfully improved agricultural output. By 2004 global cereal production approximately doubled without a change in the area cropped (Falcon and Naylor 2005).[2] But there are two major criticisms of the model: the non-inclusive framework in which the GR was promoted, and the negative environmental impacts of the agricultural techniques.

While global cereal production was increasing, the absolute number of people facing food insecurity in the developing world (excluding China) actually increased from about 600 million in 1980 to about 700 million in 2000 (Falcon and Naylor 2005). Poverty was significantly reduced in Asia but not in sub-Saharan Africa (UN 2008:6). Inequality and exclusion also existed within regions and countries; in part, due to the high cost of inputs and variable access to credit, technology and market opportunities - placing small-scale farmers,

2 Between 1961 and 1986, global cereal yield increased by 89% while only expanding the harvested area by 11% - reaching a high of 372 kg per person/year in 1986 (Funk and Brown 2009:10).

and women in particular, at a disadvantage (FAO 2011).[3] Trade liberalisation and the Structural Adjustment Programs (SAPs) of the 1980s and 1990s relied on privatization without addressing sequencing of developments such as education and training and structural issues such as the flow of information and services between local communities and broad-based economic strategies (Stiglitz 2002).

The GR techniques are associated with an unprecedented loss of biodiversity, soil health, and water and air quality (McIntrye et al. 2009). Over 40 years, almost one-third of the world's arable land was lost through erosion (Pimentel et al. 1995). Fertiliser use has resulted in eutrophication of surface waters, estuaries and coastal seas - polluting groundwater and marine environments (Tilman et al. 2001).

In 1989 the Global Assessment of Land Degradation (GLASOD) estimated 1,964 million hectares of land to be degraded, mostly as a result of inappropriate agricultural practices (Cassman et al. 2003:320).

Tilman et al. explored the potential future environmental impacts of these practices by forecasting to 2050 continued trajectories of the past 35 years or more. They found that projected increases in the use of nitrogen and phosphorus fertilisers and irrigation practices would continue to pollute freshwater systems and significantly reduce biodiversity, changing the composition and function of both terrestrial and aquatic ecosystems. Marine environments would suffer increased toxic algae blooms and hypoxic (dead) zones such as has occurred in the Gulf of Mexico. Pesticide production, which has increased for 40 years, would expand by 2.7 times, exposing humans and other organisms to markedly elevated levels of pesticides. If global trends for crop and pasture land continue, there would be a worldwide loss of natural ecosystems larger than the United States land area; representing "a third of tropical and

[3] Women are the main producers of the world's staple crops which provide up to 90% of the rural poor's food intake. In sub-Saharan Africa, women produce up to 80% of basic foodstuffs both for household consumption and for sale. Yet, fewer than 10% of women farmers in India, Nepal and Thailand own land. An analysis of credit schemes in five African countries found that women received less than 10% of the credit awarded to male smallholders (www.fao.org/gender/en/agrib4-e.htm, cited in Pimbert 2009).

Where women are the majority of smallholder farmers, failure to release their full potential in agriculture is recognised as a contributing factor to low growth and food insecurity (World Bank 2007, Godfray et al. 2010). It is estimated that closing the gender gap in agriculture could reduce the number of undernourished people in the world in the order of 12–17%, or as much as 100–150 million people (FAO 2011:vi).

temperate forests, savannas and grasslands and of the services (including carbon storage) provided by these systems” (Tilman et al. 2001:283).

Growth in crop yields is now stagnating[4] and, along with diminishing supplies of land and water, other pressures are mounting against the potential for greater food production, including climate change, a shift to more resource-intensive diets and competition for agricultural resources due to the demand for biofuels (World Bank 2007).

1.2 The attraction of Sustainable Agricultural Intensification

An agricultural development strategy is needed that not only increases food production but sustains productive capacity and improves nutrition and livelihoods for those who are most food insecure.

Alternative agricultural techniques are available that improve yields while operating within environmental constraints to protect natural resources and ecosystem services. These methods are not new, but are attracting increased attention in terms of food security and global development. This approach to agriculture is referred to as sustainable agricultural intensification (SAI), a description which recognises that in the future more food will need to be produced on the same amount of land, or even less land (Godfray et al. 2010).

SAI has been defined as “producing more output from the same area of land while reducing the negative environmental impacts and at the same time increasing contributions to natural capital and the flow of environmental services” (Pretty et al. 2011:7). SAI is not a specific farming technique but a general descriptor of farm practices based on these principles. It includes practices that build good soil structure, conserve water in the landscape, use natural crop defense mechanisms to reduce pesticide use and take advantage of the role of trees in food production systems. These same methods decrease CO_2 emissions and reduce existing atmospheric concentrations through carbon sequestration (Lal 2004). The techniques are discussed in detail in the next chapter.

[4] Annual growth in agricultural production will slow to 1.7% through 2021, down from 2.6% of the previous decade (FAO 2012). Per capita cereal production is now about 350 kg/per person/year, 6% less than the 1986 maximum, with significant variations between regions. Available food from this production is even less given that crop output is now also used for biofuels, alcohol and meat production (Funk and Brown 2009) further compromising food security objectives.

Importantly, SAI is linked to the multifunctional role of agriculture, i.e. producing commodities, supporting environmental services, and providing nutrition and livelihoods (Garnett et al. 2013). SAI is suitable to both large and small farms. Its suitability to small farmers is particularly significant in that 75% of poor people in developing countries live in rural areas and most depend on agriculture for their livelihoods (World Bank 2007). Increasing their capacity for higher productivity directly develops rural communities, improving food security through greater direct access to food and/or higher income. Increasing smallholder productivity promotes equity and contributes to faster economic growth through increased income distribution (Remenyi 2004:123).

This is not to suggest there isn't a role for large-scale farming operations in poor-countries, particularly if investors bring improvements to sustainability, added value through processing and employment opportunities (Godfray et al. 2010, Wegner and Zwart 2011). But given the demographics of poverty and agriculture, the role of small-scale famers is fundamental to poverty reduction and food security.

An International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD), involving 400 experts from 30 countries, was conducted to assess the impact of agricultural knowledge, science and technology on human health and sustainable development and the reduction of hunger and poverty. The report called for actions to lessen the environmental impacts of past agricultural practices and better address the needs of the world's 900 million small farmers (McIntyre et al 2009).[5]

Although examples of SAI exist in many countries, scaling-up its adoption is more difficult than scaling-up conventional agriculture focused on the use of HYVs, fertilisers and pesticides - primarily because SAI is less prescriptive and more knowledge-intensive (Pretty et al. 2011); and remote, widely-dispersed and poorly resourced communities find it difficult to access specialised knowledge (Scheer and McNeely 2008). Scaling-up SAI requires

[5] As with much of the development literature, the IAASTD (2009) report recognised that the success of these actions in advancing development goals also relies on factors outside of agriculture per se, including:

- increasing access of small-scale farmers to land, water and finance
- providing adequate rural infrastructure (e.g., roads)
- optimising supply chains
- reducing gender and ethnic inequities
- good governance
- basic education
- trade rules

understanding local conditions and resources such as labour availability, access to and condition of land and water, the existing ecological or institutional constraints, the needs of local farmers and local socio-economic conditions (IAASTD 2009; Garnett et al. 2013). Because of this, strategies for adoption and scaling-up SAI need to be customised at the country level. This Graduate Diploma research responds to this requirement by investigating the potential of SAI to improve food security in Timor-Leste.

1.3 Timor-Leste

Timor-Leste is selected because it is a key candidate for any system that addresses the multifunctional roles of agriculture. Over 70% of families rely on agriculture for their livelihood (RDTL 2011). There is low agricultural productivity with mountains and hills occupying 72% of the country and shallow soils of poor quality (Egashira et al. 2006). There is an increasing level of environmental vulnerability due to past agricultural practices and overgrazing; and increasing population pressures. Timor-Leste has high levels of malnutrition and poverty.

The overall question of the thesis is "How, and to what advantage, can SAI be better supported and scaled-up nationally in Timor-Leste?" This involves examination of three key questions:

1. What is the capacity of SAI to serve the multiple functions of livelihood, nutrition and natural resource management – in general and in Timor-Leste?
2. To what extent does smallholder sustainable agriculture provide a framework for rural development in Timor-Leste?
3. What are the obstacles and opportunities associated with scaling-up SAI in Timor-Leste?

The next chapter explores SAI in greater detail, describing the kind of farming techniques involved, the science underpinning those techniques, their productive capacity and the extent to which SAI is currently practiced worldwide. Chapter 3 presents the context of Timor-Leste and its development challenges. Chapter 4 presents the methodology used in this research. Research results (the capacity of SAI; and the development framework and potential to scale-up SAI in Timor-Leste) and their implications are presented in Chapters 5 and 6, respectively. Chapter 7 concludes this dissertation.

Chapter 2 Sustainable Agricultural Intensification

2.1 What is SAI?

This chapter examines sustainable agricultural intensification (SAI). It explores the kind of farming techniques involved, the science underpinning those techniques, the capacity of SAI to support natural resource management, how productive it is, and the extent to which SAI is currently practiced globally.

SAI includes a range of agricultural systems that focus on operating within environmental constraints, providing and protecting ecosystem services. These systems include, for example, agroecology, climate-smart agriculture, organic agriculture, system of rice intensification (SRI), and agroforestry systems. It incorporates conservation agriculture and aquaculture. The core principles include recycling nutrients and energy on the farm rather than introducing external inputs, integrating crops and livestock, diversifying species and genetic resources, and focusing on interactions and productivity across the agricultural system rather than on individual species alone (De Schutter 2010:6).

Many of these methods are derived from traditional agriculture (Xie et al. 2011; Gliessman 2000). Early advocates in the West include Eve Balfour and Sir Albert Howard who, in the 1940s, wrote seminal publications emphasising the importance of biologically active soil with high organic matter content. Public concern about the destructive potential of conventional farming increased following publication of Rachael Carson's *Silent* Spring (1962) and, later, a range of books about the negative impacts of the GR in developing countries.[6] By the 1980s, alternative agricultural systems were being promoted by national organisations[7] and these organisations were also coming together via the International Federation of Organic Agricultural Movements (IFOAM) which was established in 1972. Increasing interest and prominence of such systems is illustrated by the change in attitudes of agricultural institutions such as the American Association for the Advancement of Science (AAAS) which, in 1974, claimed that organic farming was 'scientific nonsense' and the 'domain of eccentrics'. Seven years later, in 1981, the AAAS "published a major research paper that found organic farms to

[6] For example, Weir, D. and Shariro, M. 1981. *Circle of Poison – Pesticides and People in a Hungry World*, Institute for Food and Development Policy, San Francisco.

[7] For example, Wynen, E. and Fritz, S. 1987. *Sustainable Agriculture, A Viable Alternative*, National Association for Sustainable Agriculture, Australia, Sydney. Also see Lockeretz, W. (Ed.) 2007. *Organic Farming – An International History*, CABI, Oxfordshire, UK.

be highly efficient and economically competitive while using less fossil energy and suffering less soil erosion than neighbouring conventional farms" (Lockeretz 2007:1). Interest has continued to grow since the 1980s as a result of green consumerism, stronger international markets for organic produce and interest from scientists and policy makers because of the need to address natural resource management.

Sustainable intensification systems are now attracting attention with respect to food security and global development (Royal Society 2009; Godfray et al. 2010). Garnett et al. (2013) identify four core premises underlying the approach:

1. the need to increase production
2. increased production will require higher yields to avoid extending agriculture into natural ecosystems
3. food security requires as much attention to increasing environmental sustainability as to raising productivity
4. SAI denotes a goal – but does not specify how it should be attained. "The merits of diverse approaches … should be rigorously tested and assessed, taking biophysical and social contexts into account" (2013:33).

The broad approach has triggered debate as to how holistic this concept needs to be (Ponisio et al. 2014). A leading proponent of agroecology, Miguel Altieri, objects to approaches which take one (positive) aspect of agroecology and place it alongside more conventional practices such as the use of genetically modified organisms (GMOs), micro-dosing of fertilisers and herbicides and integrated pest management (IPM) which combines reduced use of pesticides with more natural pest control strategies. He maintains that "Agroecology does not need to be combined with other approaches" and would be rendered meaningless by such association (Altieri 2012:5).

Horlings and Marsden (2010) argue against the narrow adoption of sustainable practices in such a way that they fail to address the social, cultural, and political aspects of agriculture within societies.

In this thesis I maintain that SAI is an approach that recognises the holism of the agro-ecological environment; and that promoting its adoption by smallholders is a means of better addressing key socio-economic issues related to agriculture. The decision to use technologies must be based on an understanding about what agricultural methods complement or contradict biological processes and ecosystem services on which farmers rely (Pretty et al. 2011).

Although strict agroecological and organic systems are viable now in many places worldwide, transition to more sustainable farming requires new information, understanding and skills – all of which most of the world's poor farmers do not have access to. In line with Horlings and Marsden (2010) this thesis focuses on the multifunctionality of agriculture. SAI is not just about adopting more environmentally sustainable farming practices, but promoting its adoption by small-scale farmers in order to improve their livelihoods, household nutrition and the long-term productivity of their land – all critical elements of food security. In this respect, SAI – in this thesis – could also be referred to as Multifunctional Agriculture (MA).

2.2 The practice and science behind SAI

The philosophy behind SAI can be illustrated with respect to agricultural practices relating to six areas: intercropping, soil health, fertilisation, pest management, water management and climate. The following discussion of each demonstrates the holistic nature of the SAI approach.

The use of GMOs is one of the key points of dispute about the direction of agricultural development, even amongst proponents of SAI. Discussion on this point has been included in Appendix B.

2.2.1 Intercropping

Intercropping is growing two or more crops together in a mixture such as corn/beans/squash. All three species are planted at the same time. Corn soon dominates the canopy, protecting beans and squash from heat stress, to which they are more vulnerable. Beans climb to occupy the middle layer and, as a legume, supply nitrogen to the corn (which has high nutrient demand). Squash remains at ground level, reducing water evaporation by shading the soil surface and aiding weed control as a living mulch and by leaching allelopathic chemicals when it rains. In this system herbivores are at a disadvantage as the mix makes it more difficult to find their food source. Corn yields can be as much as 50% greater than in mono-cropped systems. The beans and squash suffer a yield reduction but total yields for the three crops together are higher than what would have been obtained in an equivalent area planted to monocultures of the three crops (Gliessman 2000).

The intercropping of lettuce and broccoli provide an example of how other characteristics are matched. Lettuce is short-rooted and matures quickly. Broccoli roots penetrate deeper, reducing competition with the lettuce. Once lettuce are harvested broccoli, which grows large and matures slowly, can take advantage of the available space. Testing of the intercropping of lettuce and broccoli at three planting densities showed that intercropping produced higher total yields (from 10% - 36% higher) than control plots of each planted as a standard mono-crop (Gliessman 2000).

Finally, intercropping promotes the presence of beneficial insects with a more attractive microclimate and more diverse pollen and nectar sources (Gliessman 2000:224).

2.2.2 Soil health

The importance of soil protection and maintenance of its structure can not be overestimated. Soil degradation "affects 200 million hectares of cultivated land in 37 Africa countries and is becoming increasingly recognized as a primary constraint to agricultural development" (Sanchez et al. 1997 and Conway 1998 cited in Verchot et al. 2007:10). The cost of soil erosion in Kenya "is equivalent to 3.8 per cent of GDP and equal in magnitude to national electricity production or agricultural exports" (Cohen et al. 2005 cited by Verchot et al. 2007:6).

Healthy soil, a critical element of which is a high level of organic matter, is one of the fundamental characteristics of sustainable agriculture. Organic matter increases biological activity in the soil, important for pest and disease resistance; and increases the soil's cation exchange capacity, holding nutrients in the soil (reducing leaching to downstream water systems) and increasing their availability to plants. Organic matter is critical to soil structure, it creates pore spaces providing aeration and water-holding capacity - building resilience to drought and rising temperatures (Gliessman 2000).

One method of building soil health is by the use green manures, which are crops grown specifically to supply the soil with organic matter and nutrients by being turned into the soil before reaching full maturity. While growing, they protect the soil from heat, wind, and rain; reducing erosion and helping to maintain the biological activity of the soil. Green manures, or other vegetative cover in place of bare fallows, can provide an opportunity for livestock as part of the rotation; improve nutrient holding and weed management; provide a break in the cycle of pests and potentially attract pest predators[8] (FAO 2010).

Soil health and structure is also maintained by reduced tillage. Tillage causes oxidation of the organic matter[9] along with a loss of carbon dioxide, and destroys biopores in the soil structure (FAO 2010:5). Reduced tillage supports increased earthworm abundance and activity (Gliessman 2000) and reduces water runoff and erosion (Schumacher and Rickerl 2004).

'Zero tillage' is a practice that has been widely adopted and is also referred to as Conservation Agriculture (CA). Because CA commonly uses herbicides for weed control as a substitute for tillage, its acceptance as a form of SAI illustrates the debates about what should be included as SAI. Horlings and Marsden (2010) argue that zero tillage in combination with crop rotations and diversification into livestock has consistently reduced weed infestations contributing to improved food security for small farmers. Kassam et al. (2009) report that herbicide can be reduced by 30-50% in CA systems and that crop rotations reduce weeds over time. They emphasise its capacity to conserve soil, water and biological activity; and that CA is practised without herbicides in the USA, Brazil and Germany.

2.2.3 Fertilisation

In addition to green manures, SAI employs a range of fertilising practices including compost, animal dung, leguminous trees, rock phosphate and biogas residues. The macronutrients that most limit agricultural production are nitrogen (N), phosphorus (P) and potassium (K) (Badgley et al 2007) but attention to micronutrients and nutrient balancing is also important.

Nitrogen is commonly supplied through leguminous plants which, through bacteria that live and reproduce in their root systems, are able to convert atmospheric nitrogen to ammonia. The ammonia becomes a fixed part of the soil nutrient supply and can be taken up by plant roots as nitrate (Gliessman 2000). Due to the cost of mineral fertilisers, poor farmers use none or little (e.g. in African countries farmers use an average of 9kg/ha). The use of leguminous crops can supply up to 150kg nitrogen/hectare (Verchot et al. 2007) reducing dependency on

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8 For example, in Georgia, berseem is a winter legume grown as fodder/green manure and habours *Geocoris punctipes*, a beneficial predatory insect (SAREP 2011).

9 For example, while organic matter levels of 3.5% are indicative of good soil, the average organic matter content of top soil in Bangladesh declined by 20 to 46 percent (to one percent) over 20 years of intensive cultivation (MOEF 2002:19-20).

mineral fertilisers while also providing soil surface protection, diversity in cropping and cash income (Denning et al. 2009).[10]

Leguminous plants can be incorporated into the farming system as agroforestry. Agroforestry is the planting of trees or shrubs at the same time, or in rotation, with crops or pastureland. Agroforestry can provide diversification with food, fibre, fuel and/or fodder for livestock (Nunes 2003:20, ITC 2008:15). Trees provide habitat for beneficial insects to enhance pollination and pest control (Tilman et al. 2002) and provide shelter for farm animals, reducing the amount of feed required and increasing fertility and birth weights of offspring. Trees provide shade for heat-sensitive crops and help to hold water in the landscape, reducing soil erosion and the impact of floods and drought (Smith et al. 2000).

The use of shrubs or trees in rotation does not represent lost productivity. In Zambia, plants (e.g., *Sesbania sesban*) are used in a system of rotational fallows lasting 2–3 years and providing 100–250 kg of nitrogen/hectare. Maize grown after 2 years of *Sesbania* yielded more than 4t/ha compared with the usual of less than 1 t/ha.; i.e., more maize was produced in one year following *Sesbania* than would have been produced if farmers continuously cropped maize over 3 years. In addition, the *Sesbania* provided between 15 and 21 t/ha of fuel wood for rural households (Kwesiga et al. 2003 cited by Garrity et al. 2010). *Faidherbia albida* trees supply nitrogen as well as phosphorus, calcium, potassium and magnesium. They reduce wind speed and evaporation and their deep roots break up plough-pan barriers in the soil profile. The trees are dormant in the rainy season when food crops are grown, and consequently don't compete for light, nutrients or water. Their leaves shed at the beginning of the season contributing to soil organic matter content (Garrity et al. 2010).

Phosphorus is another key macro-nutrient, the deficit of which is a major constraint to agricultural productivity (Verchot et al. 2010). Phosphorus is naturally supplied to the soil by the weathering of rock. It is taken up by plants and returned to soil when the plant decomposes or is eaten by livestock which subsequently excrete phosphorus-rich dung. *Mycorrhizae fungi*, an integral part of most plants, have the capacity to develop mycelium (a thread-like vegetative mass) which extend the connection between crop roots and the surrounding soil, increasing the uptake of phosphorus and other nutrients, including zinc (the absence of which is a common contributor to malnutrition); and reduce problems with pathogens which attack the roots of plants. The addition of soluble phosphate fertilisation

[10] Regardless of the source of nutrients, a key factor in controlling the loss of nitrogen via leaching or gaseous emission is using appropriate N management practices tailored to the needs of the particular cropping system (Cassman et al 2003:331).

decreases root colonization by mycorrhizae; consequently the benefits of the fungi are higher in low-input systems. Where native mycorrhizal populations are low, they may be introduced through inoculants (Grant et al 2005).

Where phosphorous is not bound within good soil structure it can contribute to water pollution through leaching or soil erosion. Because the global supply of phosphorus is limited, there is a rising awareness of the importance of keeping phosphorus cycling within the terrestrial system. In 2008, there was an 800% price spike in phosphate rock, driven by an increased demand. Although the price later declined, it has not returned to pre-2008 levels and is trending back upwards (White and Cordell, 2012). This is a key reason SAI often incorporates the traditional method of integrating livestock into the cropping system (Tilman et al. 2002) and using farming methods that maintain a biologically active soil and reduce leaching and erosion.

2.2.4 Pest management

To avoid the use of pesticides, sustainable agriculture prioritises system design to enhance natural control strategies. If the use of pesticides is necessary, the aim is to select those targeted to a specific pest (i.e. not wide-spectrum pesticides that also kill beneficial insects) and are short-lived in the environment.

The objective of system design is to reduce herbivore populations and/or attract the natural enemies of crop pests by using diversification to establish a more complex food web. Diversity can be created with a variety of species in a single location (alpha diversity) or having different vegetation communities on adjacent sites (beta diversity) at a farm or local scale; both of which contribute to gamma diversity over a larger landscape. Diversity can also occur in time (via crop rotations). Additionally, rotations create biological diversity below the soil surface by adding crop residues with varying chemistry and biology, stimulating and/or inhibiting different soil organisms (Gliessman 2000:236-7). Diversification is especially effective in the case of *monophagous* (specialist) insects that feed exclusively, or nearly so, on one kind of food (Nicholls and Altieri 2004).

A notable example of sustainable pest management is control of the stemborer moth and the Striga weed, both major pests of maize and sorghum, important stable crops in Africa. The "push-pull" technology involves planting two crop companions: grasses (e.g., Napier grass) around the border of crops and a legume (Desmodium) within the crop. The Napier grass releases semiochemicals (chemicals that modify the behaviour of insects) which attracts stemborers to lay their eggs on the grass rather than the crop. The chemical is released at a 100-fold greater rate in the first hour of nightfall, just as stemborer moths are seeking host plants on which to lay their eggs. When the eggs hatch, 80% die as the Napier grass also produces a sticky sap that traps the larvae. The Desmodium, planted within the crop, acts in multiple ways: as a repellent, driving the stemborers away; as an attractant of the stemborer's natural enemies (primarily parasitic wasps); and by releasing root chemicals that induce abortive germination of the Striga weed. As a leguminous soil cover, Desmodium also reduces soil temperatures, guards against erosion and fixes up to 100kg N/ha/year. Both Desmodium and Napier grass provide livestock fodder. The technology has increased maize yields from 1 to 3.5t/ha and sorghum from 1 to 3t/ha. The number of farmers using push–pull technology increased over a decade from a few hundred to 25,000 (in a 10,000 ha area). The target for 2015 is 50,000 ha (Khan et al. 2011).

2.2.5 Water management[11]

The main objective of water management in agroecosystems is to ensure that the primary route for water out of the soil is through the crop; i.e. via transpiration rather than evaporation (Gliessman 2000). In semi-arid tropical croplands up to 50% of total rainfall can be lost in non-productive evaporation. Hence, improving water use efficiency includes capturing water at farm level and, importantly, increasing plant water uptake and water-holding capacity of the landscape (Rockstrom *et al*. 2009). Achieving this requires adopting the same soil building techniques as required for healthy fertility such as building organic content, continuous vegetation cover, providing shade to the soil surface and reduced tillage (Gliessman 2000).

2.2.6 Climate – adaptation and mitigation

It is estimated that since 1980 global yields of maize and wheat have been reduced by 3.8% and 5.5%, respectively due to climate induced changes in rainfall and temperatures (Lobell et al. cited by Campbell et al. 2014). A key aim of SAI is to increase the resilience of agriculture, making it more adaptable to a changing climate. It does this by the use of methods that hold water in the landscape; reduce dependency on a single crop through agro-diversity; and with the use of polycultures to better manage micro-climates and increase buffering against storms through multi-storied production. Research comparing the response of study plots on conventional and sustainable farms in Nicaragua after Hurricane Mitch[12] in 1998,

[11] Water management is discussed further in Chapter 6, section 6.1.3.2

[12] Hurricane Mitch is one of the Caribbean's five most powerful hurricanes. It caused US$6.7 billion damages, equivalent to 13.3% of Central America's GNP (Holt-Gimenez 2002).

found that sustainable farms retained more topsoil and vegetation; and suffered less erosion and landslide, and less economic losses. The difference in favour of the sustainable plots increased with increasing levels of storm intensity, increasing slope and increasing years under agroecological practices (Holt-Gimenez 2002).

These same methods mitigate against climate change. Carbon dioxide (CO_2) emissions are decreased by reduced tillage and reduced use of mineral nitrogen fertilisers and pesticides.[13] Existing atmospheric concentrations of CO_2 are reduced through carbon sequestration in and above (e.g. with agroforestry) the soil (Lal 2004).

2.3 How productive is SAI; can it feed the world?

Although the productive capacity of SAI has been referred to in the examples above, this section more directly examines yields and whether adoption of SAI farming systems can meet global food requirements.

Badgley et al. (2007) used two models to estimate the potential of organic food production. Model 1 used yield ratios (organic : non-organic) from studies in developed countries applied to the entire global agricultural land base. Model 2 used yield ratios from studies in the developed world applied to food production in developed countries and yield ratios from studies in the developing world applied to food production in developing countries. Both models are based on the amount of land devoted to crops and pasture in 2001 and the kinds and amounts of food consumed at that time.

In Model 1 organic food supply (with a yield ratio of 0.92) is similar in magnitude to current global food supply for most food categories. In Model 2 organic food supply (with yield ratio of 1.8) exceeds current food supply in all categories, with most estimates over 50% greater than the amount currently produced. Both models suggest that organic methods could sustain the current human population in terms of daily caloric intake; with model 2 suggesting organic production could support a substantially larger global population.

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[13] "Nitrogenous fertilizers have hidden C costs of 0.86 kg C/kg N (IPCC, 1996), and pesticides are at least 5 times more C intensive" (Lal 2004:15).

The authors also estimated the amount of nitrogen (N) that is potentially available for organic production, considering only what could be derived from leguminous green manures grown between normal cropping periods. All other sources of organic nitrogen (e.g., animal manures and compost) were excluded from the calculations. Even within this limitation, the study concluded that there is sufficient biologically available N to replace current use of synthetic N fertilisers.

The authors consider that potential organic production was probably underestimated as a result of no account being taken of multiple crop production in poly-cultures. In addition they note that in developed countries yields initially decline following conversion from conventional to organic production.[14] However, the research did not omit studies of short duration.

More recently, Ponisio et al. (2014) reviewed 1071 comparisons of organic versus conventional production in 115 studies in 38 countries. They found that organic yields were, on average, 19.2% lower than conventional yields. This yield gap was much smaller (8-9%) when conventional monocultures are compared to organic systems with multiple cropping - either in space (polycultures) or in time (crop rotations).

Ponisio et al. (2014) make two points regarding the potential of their study to overestimate conventional production. They found evidence of bias in the meta-dataset towards studies reporting higher conventional yields relative to organic;[15] and detected a trend to larger yield gaps in more recent studies, without causal mechanisms being determined.

One explanation for resolving the difference between the findings of Badgley et al. (2007) and Ponisio et al. (2014) is that the latter are examining the yield gap between two strictly defined systems of organic (as in certifiable) and conventional (as in GR technology) for the purpose

[14] The initial drop in yields is considered to be the result of soil degradation after years of tillage, synthetic fertilisers, and pesticide residues; with time, yields increase as soil quality is restored (NRC 1989 and Pimentel et al. 2005 cited by Badgley et al. 2007).

[15] For example, cereal crops, which have been bred for high-yields with conventional inputs and which exhibit the greatest yield difference between organic and conventional systems, were significantly over-represented in the comparisons. Although the study covered 52 crop species, cereals represented 53% of comparisons (Ponisio et al. 2014). However, it should be acknowledged that cereal production is a key indicator of food availability (especially in landlocked regions with large agrarian populations) even though it is a course metric ignoring a range of variables including nutrition (Funk and Brown 2009:6).

of revealing the difference in productive capacity of these two systems. Although Badgley et al. (2007) are comparing productive capacity between organic and conventional, both terms are more loosely defined; and, importantly, their aim, and therefore their method, is slightly different. In aiming to show the potential of organic/sustainable agriculture to feed the world, they are comparing current global food production capacity (whether by conventional high-input methods or the 'convention' of most subsistence farming systems, i.e. 'locally prevalent methods') to what production levels could be achieved with adoption of more sustainable practices – from either starting point.

Both Badgley et al. (2007) and Ponisio et al. (2014) note that the development of organic (or sustainable) systems has been considerably underfunded relative to conventional systems over the last 50 years. For example, few modern varieties have been developed to produce high yields under organic conditions.

In a well-recognised study, Pretty et al. (2006) examined the adoption of sustainable interventions. The study involved 286 cases in 57 developing countries over 37 million ha. They found that sustainable interventions increased productivity on 12.6 million farms while improving the supply of critical environmental services. The average crop yield increase was 79%; and 25% of projects reported an increase of 100%. The increased production is attributed to: i) more efficient water use; ii) improved organic matter accumulation in soils; and iii) pest, weed and disease control emphasising in-field biodiversity. In the 62 IPM initiatives studied, 74% of projects lowered pesticide use by an average of 71% while yields increased by 42% (2006: c, e). Reanalysis by UNCTAD and UNEP of only the African data found that the average crop yield was even higher, at 116% increase for all African projects and 128% for projects in East Africa (De Schutter 2010:8). A later study by Pretty et al. (2011) of the adoption of SAI methods by 10.39 million farm families showed that crop yields had doubled over a period of 3-10 years, increasing aggregate food production by 5.79 million tonnes per year (557 kg per farming household).

Finally, significantly increased yields following the adoption of SAI practices have been reported by Garrity et al. (2010) and Franzel et al. (2004) with respect to agroforestry methods; and by Styger et al. (2011) in examination of SRI. The UNEP (2011) reports yields following transition to organic production in the Eastern Europe, Caucasus and Central Asia region to be comparable, at least, to neighbouring conventional farms.

In summary, numerous studies show crop yields from SAI to be at least comparable to those of conventional agriculture and some studies show higher (or potentially higher) yields; even when all factors influencing the productivity of SAI farms are not taken into account. SAI is also likely to have higher long-term productivity in that its methods increase resilience to climate change and reduce the negative environmental impacts of agriculture, conserving finite resources (land, soil, water) on which future food production depends. Given this, the adoption of SAI should have at least as much capacity to meet global food requirements as current practices.

2.4 If SAI is so good, to what extent is it practiced?

This section examines the extent of SAI adoption worldwide. There are SAI projects throughout the world. But it is difficult to accurately estimate the number of farmers or hectares currently involved in SAI because most reports are focused on limited geographic areas and/or particular projects; and are not studies of extent. Determining extent is also difficult due to the different farming systems involved; debate about what is and is not SAI; the varying terminology; and uncertainty about whether the data arising from the multiple reports is independent from one other. Table 2.1 is not an exhaustive survey of extent, but intended to provide some indication of the scale of SAI and to demonstrate the difficulties of determining extent of practice.

Table 2.1: Data related to extent of SAI

Type of SAI	**Hectares**	**Comments**	**Reference**
SAI	28.92 million ha	208 projects in 52 developing countries surveyed during 1999-2000	Pretty and Hine 2003
Conservation Agriculture (CA)	50,000 farmers	Systems of minimum soil disturbance, permanent cover, and rotations in African countries	Altieri 2012:12
	15 million ha in Brazil		Horlings and Marsden 2011
	125 million	Including Brazil at 25.5 million ha.	Friedrich et al. 2012
Faidherbia-dominated agroforestry systems	4.8 million ha	'Faidherbia' qualification limits potential extent of all agroforestry systems	Altieri 2012
SRI	4.93 million ha	8 Asian countries	Altieri 2012
Agroecology	>120,000 ha	Latin America	Altieri 2012
Organic	37.5 million ha	Worldwide data end of 2012 (1.9 million producers)	FiBL 2013
	8.94 million in China	Certified "green"; plus uncertified "green" - allowing some chemical use.	Horlings and Marsden 2011

One aspect about extent that is clear is that the adoption of SAI is increasing. Garrity et al. (2010) report that hundreds of thousands of smallholders in Zambia, Malawi, Niger and Burkina Faso are shifting to farming systems that restore soils and increase food crop yields and incomes.

As part of their 2006 study, Pretty et al. randomly selected 68 projects from an earlier study (in Africa, Asia and Latin America by Pretty and Hine 2003) to re-sampled. They found that the number of farmers involved in the 68 projects increased 56% over 4 years (from 5.3 to 8.3 million) and the number of hectares increased by 45% (from 12.6 to 18.3 million).

Organic agriculture is also reported to be spreading. The global area of certified organic agriculture in 2001 was 0.3% (Badgley et al. 2007). Organic agriculture now takes place on 0.9% of agricultural lands [Willer and Kilcher 2011 cited by Ponisio et al 2014).

2.5 Conclusion

This chapter has presented the practices and science of SAI emphasising the connections between agriculture and natural resource management. It has demonstrated the productive capacity of SAI and the extent to which it has been adopted; which, while limited, is increasing.

While the knowledge-intensive nature of SAI makes its adoption more difficult, there is extensive support for scaling-up SAI adoption (e.g., Franzel et al. 2004; World Bank 2008; McIntrye et al. 2009; Horlings and Marsden 2010; UNEP 2011; Altieri 2012; FAO 2014). The UK Government argues that SAI is a priority and that "Producing sufficient food to feed the global population will become increasingly difficult without major changes to the food system" (GOS 2011:164). This is certainly the case in Timor-Leste which is the subject of the next Chapter.

Chapter 3 Development Challenges in Timor-Leste

Timor-Leste is the newest country in Asia, and possesses some of the most severe food security and sustainability challenges in the entire Asia-Pacific region. This chapter documents how the broader developmental problems of Timor-Leste exacerbate the food and sustainability dilemmas of the country.

3.1 The Difficult Path towards Timorese Independence

The food security and sustainability challenges in Timor-Leste cannot be divorced from the country's tumultuous history. As a Portuguese colony from the 16th century until 1975, East Timor (as it was then known) was exploited for the island's abundant supply of sandalwood. When the sandalwood trade declined, the colonisers introduced cash crops such as wheat, sugarcane, coffee and potatoes. The Portuguese reformed agriculture to suit themselves and the Chinese business class who acted as middlemen between Portugal and the locals, and conducted trade with Indonesia (Ewing 2008).

Portugal granted East Timor liberty in 1975. Only days later, Indonesia invaded and occupied East Timor for almost 25 years. The Indonesian incursion initiated a period of violence and starvation (Kingsbury 2005); 200,000 people were forced to migrate into Indonesian-controlled West Timor. Farmers were removed from their ancestral lands and traditional food production channels were destroyed. The Indonesian government monopolised the coffee and what was left of the sandalwood industries (da Costa 2003) leaving little opportunity for East Timorese to enter the industry or to develop knowledge, skills, management experience and networks.

In 1999, under international pressure, Indonesia agreed to a referendum by which East Timorese would choose between autonomy within Indonesia or independence. The vote showed resounding support for independence. Pro-Indonesia militias responded immediately with violence and destruction. Most major buildings and infrastructure that supported water supplies were destroyed or damaged (Kingsbury 2005). Electricity-generating capacity was reduced by 30% in Dili and by 50% to 90% in district capitals. Most of the fixed telephone lines were damaged and transportation was in extremely short supply. Eighty percent of all medical clinics and schools were destroyed. Banks and markets were either burgled or destroyed, and half of the country's livestock were lost. The entire public administration ceased to function (Lundahl and Sjoholm 2012; FAO/WFP 2003). It is from this position of physical and economic destruction and enormous social turmoil that East Timor had to commence its development. The United Nations Mission to East Timor (UNAMET) had administered the referendum. Due to the state of the country and events following the referendum, UNAMET became the governing body of East Timor as UN Transitional Administration to ET (UNTAET) until 2002 (Chopra 2002).

In April 2006 tensions over accusations of discrimination within the new military force led to more violence, leading to trade disruption and the suspension of shipping - temporarily cutting-off links for vital food imports. By August that year 168,000 people were displaced to make-shift camps. The government, the UN and NGOs initiated a massive program to supply rice and other basic food to registered refugees. As a result of the 2006 crisis the GDP declined by 5.8% reducing incomes to substantially lower than during the Indonesian occupation (Lundahl and Sjoholm 2012). Then, in February 2007 rice shortages triggered a new wave of violence and further disruption to food shipments, increasing the price of a 38 kilogram sack of rice from US$12 to US$30 (Kammen and Hayati 2007:1-4).

3.2 The Economic and Social Conditions of the New Nation

The legacy of colonialism and the violence associated with Timor-Leste's independence have impacted upon the economic capacity and social conditions of this country. The country's national budget is hugely reliant on revenues from the Timor Gap gas and oil fields. Oil and gas contribute almost 90% of total budget revenue (RDTL 2011), and 81% of the country's Gross Domestic product (GDP) (RDTL DGS 2013). Moreover, approximately half of the non-oil GDP (of $1.1 billion) was from state spending, 94% of which was fuelled with oil revenues (La'o Hamutuk 2013a:2).

Under Timor-Leste's 2005 Petroleum Fund Law, all oil revenues are deposited into a Petroleum Fund. All withdrawals from the Fund are channelled through the Government budget and, to protect capital, are subject to a ceiling based on an Estimated Sustainable Income (ESI) for the fiscal year (World Bank 2009). After the 2006/7 crisis, the government stimulated the economy with large public infrastructure programs and introduced pensions for the elderly, disabled and veterans. This was done by increasing withdrawals from the Petroleum Fund, which was, and continues to be, regarded with controversy by Civil Society Organisations (CSOs) and multilateral institutions (La'o Hamutuk 2014a; ADB 2008; World Bank 2009).

Although Fund withdrawals have created growth and raised per capita income to more than 20% higher than in 2002, Timor-Leste is still a very poor country. Median per capita monthly income in 2011 was US$40 (RDTL 2014a:25). This is about 14% of regional per capita income (in developing East Asia and the Pacific) or 41% of the average per capita income level in Sub-Saharan Africa (Lundahl and Sjoholm 2012:4).

The combination of large oil and gas reserves with severe poverty makes Timor-Leste a classic case of the contradictions of resource-based, export-led development. At present, the petroleum industry is the focus of mega-project developments on the south coast; along with new airport and port facilities. But oil and gas currently provide few jobs while agriculture, on which more than 78% of the population depend for their livelihood (FAO 2014b), remains primarily subsistence. Agriculture suffers from lack of services (extension and credit) as well as a lack of infrastructure, including irrigation, markets, roads, food storage or processing facilities. The only significant agricultural export sector is coffee which accounts for approximately 80% of non-oil export revenue. Although it provides important foreign exchange and contributes income to an estimated 50,000 families (RDTL 2011:127) coffee growers are amongst the poorest farmers in Timor-Leste (Da Costa et al. 2013:84). A large percentage of trees are old and in need of improved management (Amaral 2003). There is no sign of an emerging manufacturing industry (Lundahl and Sjoholm 2012:6).

The lack of physical infrastructure (deficits of which were described by the World Bank in 2009 as “severe”) and limited access to finance (only 7% of the population use banking facilities) has seen Timor-Leste ranked as 170th out of 180 countries worldwide on overall ease of doing business (World Bank 2009:9-10). The central area of Dili and the regional centre of Baucau have 24 hour access to electricity but there are regular outages. About one-third of the population has very limited access to electricity, for approximately six hours per day (RDTL 2011); and many in rural areas have no access to electricity at all. For example, in the 20% of sucos identified by the ADB as having the lowest living standards, the average share of households with electricity is only 3%; and only 66% in the sucos with the highest living standards (ADB 2013:5).

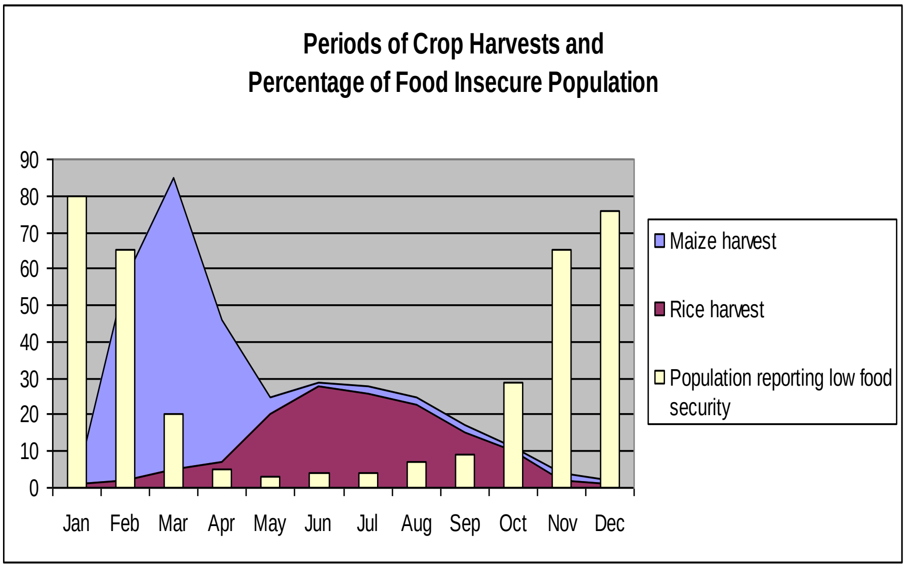
3.3 Food and Nutritional security status

The overall poverty of Timor-Leste is unsurprisingly correlated with parlous levels of under-nutrition and food insecurity. At a national level, the country imports 33 times as much as it exports (RDTL DGS 2014 cited by Scheiner 2014:1); and is also a net food importer. In 2011 food imports were valued at US$81.3 million while agricultural exports were valued at US$12.3 million, 97% of which was coffee (FAO 2013).

Current food security is reflected in the high level of chronic malnutrition, primarily undernutrition. Undernutrition is caused by poor diet or poor biological use of nutrients consumed as a result of repeated infectious disease. Indicators of undernutrition include being underweight for one's age, too short for one's age (stunted), dangerously thin for one's height (wasted) and deficient in vitamins and minerals. For children under the age of 5 years, more than 45% are underweight, 58% are stunted and 24.5% suffer wasting. Among the 20 countries in which rates of underweight and stunting are the highest in the world, Timor-Leste is at the top of the list, with the highest incidence in both categories (FAO 2014a).

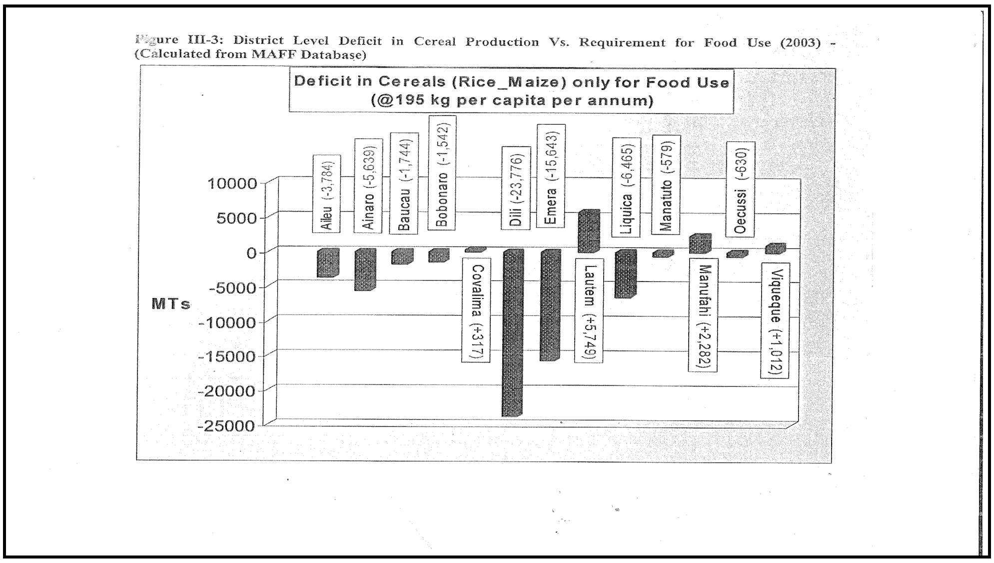
In addition to chronic malnutrition, the people of Timor-Leste experience severe food shortages between the months of November and February. Figure 3.1 shows the timing of maize and rice harvests and reports by populations experiencing low food security. Food insecurity reflects crop yields, which are amongst the lowest in the East Asian and the Pacific region (World Bank 2009); and post-harvest losses (25% of total production in 2010) to rodents and insects (RDTL 2011:120). By November each year, stocks are largely exhausted and the absence of staple crops to harvest initiates the beginning of what the Timorese call the 'hunger season'. The extension of the hunger season into February when maize harvesting is reaching its peak may be associated with access problems due to the differences of district-level deficits (see Figure 3.2), purchasing power, and transport problems (FAO/WFP 2003), particularly given that February is in the wet season when bad roads are sometimes not traversable.

Figure 3.1: Periods of Crop Harvests and Percentage of Food Insecure Population



Source: UNWFP 2005:12

Figure 3.2: District-Level Deficit in Cereal Production Vs. Requirement for Food Use



Source: UNWFP 2005:27

The population also experiences “hidden hunger” which results from insufficient vitamins and minerals due to a lack of nutrient-rich foods (World Bank 2007). Nutrient deficiencies in Timor-Leste include Vitamin A, iron, folate (Vitamin B9), iodine and zinc. Forty-six percent of children under 5 suffer from Vitamin A deficiency; 33.3% suffer zinc deficiency and 62.5% suffer anaemia (RDTL 2014b:16). Caloric and nutrient deficiencies have significant social and economic consequences. For example, iron deficiency anaemia impairs growth and learning, lowers resistance to infectious diseases, reduces physical work capacity and increases the risk of maternal death and delivering a low birth weight infant (URT, 2011). The World Bank notes that in the worst-affected countries, such deficiencies lead to estimated productivity losses equivalent to 10% of lifetime earnings; and, collectively, losses to GDP[16] of 2 to 3 % (2007:95). Timor-Leste ranks amongst the 20 countries whose fruit and vegetable supply is the least. On a per capita basis the supply decreased between the periods 1990-92 and 2009-2011 (FAO 2014a:28). In 2010 the country imported more than 6,000 tonnes of fruit and vegetables (RDTL 2011:126). Protein intake is also low compared to the global average, with limited access to protein-rich foods such as fish, animal meats and legume pulses.[17] Approximately 40% of cereal food consumed is imported. Food accounts for 60% of the consumer price index (RDTL 2014a:25); with poor families spending 75% of their average income on food (UNWFP 2009).

Beyond the need to improve access to a better diet, the capacity to absorb and retain nutrients is affected by infectious disease associated with the lack of clean water supply and poor sanitation. As of the 2010 Census, only 42% of urban households had access to household tap water and only 25% of rural households had access to drinking water from a well or spring. More than a third of households need to walk ten minutes or more to access water (RDTL 2011:77). In 2011, 38.7% of households had improved sanitation facilities (UNICEF 2013).

The future prospects of Timor-Leste's agriculture to both increase and sustain production depends heavily on improved natural resource management, discussed in the following section.

3.4 Timor-Leste's physical environment and climate

Timor-Leste's physical environment and climate emphasises the need for good natural resource management to ensure food security. The country is small, with total land resources of less than 1.5 million hectares (FAO 2011). Seventy-two percent of the country is mountainous, with a main ridge extending down the centre from west to east. The country can be divided into six ecological regions including the mountainous areas, highland plains, moist

[16] For example, "Iron deficiency among female agricultural workers in Sierra Leone will cost the economy $100 million in the next five years" (World Bank 2007:95).

[17] Average per capita consumption of meat and fish protein in Timor-Leste is 19.4 kg/year (RDTL 2011:65) as compared to a world average meat consumption of 32 kg/capita/year (GOS 2011:14) and per capita fish consumption of 17.8kg/year (RDTL 2012:6) being additional.

lowland areas, arid lowland areas, marine and coastal areas, and urban areas (RDTL and UNDP 2006).

The climate is typically monsoonal with a wet season occurring from about December to March; the southern part of the country has a second peak of rainfall during May-June (Fox 2003). The north has an annual rainfall of 500 to 1,500 mm and a dry season of four to five months; and the south receives over 2,000 mm with a dry season of three months (RDTL and UNDP 2006). Rainfall can be very irregular (UNDP 2006 cited by Lundahl and Sojholm 2012). Most rivers are completely dry for large parts of the year. Droughts are regular (about every four years) and can reduce food production by up to 30% (Lundahl and Sojholm 2012).

Approximately half of the land has a slope of 40% or more (Thompson 2011). The mountainous topography means there is limited suitable land for cultivation of crops; and much of the lowland area used to produce rice is constrained by availability of water (Benevides 2003). In general, the soils are fragile and low in fertility. On the slopes they "are shallow, rocky and often leached of nutrients. Some more fertile alluvial soils are located in the valleys and along the north and south coasts but these are generally small in area" (Lopes and Nesbitt 2012:2). As a result of steep slopes, soil type and heavy rainfall, erosion rates are high (RDTL and UNDP 2006). This is exacerbated by historical deforestation and by a continuing tradition of slash and burn farming practices, logging for timber and fuel wood and overgrazing (da Costa 2003; Wesley-Smith 2005; World Bank 2009). In the past, shifting cultivation incorporated a fallow period up to 15 years. The fallow period is now shorter due to limitation of available land with a growing population (RDTL and UNDP 2006), meaning the land has less time to recover.

Crop failures and damage resulting from floods, strong winds and occasional locust infestations are a regular phenomenon (UNICEF 2009).

Climate change is likely to aggravate this situation. Following a review of studies and analysis of climate change models, the Timor-Leste National Adaptation Plan of Action (RDTL 2010b) summarises the likely impacts (see Table 3.1).

Table 3.1: Likely impacts of climate change in Timor-Leste

Parameters	Changes
Temperature	• Overall increase without significant variability across the seasons. • Extreme temperature events are expected to increase in intensity and length.
Rainfall	• Expected increase in mean rainfall values. • Dry season expected to become drier. • Extreme rainfall events expected to increase in intensity and decline in frequency.
Sea level rise[18]	• Increase in line with global projections is expected
Tropical cyclones	• Expected to decrease in frequency and length of event, but expected to be more intense in their nature.
Ocean	• Expected to become more acidic.

Source: RDTL 2010b:26

Timor-Leste's complex landscape and variable rainfall results in a large amount of ecological diversity (Fox 2003). It is geographically positioned in one of the world's 34 'biodiversity hotspots'. The region has lost at least 70% of its primary vegetation (RDTL 2011:57); and only 1.9% of the country's primary forest remains (Egashira et al. 2006).

3.5 Conclusion

The history of Timor-Leste left this small country with a legacy of underdevelopment and devastation. Since independence there has been economic growth but a large portion of the population remain in poverty. Agriculture, which employs almost 80% of the population, has not been developed. This, along with the lack of infrastructure development and degraded natural resources means food and nutrition security remains elusive and subject to future

[18] However, with respect to inundation, Timor-Leste is rising upwards as a result of the Australian and Eurasian crustal plates converging, at a rate of 5 to 10 mm per year (Thompson 2011: 3, 22).

climate change impacts. There is capacity to address food security through smallholder adoption of SAI; and, in doing so, also address poverty, malnutrition and natural resource management. Analysis of how this might happen follows; but, first, discussion of the research methodology of this thesis is presented in the next chapter.

Chapter 4: Methodology

This chapter presents discussion about the methodology adopted for the research. The choice of methodologies used to assess the multifunctional capacity of SAI in general and in Timor-Leste in particular is presented first, followed by a description of the related field work. Here, I examine how the methodology was impacted by personal reflexivity and by in-situ negotiations with the NGOs with whom I undertook the field work. Lastly, I present the methodology used in pursuit of questions about the role of SAI in national development.

4.1 Choice of Methodology

To assess the capacity of SAI to serve multiple functions requires an evaluation of what difference these practices make to farmers' livelihoods, household food security and natural resource management.

The methodology selected must determine if SAI can improve livelihoods and household food security. It must provide an understanding of the local biophysical circumstances (e.g., access to land or water, soil fertility) and what constraints they present to production. Assessing the multi-functional capacity of SAI requires understanding the socio-economic circumstances of participating farmers, e.g., whether the required inputs are available or affordable; whether farmers can access needed information, equipment or labour; and whether the benefits can be realised within a feasible timeframe for the farmer (e.g. with respect to land tenure).

In pursuit of these methodological requirements, this research adopted a case study approach, in line with a number of other leading studies in this field, including Pretty et al. (2011), Garrity et al. (2010), Franzel et al. (2004) and Styger et al. (2011). The methodology was selected because it allows the researcher to investigate the biophysical and socio-economic context in which practices are being adopted; interview farmers undertaking this adoption to assess their assets and in what way SAI might increase the value realised from those assets or overcome constraints. Case studies allow the researcher to evaluate the impact, or potential impact, of SAI on what is produced and how much. The method allows as assessment of the impact of current farm practices on natural resources in order to evaluate whether SAI techniques will improve on this and therefore on long-term production capacity. This approach allows the researcher to learn what the farmer thinks about the process of change, how the process can be improved and what obstacles farmers' face beyond the farm gate, in order to understand how these factors might impact on farmers' incentive to adopt SAI, and therefore the up-scaling of SAI.

Of particular methodological interest to my examination of SAI in Timor-Leste is the work by Lemos (2009). It is a historical analysis of the impacts of military occupation on traditional agricultural practices; and employs the methodology of interviews with farmers and key informants in Timor-Leste. The focus of Lemos' methodology is giving voice (Raghuran and Madge 2006) to farmers, who agricultural development most affects, but who are often under-represented in the decisions that drive such development. Lemos argues that food security is best achieved by striving for food sovereignty.[19] Lemos' aspirations for the work were to act as a stimulus to further debate the best means to ensure sustainable livelihoods in Timor-Leste (2009:iv). The use of his work provides additional input of farmers' experience and perspective, and a historical context for my research.

Before turning to implementation of the methodology, I draw attention to the significance of place-based research for this purpose. As noted in Chapter 1, SAI is not a specific farming type but a descriptor of farming practices adapted to local agroecologies and socio-economic circumstances. The case studies presented by Franzel et al. (2004) demonstrate this 'place-based' principle with on-ground examples.[20] In the same way, scaling-up SAI at the national level needs to be customised, designing policies and processes most suited to each country's economic and social conditions (World Bank 2007). Consequently, in examining the potential for success of SAI in Timor-Leste and the degree to which it is part of the national development framework, I need to investigate the country's development plans, agricultural programs and policies; and farmers' access to resources, services, infrastructure and markets. As the majority of international studies regarding SAI indicate that the context will significantly influence the success of implementing and scaling-up SAI, I am investigating how these commonly identified factors apply to Timor-Leste; and, within this place-based context, what barriers and opportunities exist.

[19]Food sovereignty is "the right of peoples, communities, and countries to define their own agricultural, labour, fishing, food and land policies which are ecologically, socially, economically and culturally appropriate to their unique circumstances. It includes the true right to food and to produce food, which means that all people have the right to safe, nutritious and culturally appropriate food and to food producing resources and the ability to sustain themselves and their societies" (International Planning Committee of La Via Campesina 2003:1 cited by Lemos 2009:4-5).

[20] Examples that address local production constraints, such as the need for livestock feed in Kenya; soil erosion in the Philippines; and soil fertility problems in Zambia.

4.2 Assessing SAI's multifunctional capacity in Timor-Leste

The capacity of SAI to serve multiple functions in Timor-Leste was assessed by investigating projects run by two NGOs, World Vision (WV) and Mercy Corps (MC).

World Vision is implementing two projects which embody the principles of SAI. The first is Farmer Managed Natural Regeneration (FMNR). FMNR involves the systematic regeneration and management of trees and shrubs from stumps (Figure 4.1) and from new plantings (Rinaudo 2012 cited by Francis and Weston 2015). The stumps are what remain of previously cut or burnt trees, often at ground level but with extensive living roots. In FMNR farmers nurture the stumps/trees and prune selected stems according to their own objectives (e.g., dry-season fodder, firewood, fruit, timber, medicinal products). It is a low-cost approach that integrates farming, land-restoration and biodiversity. By restoring tree cover on degraded and/or steeply sloping land, it reduces erosion and the impact of extreme weather conditions on soil, crops and livestock (Francis and Weston 2015).

Figure 4.1 FMNR tree regeneration (Rinaudo 2013)

World Vision's second project is "Building Resilience Against a Changing Climate and Environment" (BRACCE). BRACCE assists communities to establish nurseries for production of tree seedlings and to improve soil structure and water management through the production and use of local fertilisers, green manures, compost and mulch.

Both WV projects provide an opportunity to examine the multifunctional capacity of SAI in that they are designed to improve the livelihood of farmers by increasing the amount and diversity of crops grown; thereby also improve the nutrition of participating households; and improve natural resource management and adaptation to climate change.

The second NGO case study is Mercy Corps' "Combating Malnutrition and Poverty through Aquaculture in Timor-Leste" (COMPAC-TL). COMPAC-TL is a 2.5 year program (commenced in December 2013) which operates through a consortium of Mercy Corps, Hivos and Worldfish. In line with the National Aquaculture Strategy (MAF 2012) it targets 1500 poor farming households to establish and integrate fish farming with existing agriculture. The project serves the multiple purposes of improving the livelihoods of participating farmers through farm diversification and the sale of fish; and improving nutrition by increasing access to a healthy source of dietary protein. The natural resource management benefits of integrating aquaculture with agriculture have been demonstrated in the traditional rice-fish (RF) co-culture (Xie et al. 2011).

4.3 Field Work with farmers

Preliminary meetings were held with both NGOs in Dili in September 2014 to confirm arrangements for working together. Field work was carried out in January/ February 2015. I aimed to interview 15-20 farmers from each NGO. Two districts were targeted: WV farmers in Aileu and MC farmers in Manufahi. These two districts are adjacent to one another (see Figure 4.2).

The two districts were selected on the basis that there is no significant difference between these two and the other districts in which the NGOs are operating. World Vision operates in Aileu and Bobonaro. Mercy Corps operates in six districts, three on the south coast and three in the northeast part of the country, further from Dili. Mercy Corps' selection criteria for the six districts included communities with limited access to marine fish; high levels of poverty and malnutrition; and limited access to alternative livelihoods. Further technical criteria include reliable water source; water retention qualities of the soil; capacity to develop ponds in the area according to regulations and land rights; previous experience with aquaculture; and a 'can do' attitude from the community.

Once it was determined that I would be interviewing WV farmers in Aileu (being the closest to Dili) then it was logical to select a MC district from amongst the three on the south coast, reducing travel time to field work.

Figure 4.2 Map of Timor-Leste

Both organisations supported the field work with a vehicle, driver and regional staff member. I organised independently for a translator to accompany me. I field-tested the method with the translator during the preliminary visit to Timor-Leste in late 2014 while visiting a few WV farms.

In return for their support, WV requested that students from the National University of Timor-Leste (UNTL) join me in order to increase their field experience and provide an opportunity to engage with farmers who are adopting new practices. This was agreed after discussion with my supervisor and setting out conditions of there being no more than two students observing any interview and only with the permission of the farmers.

Mercy Corps requested that I document their project's objectives, process, evidence, and outcomes; and that I facilitate a meeting between themselves and WV to initiate improved communication and possible collaboration between the two NGOs.

A draft questionnaire for the farmers was circulated to both NGOs in December 2014 and, with their input, revised in January 2015. Participant Consent Forms (PCFs) and Participant Information Sheets (PISs) were also sent in December and each organisation took responsibility for translating one of these documents to Tetun (the language used by participating farmers).

4.3.1 Selecting farmers to interview

During the period late 2014/early 2015 I discussed with the organisations the process of selecting farmers to interview. I requested a list of participating farmers, explaining that it is important that my selection is random so I am not interviewing only farmers with particular advantages or disadvantages (such as farm size or locations relative to markets or rivers). Selecting names at random (e.g., every third name on the list) improves the likelihood of interviewing farmers whose circumstances vary and whose farms are different sizes. This process provides a better understanding of the impact of the project itself. This information was also included in the PIS to farmers so they understood how and why they were selected.

World Vision operates in 17 villages in the Aileu district, with between 18 and 55 farmers in each village. I selected every 6th village, leading to a total of three: Asumata, Rileu and Tabulasi; and selected approximately seven farmers in each village. Mercy Corps sent a list of 69 farmers from 11 villages in Manufahi. I eliminated villages with only one or two participating farmers; and then selected every third farmer.

Allowing for travel time in the wet season and on poor roads, I estimated that I could comfortably interview two farmers per day; allowing two weeks for each NGO. While this process was generally agreed to by the NGOs, there were problems with implementation. Just prior to conducting my field work, both NGOs informed me that they would like me to complete interviews within one week. This had implications for fieldwork which are addressed below.

4.3.2 The interview process

The broad scope of information being solicited from farmers included qualitative and quantitative data. I selected interviews as the appropriate methodological tool because of the need to learn what is happening at the farm level, to ask open-ended questions to achieve meaningful understanding and because the approach is suitable to inductive analysis (O‘Leary 2004:195). Questions and answers were communicated through the translator. I recorded answers by written notes as I didn’t want to introduce technology that might further set apart the socio-economic differences between myself and the farmers interviewed.


Figure 4.3 Interviewing

In total, I interviewed 37 farmers (17 from WV and 20 from MC). The interviews were structured using pre-established questions, asked in a predetermined order with a standard mode of delivery (O'Leary 2004:164) and designed to create a pyramid structure, starting with easy questions about farm assets and later asking more difficult or sensitive questions.

The data collected includes:

- Farmers' assets - land size, tools and type and number of livestock
- Farm practices - identifying which are traditional and which are new practices
- Production and marketing - generally what crops are grown and whether they are for home consumption or sale
- Problems with land management, water, seeds, getting information about farming, crop pests and marketing.
- Household food security and coping strategies
- Some insight into the process of change
- What farmers expect to gain from adopting new practices and some early indication of the outcomes or potential outcomes
- Farmers experience regarding climate change

4.3.3 Reflections on the interview process

The main difference between the planning and the implementing of interviews was the request of the NGOs that I complete interviews within one week. Prior to the fieldwork commencing, a longer time-frame had been assumed. However, given that the NGOs acted as gate-keepers to the communities, I had to accept this change. It did, however, place constraints on the interview process, requiring me to interview an average of five farmers per day.

Due to a religious event in Aileu, WV regional staff was not available on the first day I arrived in the district. During the following three days I was able to complete 14 interviews in the three villages. I realised that many of these farmers had only been working with WV for a year; in Asumata, only for six months. I discussed this with WV and we agreed that rather than travelling back to these distant villages on the final day, I would interview farmers in Fahiria, which is close to the regional office and an area in which farmers have been working with WV for several years. Given that the first 14 interviews were at smaller, more remote farms, and with farmers who had less 'SAI' experience, I considered that selecting Fahiria non-randomly for additional interviews should not bias results, but possibly balance out the sample.

To facilitate interviewing five farmers per day, the NGOs brought farmers in each of the selected villages together in one farm house. This was always the case with WV; and, with MC, in two of seven villages. Conducting five interviews a day did mean that the interviews were restricted by time, with farmers waiting outside the farm house for their turn to be interviewed; and with added pressure in Rileu and Asumata to leave the village before the afternoon rains to ensure we could traverse the poor roads. As a result, although logistics and the process generally went smoothly, the interviews sometimes felt rushed and it was necessary to find ways to manage the process within the restricted timeframe.

The composition of the questionnaire was built from a baseline survey designed by WorldFish that had been conducted by MC to, in part, gather data against which future progress on objectives could be measured. The advantage of aligning my questionnaire to the baseline survey was to generate comparable responses to key issues. My approach with respect to the baseline survey was to accept whatever appeared consistent with my purposes and practical within my (original) timeframe; to eliminate what didn't meet these criteria; and to add what additional questions I or the NGOs thought necessary. Generally, I maintained the language of the Baseline survey or what had been added by the NGOs.

Even though my questionnaire drew on the Mercy Corps baseline survey, there seemed at times to be inefficiencies related to terminology. For example, there was sometimes confusion when I asked farmers, on page one, about the different areas on their farms (e.g. 'agroforestry plot' or 'upland crops'). I later learnt that not all farmers are familiar with the term 'agroforestry'; and the term 'upland crops' is broader than I thought and can refer to growing many crops that are also grown in home gardens or under agroforestry arrangements.

The layout of my questionnaire could have been improved. I used the 'Remarks' column on this first page (added by WV) to note what farmers grew in these areas. There should have been a 'crops' column here. Twice I missed recording what farmers grew as 'upland crops'; and if farmers began talking about vegetables or fruits, I turned to page two, where vegetable, fruit and legume production was covered. As a result, when interviewing WV farmers in Rileu and Asumata (the two most time-constrained villages) I missed asking whether 'upland' crops were for home consumption or for sale. I also missed this question with one farmer in Fahiria regarding rice production on 0.5 hectare. Consequently, for 11 WV farmers data on whether upland crops are for home consumption and/or sale is absent.[21]

In terms of the overarching objectives of the study, the implications of this missed data are minimal. It was never my intention to identify exact farm production and incomes – but to generally understand the socio-economic situation of the small-scale farmers trying to adopt new farm practices and the impact of the new practices. Even for the 11 out of 37 farmers for whom I am missing 'upland crop' data, I still have data on whether they market vegetables, fruits and legumes; plus an appreciation of their general socio-economic circumstances through answers to other questions such as livelihood assets, the burden of transport costs ($1.50) in getting their vegetables to market; from their expectations of participating in the NGO projects (e.g., being able to afford school fees) and from their answers regarding household food security. The missing data does not impact on my capacity to answer the key research questions.

[21] The missing information is generally in regard to coffee and/or corn – which most farmers grow, at least for home consumption and sometimes also for sale; and in one case, rice; and another case, peanuts. Nationally, most all maize and about 75 percent of the rice is for home consumption; very little agricultural produce is traded (Lundahl and Sjoholm 2012:8). The level of involvement in coffee production varies between sucos, ranging from between 26% and 46% of households; and between 45% and 72% of households are involved in maize production (ADB 2013:42).

Reflecting on the constraints after the WV interviews informed subsequent MC interviews (Hsiung 2010). Improvements to the interview process were made possible with minor revisions to the questioning procedure; and because I (and the translator) had gotten better at interviewing efficiently. Also, MC staff were available to start early; and because there was less distance between farms in the Same area and better roads, returning to the regional office in the rain or after dark was not a problem. Finally, while having to rush the interviews was unfortunate because it also meant a lack of opportunity to relax more into the interview and explore issues in more depth, the overall purpose of the interviews was not compromised and the data remains relevant to the task at hand.

4.4 Field work - SAI and rural development framework

To assess the extent to which smallholder sustainable agriculture provides a framework for rural development in Timor-Leste requires evaluating whether instruments that have been identified for that purpose are being used in Timor-Leste.

To this end, the current project augmented farmer interviews with the examination of relevant national policies and programmes, reports from research and educational institutions and from CSOs; and interviews with key informants working in the field of agriculture and development in Timor-Leste.

Before presenting further detail on these components of the research, it should be made clear that scaling-up does not imply promoting SAI practices to larger farms or aiming to make the small sustainable farms bigger. It is about both spreading the adoption of SAI practices horizontally across geographical areas to more people (small-scale farmers in particular) and vertically, which is “institutional in nature, involving different types of organizations with different functions from grass roots farmer groups to extension services, policy makers, private companies, and national and international organizations” (Franzel et al. 2004:330). Vertical up-scaling links national and local planning (e.g. to improve agro-biodiversity outcomes) and improves collaboration between agriculture and other sectors (e.g. health to ensure nutrition as a core agricultural outcome, and the impact of trade on production).

This vision of SAI guided my interviews with key informants. The aim was to gain a broader perspective with insights to, for example, local institutional capacity; the type of support being provided for agricultural development; collaboration between stakeholders; how food security decisions are made and how that impacts on the capacity to realise the multiple benefits of agriculture; and what strategies individuals or organisations have found to be successful in adoption and diffusion of SAI.

The interviews with key informants involved 13 persons in eight semi-structured interviews (and one informal, unstructured interview). As this suggests, I started with a prepared line of questions but the interviews were carried out in a conversational style and allowed for exploring issues that arose unexpectedly or opportunistically (O'Leary 2004:164). Because I was seeking this conversational style; and because, generally, all key informants spoke English, a translator was not used for these interviews. The interviews included staff members of WV and MC to explore a range of issues including barriers and opportunities related to implementation and scaling-up SAI in Timor-Leste; an agricultural faculty member and department head at the UNTL; and a senior staff member within the Ministry of Agriculture and Fisheries (MAF).

A representative from the AusAID funded Seeds of Life (SoL) was interviewed concerning research of seeds and how this meets the agriculture and nutrition needs of the community. The interview was sought not only to gain the benefits of experience and insight of persons working within this organisation; but also because of the need for alternate and pluralistic points of view (O'Leary 2004:51), particularly in dealing with potentially contentious issues, such as HYVs can be in Timor-Leste. Being aware of the "different ways of seeing provides a richer, more developed understanding of complex phenomena" (Cohen and Crabtree 2006).

I also met with other organisations working to promote more sustainable agriculture in Timor-Leste, including representatives of the UN Food and Agriculture Organisation who are introducing CA; staff members of GIZ's[22] Agro-Biodiversity and Rural Development Programs; and Oxfam, an NGO working with farmers to promote SRI.

Presentation and discussion of the results of field work relating to the three key questions are discussed in Chapters 5 and 6.

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[22] Deutsche Gesellschaft fur Internationale Zusammenarbeit of Germany (German Corporation for International Cooperation)

Chapter 5 Results of Field Work

This chapter examines the results of the research in Timor-Leste investigating the capacity of SAI to serve the multiple functions of agriculture. It starts by describing the sample of farmers selected to be interviewed; and extrapolates from this to the broader population. Discussion then turns to the potential of SAI to improve the livelihood, household nutrition and natural resource management of farmers interviewed.

5.1 The Farmer Survey

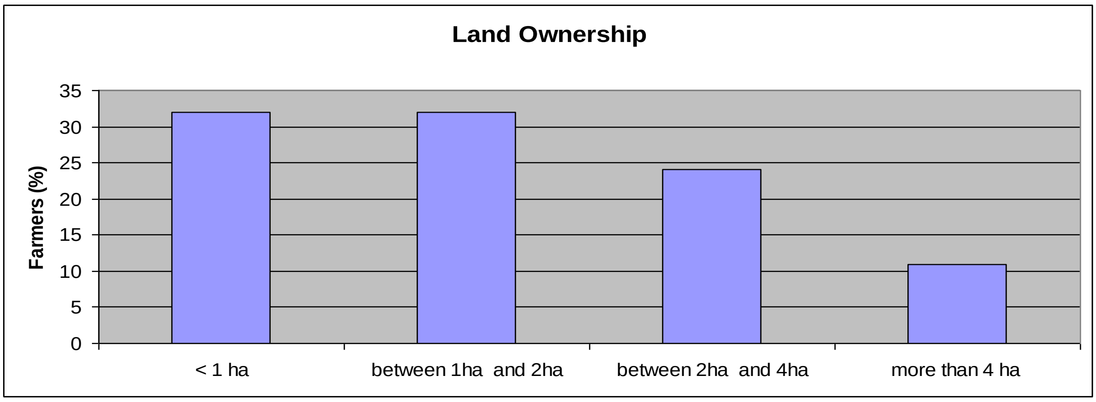
The socio-economic circumstances of the farmers interviewed for this research is described by their land ownership; livestock; tools and machinery; an indication of household income from farming; and household food security. In each case there is some indication of how representative or generalizable the circumstances of the farmers interviewed are to the larger population of Timor-Leste.

5.1.1 Land ownership

Land ownership is presented in Figure 5.1. How typical this is of land ownership nationally is difficult to assess; in large part, due to a traditional system of land tenure. Thirty-two percent of farmers interviewed reported owning less than one hectare and 35% reported owning over two hectares. The World Bank reports that less than 5% of the landowning rural population in Timor-Leste have more than one hectare (2003:74); and Lopes and Nesbitt state that due to the lack of available labour to control weeds, most farm households only crop 0.7 to 0.8 ha (2012:9).[23] It is possible some farmers are including in their ownership, land farmed with a group, as occurred in the MC Baseline survey (van Duijn 2014).

[23] Five of the 37 farmers interviewed report not planting all of the land they own; in part, due to steepness of the land. In general, farmers in Manufahi have the highest land ownership compared with other districts included in the MC Baseline Survey, but lowest level of land cultivated (van Duijn 2014).

Figure 5.1: Land ownership of 37 farmers interviewed for this research



5.1.2 Livestock ownership

Livestock ownership for farmers interviewed in Aileu and Manufahi is shown in Table 5.1 (poultry) and Table 5.2 (larger livestock).

Seventy-six percent of households own poultry (including chickens and ducks). The households with larger numbers of poultry (7-60 birds) are all in Manufahi where poultry can be integrated with aquaculture.

Table 5.1: Poultry ownership

Poultry numbers	# MC farmers Manufahi	# WV farmers Aileu	Combined farmer #	Combined percentage (%)
No poultry	3	6	9	24
1-6	10	11	21	57
7-20	5	0	5	13
21-60	2	0	2	5

Regarding larger livestock, 81% of households owned goats and pigs, with around 76% owning less than five head, usually one or two head; and ownership of pigs significantly more common. In relation to cattle, 76% of households reported owning no cattle, and around 18% owned less than five head.

Table 5.2: Larger livestock ownership

Livestock numbers	MC farmers Manufahi	WV farmers Aileu	Combined farmer #	Combined percentage (%)
Own pig or goat	16	14	30	81
< 5 head	15	13	28	76
≥ 5 head	1	1	2	5
Own Cattle	3	6	9	24
<5 head	1	6	7	18
≥ 5 head	2	0	2	5
One horse	0	3	3	8

These findings are comparable with the Baseline Survey[24] and show slightly less livestock ownership than Oxfam's findings in the districts of Covalima and Oecusse (2009).[25]

Large livestock is rarely eaten at home. Livestock are commonly used as an asset to sell at the time of a ceremony or when cash is needed (e.g. during difficult times or when there are extra costs for the household such as for school supplies).

5.1.3 Tools and machinery

All farmers interviewed indicated that the tools they use in farming consist of a hoe and digging stick for their tillage and planting; many have pick axes and mattocks and use knives and machetes to clear weeds. The exception is three farmers (8%) who use a government hand tractor on loan in an arrangement where farmers pay for the fuel only. This is typical of farmers in Timor-Leste, with the exception of lowland rice where buffaloes are used to puddle rice paddies (Lopes and Nesbitt 2012:5).

5.1.4 Farm Income

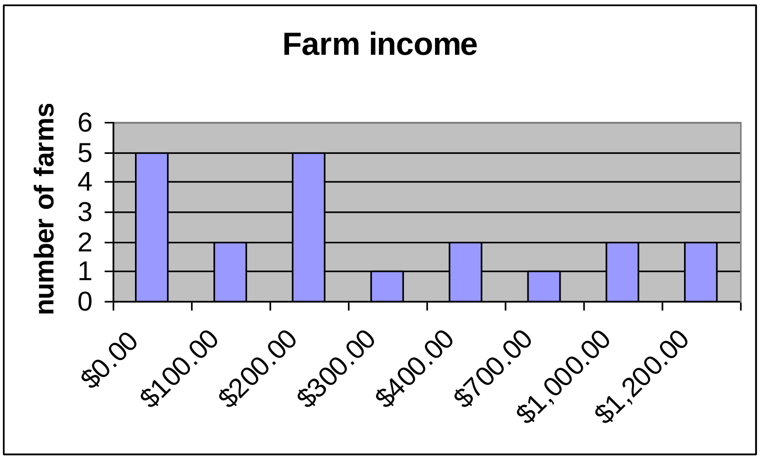
This research was not intended to assess farm income per se, but to generally get an idea of how much food is currently being produced relative to household needs; and in what way these farmers are participating in the marketplace. Most farmers produced primarily for home

[24] The Baseline survey showed that in all six districts, most households own animals, with almost 72% owning chickens/ducks; 87.3% owning pigs (usually one or two head); almost 29% owning sheep or goats (with average of just over one head); and 37.3% owning cattle or buffalo, with an average of two head (van Duijn 2014:24).

[25] "Livestock ownership was limited in Covalima and Oecusse. Ninety-three percent of households (N=148) in Covalima and 70% in Oecusse (N=105) owned goats and pigs, with around 55% owning less than five head. In relation to cattle and buffalo, 36% of households (N=112) reported owning none, and around 22% (N=71) owned less than five head" (Oxfam 2009:5).

consumption, with small amounts being sold. For the 20 MC farmers, I roughly estimated an average annual income from farm sales (Figure 5.2) to be $433.22.[26]

Figure 5.2 Estimated Farm Incomes (Manufahi)

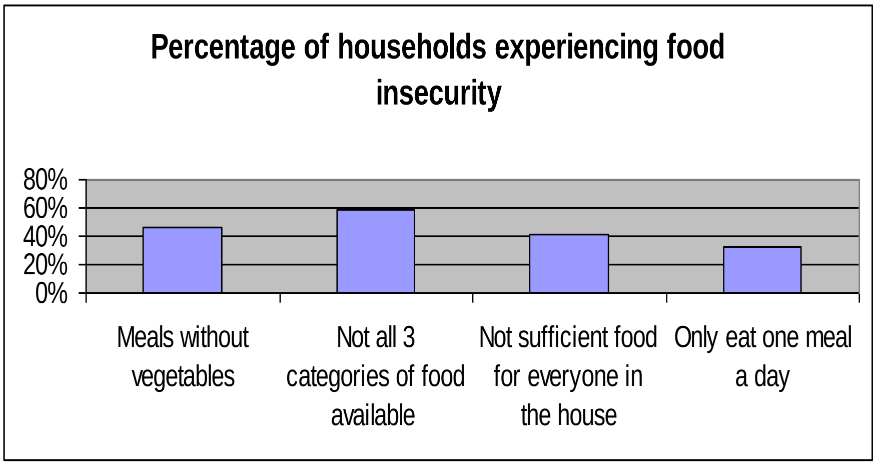


By comparison, the median per capita income nationally is $480/year (RDTL 2014a:25).

5.1.5 Household Food Security

Food insecurity is experienced primarily in the dry season. The level of insecurity experienced by those interviewed is represented in Figure 5:3.

Figure 5.3 Household food security[27]



[26]This is relatively consistent with MC' Baseline Survey (n-214) showing the average household income to be $414.50 in the six districts in which MC's aquaculture project is taking place (out of 13 districts nationally). In Manufahi, the Baseline Survey found the average income was $513.30, or $1.41/day. The incomes assessed by the Baseline Survey are based on income from multiple sources. However, approximately 86% of incomes are from crop sales, followed by livestock sales (51.4%) (van Duijn 2014:27).

[27]The meaning of "Not all three categories of food available" is that grain, vegetables and legumes are not all available.

Most respondents were reluctant to specify the time period in which they experience food shortages. Many stated "sometimes"; others indicated that the problem is in the dry season (approximately November to February), with only one person specifying that food can be a problem for 2-3 months.

By comparison nationally, on average, rural households go without enough rice or maize to eat for 3.8 months of the year (RDTL 2011:107). The majority (56.6%) of households surveyed as part of the MC baseline study, report that, on average, they suffered food shortage for 1-2 months during the previous 12 months – primarily due to running out of home-grown food and not having enough income to buy food. People usually cope by reducing the meal size (46% of households), consuming less preferred food (37%) and reducing the number of meals (26%) (van Duijn 2014:11).

Most farmers interviewed for this research coped by borrowing food or money from neighbours or family; or by eating less. In the words of three respondents:

> *"When we only have enough for one meal we eat some (like cassava or potato) for breakfast and corn or rice for dinner"*
>
> *"I'm too shy to borrow, I just wait"*
>
> *"We eat cassava and work less hard"*

In trying to extrapolate from the description of farmers interviewed, I turn to the Asian Development Bank (ADB) study which ranked living standards of each of Timor-Leste's 442 sucos. Sucos were categorised in five groups, with group one having the lowest living standard and group five having the highest living standard. There are 88-89 sucos in each group; i.e. approximately 20 percentile categories (ADB 2013:v). The ranking of the sucos in which farmers were interviewed for this research is shown in Table 5.3.

Table 5.3 ADB ranking of living standards in sucos of farmers interviewed

Location	Rank of living standards	Group	Adult literacy (%)	Electricity (% with)
Alieu				
Fatabloko	92	2	37	1
Asubilitoho	170	2	50	1
Sloi Kariak	250	3	58	4
Fahiria	375	5	54	57
Manufahi				
Holarua	258	3	49	38
Letefoho	409	5	70	78

Source: data taken from ADB 2013

From the data in Table 5.3 it is clear that farmers interviewed for this research are located in sucos representing almost the full range of living standards. The lowest category (group one) is not included. However, several points can be made:

- the ranking is based on sucos and does not account for differences in living standards between aldeas within sucos.
- In terms of asset ownership, the ADB study showed ownership of hand tractors to be between approximately 9% and 18%, amongst the sucos with the lowest and highest living standards respectively (ADB 2013:40); none of the farmers interviewed owned hand tractors.
- In the 20% of sucos identified by the ADB as having the lowest living standards (group one), the average share of households with electricity is 3%; the group two sucos of this research were both assessed by ADB as having only 1% electricity (2013:5).
- Average adult literacy rate ranges from 35.7% in sucos with the lowest living standard to 69.3% in sucos with the highest living standard; and total average is 47.5% (ADB 2013:41). Five of the six sucos in which farmers were interviewed show a higher literacy rating than average; and all greater than group one sucos (see Table 5.3). However, all farmers interviewed were not literate.
- ADB assessed livestock ownership per person rather than household so a comparison is difficult to make. However, in estimating 5 persons per household,[28] it is concluded that, on average, farmers interviewed owned less livestock than the average household in Timor-Leste.

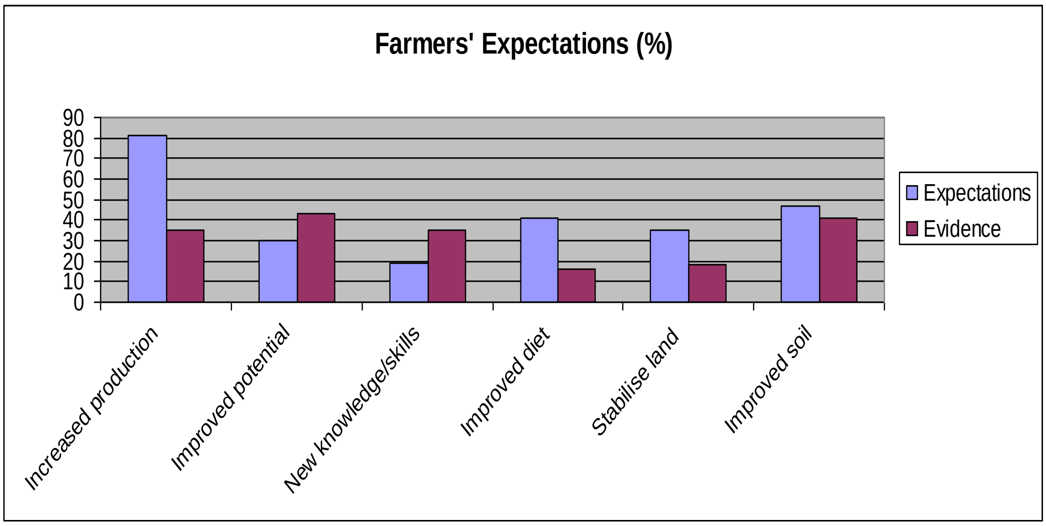
[28] The COMPAC-TL Baseline Survey found that the average number of household members in the six participating districts is 5.2. In Manufahi the average number is 4.4 (Van Duijn 2014:17).

The conclusion is that, overall, there is no obvious way in which farmers interviewed had any distinct advantage over other farmers in Timor-Leste. In other words, their capacity to successfully adopt and benefit from SAI is no greater than other farmers.

5.2 Multifunctional capacity of SAI in Timor-Leste

The capacity of SAI to improve farmers' livelihoods, household nutrition and natural resource management in Timor-Leste was assessed by asking farmers involved in the process about their expectations of adopting changes and whether they are satisfied, or there is evidence, that expectations will be met. Their answers are illustrated in Figure 5.4.

Figure 5.4 Expectations and early indications of SAI's multifunctional capacity



Improvement of livelihoods is reflected in the first three indicators (increased production, improved potential production[29] and learning new knowledge and skills). The capacity of SAI to impact on nutrition is reflected in the next indicator (improved diet). The last two indicators (stabilise land and improved soil) reflect the capacity of SAI techniques to affect natural resource management. The light columns represent what farmers expected to gain from adopting the new practices**.** Dark columns reflect the degree to which farmers feel that expectations are realised. In each of the NGOs, some of the farmers were part of pilot studies, while others have only been involved in the projects for a year or less.

[29] Improved potential production refers to having planted fruit and timber trees that are not yet being harvested but will be harvested in the medium to long term, respectively; or the added potential of having a fish pond. Evidence of realising this potential includes, e.g., 'trees are growing well' (but not yet fruiting) and 'fish are growing well' (but not yet harvested).

5.2.1 Livelihoods

Eighty-nine percent of farmers interviewed for this research indicated that they expected their livelihoods to be improved by participating in the WV and MC projects. As illustrated in Figure 5.4, these expectations are starting to be realised.

Thirty-one percent of farmers reported production levels were up. Some relevant responses include:

> *"Composting and other practices from World Vision have increased food production and income…"*
>
> *"We've sold about 10 kg. of fish at $3/kg"*
>
> *"Last year I sold 100 fish in total"*

Forty-one percent said that the potential of their farm has been increased:

> *"Now we can make a garden even on sloping land"* (i.e. land that was previously unusable is now terraced).
>
> *"The Mahogany is growing fast and the cherry tree is growing"* (i.e. for future timber and fruit).
>
> *"This project has already improved soil and food production; and some seedlings are not yet harvested so we will have more production in the future."*

Thirty-four percent said that they have gained new knowledge and skills that will improve their livelihood in the future. For example:

> *"Fish are growing well after training from Mercy Corps"*.
>
> *"In the past the land was red but now the soil is better after using compost. Also, production increased with learning about planting space."*

The impact of adopting knowledge-intensive practices on farmers' understanding of production processes and natural resource management - and therefore their capacity and confidence to continually learn and innovate (Styger et al. 2011) was also exhibited:

> *"We now have more food and the family eats more variety of foods. We prune with intention now and protect our land with terracing - less landslides and better soil..."*
>
> *"Fingerlings are growing well. This project gives us benefit and I am proud."*
>
> *"Fish are growing well now and we have added more fingerlings."*

Other evidence of improved livelihoods as a result of adopting SAI comes from sources other than the farmers interviewed. The average earnings of participants in MC' pilot project increased by $3/month (i.e., up 5-10%) from sales of fish and fingerlings. This average was across a group where not all participants had yet commenced selling. One individual fish farmer interviewed by an external evaluator reported earning, on average, $80/month (MC et al. 2013:3).

World Vision hosted a farmer field day at a site where they harvested maize (that had been intercropped with beans) at 13 tonnes/hectare. "The area planted was only 20m x 30m but we were able to calculate the yield per hectare through several sample sites on this plot. We harvested and measured during a farmer field day so plenty of people were there to see this amazing result" (Tessema 2015).

Oxfam reports that following the introduction of SRI in Bobonaro, farmers who practiced at least some SRI elements had on average 56% or 2.3 tons higher yields compared to their conventional fellow farmers (See Table 5.4).

Table 5.4 Production data related to Oxfam's introduction of SRI in Bobonaro

Parameter	**Season 2006/07**	**Season 2007/08**	**Season 2008/09**
No of SRI farmers	35	450	1228
Total area		297 ha	982.4 ha
Average yield (SRI)	3t/ha	4.3 t/ha	5.3t/ha
National average (MAF estimate)	2t/ha	2t/ha	2.5t/ha
Bobonaro average (MAF estimate)		2t/ha	3t/ha

Source: adapted from Diechert et al. 2009:5.

5.2.2 Nutrition

Thirty-nine percent of farmers interviewed identified home consumption of more or different food as an expectation of participating in the projects. There is evidence to suggest the projects are successful in improving household nutrition. Figure 5.4 indicates 16% have experienced an improved diet. However, when account is taken of data related to greater production (as opposed to 'improved diet' per se), the evidence shows that 35% of households have increased access to food. Two farmers commented:

> *"Now we have more food and the family eats more variety of foods."*

"We used sometimes not to have meat - but now we have so many vegetables we can also afford to buy meat."

Mercy Corps' pilot aquaculture project (2010-2013) found that fish consumption increased by 33% in targeted households and overall Household Dietary Diversity Score was raised by 1.6 points in a range of 0-12 (Mercy Corps et al. 2013:3). Fish consumption promotes health and nutrition by:

a) providing animal protein, essential fatty acids and micronutrients including iron, zinc, iodine, magnesium, phosphorus and calcium;
b) supplying essential fats for brain development and infant development (WSDH 2015); and
c) helping the body to absorb micronutrients, particularly iron and zinc, from other foods in a meal (Mercy Corps et al. 2014:8).

5.2.3 Natural Resource Management

Whereas MC' aquaculture project is intended to improve livelihoods and household nutrition; the FMNR and climate-smart practices promoted by WV are focused on improving livelihoods and natural resource management. This is reflected in the response of farmers to questions about farm practices. In Figure 5.4, the farmers that expect the new practices to stabilise their land and improve soil are all farmers participating in the WV projects.

Table 5.5 compares the practices of WV farmers with those of MC farmers. FMNR and climate-smart practices have not been promoted to these MC farmers. In this regard, MC farmers may more closely represent the average farmer in Timor-Leste.

Table 5.5 Comparison of farm practices

Practice	**Percentage of WV farmers using practice**	**Percentage of WV farmers stating that they intend to use practice soon**	**Percentage of MC farmers using practice**
Till with hoe	100		94
Burning land	47[30]		78
Clearing land	47[31]		72
Compost	65	76	28
Mulch	100		89
Green manure	59	65	33
Terrace	65	82	33*
FMNR	94		0 (no awareness)
Intercrop	100		83
N-fixing legumes as fertiliser	88		83
Chemical fertiliser (0.5 - 1.5 kg)	47		17

* N/A to all MC farmers – see text

A higher proportion of the MC farmers burn and clear their land, increasing evaporation of soil moisture and the risk of erosion. Fewer MC farmers use compost, mulch and green manure – all practices that build soil fertility, structure and biodiversity.

Seventy percent of Timor-Leste's land area has a slope of over 26%, with the majority of rural households cultivating within these areas (RDTL 2011:116). Sixty-five percent of WV farmers are involved in terracing hillsides to improve management of steeply sloping land. More WV farmers plan to terrace land in the near future[32], raising the percentage to 82%. Although only 33% of MC farmers use terracing, terracing is not applicable to 39% of these farmers as they have no steeply sloping land. Consequently, of those MC farmers to whom terracing applies, 54% used this practice; non-users did not indicate intention to terrace in future. No MC farmers are aware of the practice of FMNR.

Terracing makes the use of steep land more accessible to the farmer, slows down the flow of rainfall and, in doing so, increases water absorption into the landscape and catches sediment

[30] An additional farmer has modified his burning and now only burns small piles of wood, rather than the whole hillside.

[31] An additional farmer has modified his clearing and now leaves some trees to shade coffee.

[32] These farmers indicated that they hadn't yet done the training to learn how to build terraces; or that terracing steep slopes is difficult and they were waiting until community members were available to help.

moving down slope. WV is promoting both hard benches (Figure 5.5) and soft ridges for this purpose.

Figure 5.5 An example of steeply sloping land terraced with hard benches and the use of trees. The crops here include pineapple, cassava, *Eucalyptus alba*, oranges and beans.

There is less difference between the two groups regarding the use of intercropping and N-fixing legumes (Table 5.5). WV farmers reported that while intercropping and planting beans are traditional, they only started inter-cropping beans with corn once advised by WV about how legumes increase soil fertility.[33]

Finally, Table 5.5 indicates that chemical fertilisers are used more frequently by WV farmers (47%) than by MC farmers (17%). This may seem contrary to SAI practices as chemical fertilisers by themselves do not directly contribute to improving soil structure. However, the amount of chemical fertiliser being used is exceedingly small (0.5 kg to 1.5 kg/ha); and all are using this in combination with organic fertilisers. While there is a range of problems

[33]Mixed cropping is a traditional cultivation method in Timor-Leste (Egashira et al. 2006) but there is some suggestion that it may be a system farmers have somewhat lost, and are now re-adopting (Da Costa et al. 2013). It is the experience of WV staff that there are many legumes in the food system in Timor-Leste, but they are primarily grown as a food not as a soil building plant (Tessema 2015). This is consistent with findings by SoL that the most frequent inter-cropping combination is of corn, cassava and sweet potato; and that only about a 37% of farmers incorporate peanuts into the mixed plantings (SoL 2012 cited by Da Costa et al. 2013:86-87). The SoL program has successfully promoted the inter-cropping of corn with Velvet bean (*Mucuna pruriens var utilise*) to increase grain yields, improve soil fertility and shade out weeds (Lopes and Nesbitt 2012).

associated with the use of synthetic fertilisers – these are associated with much higher levels of use and growing dependency. The use of no fertiliser can also be a problem, critically depleting soil organic levels (Tilman et al. 2002).[34] The data could suggest an increased awareness by WV farmers of the need for soil nutrients.

The MC aquaculture project is in its early stages. MC does plan to progress to integrated aquaculture and agriculture, the environmental benefits of which are well recognised. For example, rice-fish co-culture is designated as a 'globally important agricultural heritage system' and has been maintained in south China for over 1,200 years. A field survey comparing paired farmers from rice monoculture (RM) systems and rice-fish (RF) systems showed that fish consume insect pests and weeds in the rice crop and contribute to disease control by shaking dew drops from rice leaves, which reduces the risk of spore germination. As a result, RF systems require 68% less pesticide than RM systems. The study also indicated a complementary use of nitrogen (N) between rice and fish in RF, resulting in low N fertilizer application and low N release into the environment (Xie et al. 2011).

Several MC farmers are using an integrated system but, as yet, none of those interviewed integrated fish production with cropping. Integration is demonstrated by using chicken droppings to feed the fish (Figure 5.6). This allows the farmer to diversify production by recycling an output from one sub-system on the farm to another sub-system, resulting in a greater efficiency of production through the use of low-cost, on-farm resources (Prein 2002).

[34] Because reliance on synthetic fertilisers are neither environmentally nor economically sustainable, increasing attention is being drawn to integrated fertility management using micro-doses of chemical fertiliser in combination with natural fertilising techniques to build soil structure and contribute to crop growth. Tilman et al. (2002) state that greatest efficiency of nitrogen fertiliser is achieved with the first increments of added nitrogen; efficiency declines at higher levels of application (2002:673). Studies with 160,000 households in Zimbabwe showed that when natural fertilising techniques were combined with the use of 8–10kg/ha of non-organic nitrogen, production and food security increased by between 30 and 50 per cent depending on the amount of rainfall (Verchot et al. 2007:14).

Figure 5.6 Integrated fish and chicken system.

5.3 Conclusion

Generally speaking, the farmers interviewed do not differ significantly from other farmers in Timor-Leste. The early experiences of farmers who have adopted SAI practices demonstrate its capacity and/or potential to improve livelihoods, household nutrition and natural resource management; and, therefore, to improve food security in Timor-Leste. Realising this capacity ultimately depends on the extent to which the multifunctional services of agriculture are considered fundamental to development in Timor-Leste. This is the subject of Chapter 6.

Chapter 6 Extent of Smallholder SAI in Timor-Leste's development framework

The proposition that smallholder SAI should be at the core of rural development in Timor-Leste rests on three assumptions: that agriculture should be the focus of development; that development efforts should be targeted at smallholders; and that there is a need for more sustainable agriculture in Timor-Leste. In this chapter, these three assumptions are addressed prior to examining the extent to which the development framework focuses on smallholder adoption of SAI.

6.1 Three assumptions regarding smallholder SAI

6.1.1 What agriculture can do for development

Over 70% of the population of Timor-Leste live in rural areas and more than 78% of the labour-force work in agriculture (FAO 2013). Consequently, increasing the productivity and growth in this sector has the capacity to improve the livelihoods of a large segment of the population, and subsequently to foster overall economic growth through a multiplier effect (Remenyi 2004). This is evidenced in other agricultural economies. "Cross-country estimates show that GDP growth originating in agriculture is at least twice as effective in reducing poverty as GDP growth originating outside agriculture…. For China, aggregate growth originating in agriculture is estimated to have been 3.5 times more effective in reducing poverty than growth outside agriculture—and for Latin America 2.7 times more" (World Bank 2007:6). Focusing on non-agricultural growth is more likely to widen the income disparities between rural and urban areas (World Bank 2007:28); and it is difficult to redistribute income from these sectors to those living and working in the rural areas.[35]

[35] More generally, but highly relevant to Timor-Leste as a post-conflict country, Falcon and Naylor point to empirical studies in support of re-establishing the central role of agricultural research and development in addressing food security in developing countries and linking this to political stability. "Given the fundamental role that agriculture plays in pro-poor growth, it seems that a strong rural sector can perform the dual roles of improving food security and improving national security" (2005:1116).

In Timor-Leste, one key informant advised that all of the organisation's projects are under the roof of peace building and conflict resolution. From the perspective of the interviewee there is potential for conflict in Timor-Leste resulting from a growing population and limited natural resources. "*There are conflicts about water and land. If upland areas are not dealt with we will have less water and land for food production and then there will be a problem*".

6.1.2 Targeting smallholders

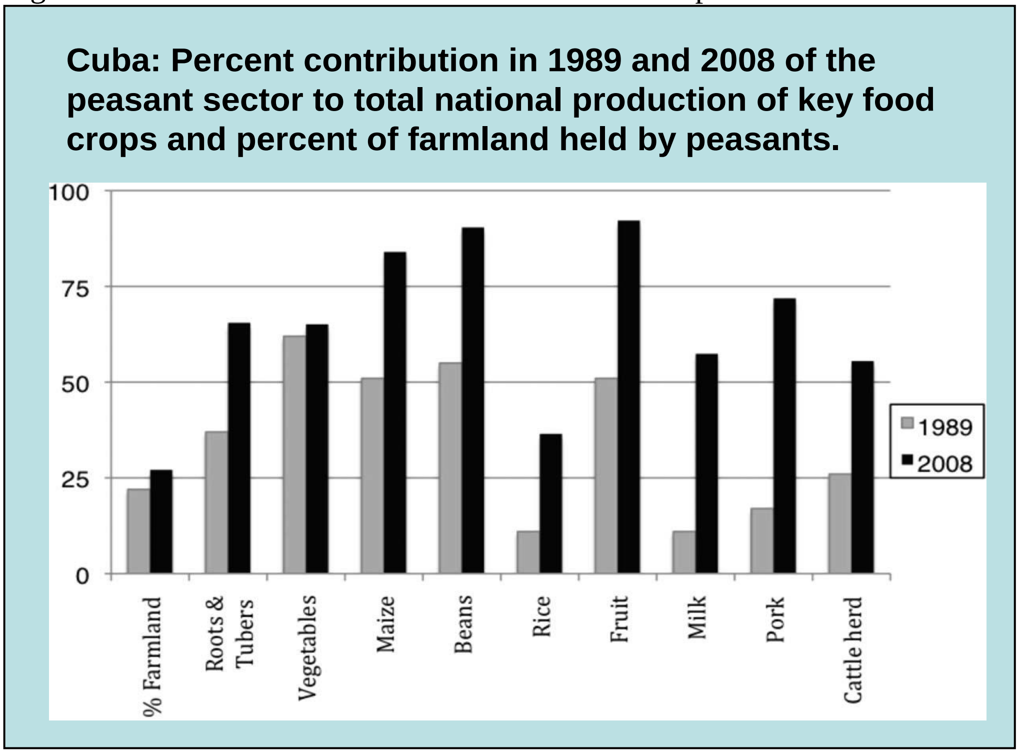
Targeting smallholders is especially important in countries such as Timor-Leste where the vast majority of farmers operate at small-scale subsistence level; and where poverty and food insecurity is highest in the rural agricultural areas (Lundahl and Sjoholm 2012).

In a comparison of agricultural development policies in other Asian countries, countries whose policies increased productivity of small farms (through low-input, labour-intensive agriculture) experienced rapid economic development, increased employment and equality, staved off food import dependency, and achieved higher food production. The yields on small farms were greater than those on plantations, including for cash crops such as sugar and rubber. Countries that failed to adopt or implement strong egalitarian land reform policies along with support[36] for small farm development continue to experience inefficient farming, lower yields and high levels of poverty – despite the abundance of natural resources (Studwell 2013).

Cuba provides another example. When the Soviet bloc collapsed in 1989 Cuba was unable to import sufficient food, fertilisers, pesticides, fuel, tractors or parts; and local food production collapsed. Out of necessity, farmers adopted farming technologies based on local resources. By spreading the technology from farmer-to-farmer the adoption of such practices went from 200 families in 1999 to 110,000 families (about one-third of the peasant sector) by 2009. Figure 6.1 shows the increased contribution of smallholders to national production during the period in which agroecological interventions were being adopted and scaled-up (Rossett et al. 2011).

[36] Along with land reform, support refers to the provision of infrastructure, credit, extension services, storage facilities and marketing (Studwell 2013).

Figure 6.1 Smallholder contributions to national food production in Cuba



Source: Rossett et al. 2011:180

By 2007 the production of vegetables, typically a peasant crop, increased by 145% over 1988 levels despite using 72% fewer agricultural chemicals. Figure 6.1 also demonstrates an increase in the percentage of farmland held by peasant farmers during this time. In 2008 peasant farmers produced more than 50% of many food items while holding just 27% of farmland (Rossett et al. 2011:181).

These changes in Cuba not only improved livelihoods, but increased the number of livelihoods. Rosset et al. (2011) report that due to diversification on the farms, sons, daughters and extended family members are returning to the farms to engage in productive labour. [37]

This is highly relevant to Timor-Leste where the private sector's capacity to provide jobs is limited to approximately 400 new formal positions each year (RDTL 2011:119). There is already a high level of unemployment and youth unemployment in particular (RDTL 2010a:63). The Timor-Leste Strategic Plan identifies the need to ensure jobs in rural areas for these young people (RDTL 2011:107). But the labour force in agriculture has been declining

[37]Garrity et al. (2010) provide another example from Burkina Faso, where, after the harvest, men commonly migrated to urban areas for employment. But following adoption of SAI technologies with increased crop yields and incomes, indicators suggest that this pattern is changing as more men remain in the villages because they can now earn sufficient incomes from agriculture.

since 1999, and at an increasingly higher rate. In the period 2009-2014 the annual rate of growth in agricultural labour was -0.26 (FAO 2013).

6.1.3 The need for SAI in Timor-Leste

Timor-Leste is a prime example of how food security requires as much attention to increasing environmental sustainability as to raising productivity (Garnett et al. 2013). Two key elements of food production highlight the need for SAI in Timor-Leste, land and water.

6.1.3.1 Land

In Timor-Leste land degradation includes water and wind erosion, soil fertility decline, waterlogging, salinization, lowering of the water table and soil acidification (Egashira et al. 2006:370). Despite the mountainous topography and fragile soil on which farming occurs, the typical cycle has been to cut and burn the hillside; produce a good crop, which then diminishes over a couple years as soil fertility declines; and then move to a new area where the cycle begins again. This has contributed to deforestation (now at a rate of 1.7% a year) and consequent exposure of erodible soils which heavy rainfall washes away (Gusmao 2015).

Figure 6.2 Landslips

Key informants are concerned that increasing soil degradation will result in some land not ever being made productive again. The national population is growing at an annual rate of 3.2%. If this rate continues, Timor-Leste’s population will double in 17 years (RDTL

2011:107). The amount of land used for arable crops has been increasing annually while forest cover has diminished[38] (FAO 2013). Farmers adopting SAI are recognising the need to work within the environmental constraints of the country's topography and its soils. According to three respondents:

> *"We've made many changes. The soil has improved and there's no need to move to new land - instead we make this land better all the time."*

> *"I would like to plant more but my steep land suffers from landslide; we will terrace soon and plant more"*

> *"FMNR will prevent landslides. Some of the tree crops are for short term income (e.g., oranges) and some for long term income (mahogany, Casuarina). I expect more food and a more secure livelihood with the land being more secure."*

6.1.3.2 Water

"The International Water Management Institute predicts 'that most developing countries will face either physical or economic water scarcity by 2025. Water diverted from rivers increased 6-fold between 1900 and 1995 (Shiklomanov 1999), far outpacing population growth'" (Pretty et al. 2006).

Timor-Leste is a prime example of this, with a rapidly growing population and already amongst the highest 20 countries with respect to total water withdrawal per capita[39] (2000-2010) (FAO 2014:48). Due to the country's complex topography rainfall is variable from place to place and from season to season; and the country is strongly affected by the El Nino Southern Oscillation (ENSO) cycle so suffers erratic phases of drought and flood (Fox 2003).

Sixty-five percent of farmers interviewed indicated that cropping in the dry season is water-restricted, with 11% growing for home only and an equal number not growing at all in the dry season. Eight percent of farmers said water was not a problem – primarily because they are

[38] The amount of land used for arable crops increased by 1.49% per year between 1997 and 2002, and by 2.71% per year between 2002 and 2007; while forest cover diminished from 0.89 million ha in 1997 to 0.72 million hectares in 2012. The annual rate of forest decline has also increased in the period 2007-2012 (FAO 2013).

[39] Fresh water availability per capita dropped from 9.45 thousand cubic metres in 1996 to 7.50 thousand cubic metres in 2011 (FAO 2013).

near the source of water; and all are in the Same area where rainfall is greater than in Aileu (Table 6.1).

Table 6.1 Water availability in the dry season

Water availability	WV Farmers	MC Farmers	Combined (%)
Crops for market – but more limited	11	13	65%
Grow for home only	2	2	11%
No growing in dry season	4		11%
Water not a problem		3	8%
Did not plant a garden this season		2	5%

Climate change will increase mean rainfall values but some of this will fall via extreme rainfall events with increased intensity, making it more erosive and less valuable where there is no capacity for it to be captured. The dry season will be drier and, overall, temperature will rise with extreme temperature events increasing in intensity and length (RDTL 2010b). For agriculture, this signals both a higher capacity for soil loss, sedimentation and flood damage; and crops subject to water stress, with higher evaporation rates (from land and water storage areas).

The need to integrate soil and water management is critical. To date, money has been wasted on dams that fill with sediment (MAF informant); irrigation systems are damaged by flooding rivers (Lundahl and Sojholm 2012); and many hectares of previously irrigated land are unusable or underused because irrigation systems have lacked maintenance (RDTL 2011:121). Although schemes based on weirs and river diversions are considered inappropriate to Timor-Leste (Young 2013), there are plans to significantly extend irrigation systems and discussion about constructing more dams (RDTL 2011).

International recommendations for small farmers focus on capturing water with small on-farm systems and, importantly, using farm practices that are water-efficient and hold water in the landscape – reducing the impact of flood and drought. This approach can more than double productivity in rainfed areas with currently low yields (Rockstrom and Barron 2007). Key informants indicate that this approach is increasingly being advocated in Timor-Leste (also see Egashira et al. 2006).

The farmers interviewed are aware of the lack of a clear water-management plan and are concerned about future water supply. As national planning for water management occurs it will need to take into consideration impacts on local farming communities currently relying on the existing water system (Nugroho 2015).

6.2 Instruments of change

Having addressed the assumptions inherent in the proposal that Timor-Leste's development should focus on smallholder adoption of SAI, discussion turns to the extent to which that is the case. This is assessed by evaluating the degree to which key instruments recognised as effective for this purpose are being implemented. Obstacles and opportunities are identified.

6.2.1 Embedding the multifunctional value of agriculture in national policies

Effective instruments for scaling-up SAI generally focus on improving the productivity, profitability and sustainability of smallholder farming. This requires embedding the multifunctional value of agriculture in national policies and strategies and ensuring that public spending reflects these values (World Bank 2007).

The direction of Timor-Leste's development is set out in its Strategic Plan (2011-2030) (RDTL 2011). With respect to focusing on smallholder SAI, the Plan is inconsistent and ambiguous. Although the Plan states that extension officers will be trained in sustainable agricultural techniques, it also states that food security strategies are modelled on the 'green revolution' in India (2011:119).

India's experience of the GR is complex - the details of which clearly signal to 'be careful what you wish for'. Seventy-five percent of farmers who were without larger areas of land to profit from these technologies were marginalised; and by 2004, 233 million people remained malnourished (Muller and Patel 2004:6, 46).

The GR substantially increased yields and livelihoods in the more fertile north-western regions of the country. But it also lead to concentration of land ownership and created a fundamental shift in agro-technological systems, increasing dependency on high levels of fertiliser and pesticide use, reducing genetic diversity, and increasing vulnerability to problems such as pests, soil erosion, and water shortages. The outcomes are so unsustainable that in 2011 the Government of India called "for 'out-of the box' thinking to help resolve the agriculture problems facing India, a seemingly tacit acknowledgement of the limitations, if not failings, of the prevailing paradigm" (Pritchard et al. 2014:53).

The Timor-Leste Government will continue to offer farmers subsidies for fertilisers and pesticides to increase productivity (RDTL 2011:113, 124-126). In India, subsidies contributed to dependency, putting farmers on a chemical treadmill. Despite using increasing amounts of fertilisers to maintain the same yields (Hazell 2009:16 cited by Pritchard et al. 2014:56), production plummeted (Figure 6.3).

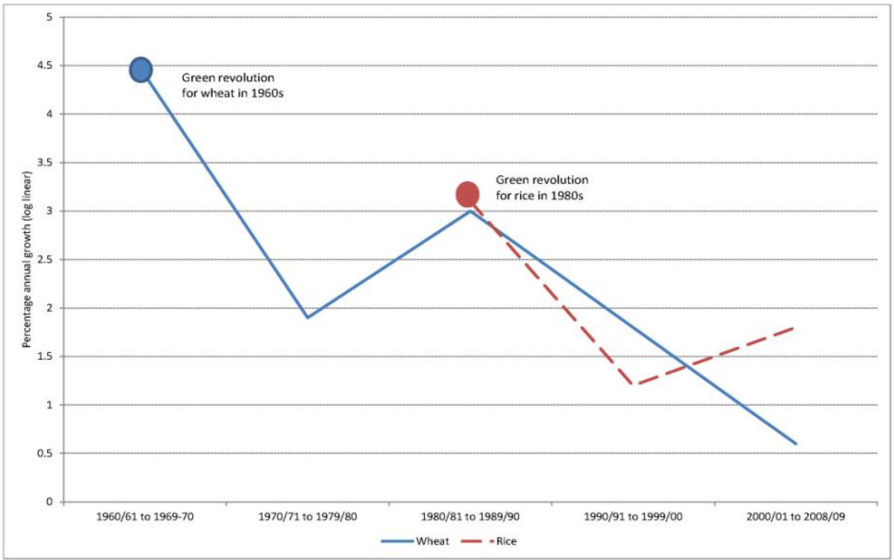


Figure 6.3 Average changes in wheat and rice yield in India, per decade
Source: Gulati, Ganguly and Shreedhar (2011:31) cited by Pritchard et al. 2014:56

When Indian cropping output over the whole of the GR period (1960s – 2000) was evaluated, it was found to have produced a net decline in total factor productivity (Nin et al. 2003 cited by Pritchard et al. 2014:56). India is not an isolated case.[40]

Timor-Leste currently exports organic coffee and the Plan indicates that this model can be expanded "as most of our subsistence crops are, by default, organic". The strategy is to use non-organic fertilisers and pesticides in order to achieve food security and reduce rural

[40] A study of the impact of high-input technology in southwestern Bangladesh found food production was remarkable but the harmful impacts were equally alarming with serious degradation of the quality of farmland and, over a five year period, a significant decline in the yield of rice (Ali 2004:291-296). As the promotion of these practices continued, Ahmed (2011) reported that despite the short-term positive production and economic benefits of intensive cropping with the use of power tillage, mineral fertilisers and pesticides, the overall impact was a negative cost:benefit ratio. In China and Pakistan, as much as a third of the productivity gains "have been negated by soil and water degradation and this does not include the off site pollution costs" (World Bank 2008:53).

poverty – with organic options being pursued in the longer term (RDTL 2011:119). This approach fails to recognise that creating sustainable systems is an inherent part of achieving food security and does not happen over night. ‘Organic’ is not only the absence of negative inputs but establishing an ecologically sustainable system so that such inputs are not necessary; and requires a sustained, pro-active strategy. Subsidising the use of fertilisers and pesticides creates a disincentive to building long-term, low-cost soil fertility and natural in-field biodiversity.

In working towards sustainability Timor-Leste could take an approach similar to Malawi - where a ‘subsidy to sustainability’ pathway linked fertiliser subsidies directly to on-farm investments that provide for long-term sustainability in nutrient supply, gradually shifting all investment from fertilizer subsidies to natural fertility regeneration (Garrity et al. 2010).

Another aspect of the Strategic Plan which makes smallholder SAI as a focal point doubtful is the establishment of special agricultural zones encouraging coffee estates and new food crop plantations; with new business laws and regulations and financial incentives for foreign companies (RDTL 2011:114-115). Although details are not available, concerns pivot on the potential for increasing monocultures; in what way this may compromise land rights or support the multifunctionality of agriculture; and whether assistance to be provided to the private sector will benefit the majority of smallholders.

6.2.2 Research and extension

A key element in scaling up SAI is providing for farmer-centred research and extension (Franzel et al. 2004; Garrity et al. 2010; Rossett et al. 2011). The World Bank reports that investment in agricultural research and extension results in high returns of between 35% and 50%; and that the necessary level of agricultural investment is approximately 10% of national budgets[41] (2007:40). The budget for agriculture in Timor-Leste has been closer to 2% for several years (La’o Hamutuk 2013a:2). This year’s State Budget allocates $25.68 million (1.7%) (RDTL 2014c:79, 100). Although this amount is almost doubled by donor contributions to the agriculture sector of $21.4 million in 2015 (La’o Hamutuk 2014b:1), it still represents the equivalent of only 3.1%.

[41] The 10% is based on the level of investment in transforming and urbanised countries, which was approximately 14% and 8% respectively during the period in which they experienced agricultural growth (World Bank 2007:41).

6.2.2.1 Research

Key informants say that only $400,000[42] is available in the budget for research, no one is driving a research agenda, and there are no resources available to incorporate research into the educational environment at university level.

The largest agricultural research project in Timor-Leste is the SoL program. It identifies HYVs of the staple crops of Timor-Leste (rice, maize, sweet potatoes, cassava, and peanuts) with the objective of increasing yields to reduce the shortfall of staples during the annual 'hunger season'; and reduce dependence on importing seeds from Indonesia (Lopes and Nesbitt 2012).

There are a number of points on which debate about agricultural research centres: i) although the HYVs have resulted in increased production, research and development focused on staples has contributed little significant improvement in terms of malnutrition levels (La'o Hamutuk 2013b:3); there is little or no research on the agricultural or nutritional value of traditional varieties which farmers still use; the HYVs have less storage capacity; and central to this thesis, focusing on breeding strategies for higher yields is counterproductive unless resources are also made available to promote land management.

Nutrition

Internationally, there is a lack of evidence that agricultural interventions have a positive impact on community nutritional status (Masset et al. 2011, Haddad 2013); and progress on human nutrition has lagged behind efforts to end hunger with excessive dependence on a few high-yielding crops (Garnett et al. 2013:34). This applies to Timor-Leste.

In 2002 UNICEF reported that in Timor-Leste 43% of children under the age of five were underweight; 47% were stunted; and 12% were suffered wasting (FAO/WFP 2003:12). After more than a decade, these figures have not improved (FAO 2014a:218).[43]

[42] The 2015 Budget indicates that the National Directorate of Special Services and Research are allocated $591,000 (RDTL 2014c).

[43] UNICEF report that the percentages in 2009 were: 49% underweight; 54% stunted; and 25% for wasting (2011:94). Based on 2012 data, FAO report that more than 45% are underweight, 58% are stunted and 24.5% suffer wasting (2014a).

The Timor-Leste Demographic and Health Survey (2003) revealed a high prevalence of anaemia in children under the age of five; 31.3% in children aged 6–59 months and 38.2% in children aged 6–23 months (Argo et al 2008). FAO (2014a) report that in 2014, 36.2% of children under the age of five suffer anaemia; and RDTL report that 62.5% of the general population suffer anaemia (2014b:16).

Focusing on a few high yielding crops can be counterproductive if they reduce dietary diversity (Garnett et al. 2013:34). More than 32% of farmers interviewed reported a heavy reliance on staples such as cassava, white rice or bananas – particularly during the 'hunger season'.

Underscoring the need for a balanced diet is the risk presented by over-consumption of cassava. Cassava is beneficial in that it is drought tolerant. The roots are the main part of the plant consumed and are high in energy content but low in micronutrients (vitamins and minerals); while the leaves have higher protein, vitamin and mineral content. However, cassava contains anti-nutrients and toxic substances[44] that can interfere with nutrient absorption and present toxic side effects, depending upon the amount ingested. Processing cassava can reduce the problems but can also reduce cassava's nutritional value (Montagnac et al. 2009). Consequently, reliance on cassava and the other staples alone can be problematic.

Also, a significant part of the malnutrition problem in Timor-Leste is a low level of awareness and understanding of nutrition; even in higher income households – improved incomes alone do not guarantee improved nutrition (Agho et al. 2008; van Duijn 2014).[45]

Consequently, although research has increased production of staples, there is a need to increase integration of agriculture and nutrition with more attention to nutrient-rich foods;

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[44] Compounds in cassava that interfere with nutrient absorption include a high abundance of phytic acid along with tannins and oxalates – affecting absorption of calcium, iron, zinc and other minerals and vitamins. Cassava also has a high cyanide level, particularly the bitter varieties. The FAO recommends a safe level of cyanide is < 10mg cyanide/kg dry matter (DM). Cassava leaves contain from 53 to 1,300 mg cyanide equivalent/ kg DM and the cassava root contains 10 to 500 mg cyanide equivalent/kg DM. Consumption of 50 to 100 mg of cyanide has been associated with acute poisoning; and lower amounts taken over long period can cause severe health problems (Montagnac et al. 2009:188).

[45] "Although the households raised small animals, such as pigs, chickens, goats, sheep, and vegetables in garden as part of household foods, these were not for consumption rather for sale, and parents were not aware of the relevant nutritional value of animal protein and other sources of vitamin A for children aged 6–23 months. … Children of the richest and middle-class households had lower mean Hb concentrations than those of the poorest households" (Agho et al. 2008:206-207).

UNICEF nutritional officer in Timor-Leste states that "To be thin and small is perceived to be the norm; it [chronic malnutrition] is not perceived as a problem..." (IRIN 2011:2).

focus on nutrition supplied through a balanced diet; and strengthen nutritional education. At a project level, MC's COMPAC-TL aims to achieve these nutritional objectives. But such an approach is needed nationally. Provision of a balanced diet requires not just increased production of healthy foods but increased access - emphasising the need for multifunctional agriculture to support improved livelihoods.

Lack of attention to traditional varieties

Little research has been carried out to assess the agricultural and nutritional value of indigenous and traditional species and to develop their potential in Timor-Leste. The loss of traditional varieties as well as the knowledge of seed-saving is an on-going concern of the farming community (Lemos 2009), civil society (LH 2013c), and professionals working in agriculture and development in Timor-Leste (key informants).

GIZ have worked with Forestry and other partners to identify 200 indigenous species (554 varieties) to establish a baseline of what indigenous plants exist and how they are being used by farmers, to compile a training manual for extension officers and hold seed fairs for exchange of seeds between farmers. There is concern that the work will not progress beyond this stage.

The FAO has emphasised the importance, globally, that action be taken to maintain genetic diversity in order to reduce risk and increase overall production stability; and as the basis for breeding new crop varieties to meet existing and future challenges. One of the key ways this has been done to date is through on-farm management of genetic resources (FAO 2010:4, 184).

An approach to seed selection and supply which is highly suitable to Timor-Leste with its variable rainfall and ecological diversity is Participatory Plant Breeding (PPB). PPB is a form of decentralised plant breeding in which farmers choose which varieties best suit their needs and conditions. Farmers and other partners then develop the new varieties which are adapted to both the physical and socio-economic environment in which they are utilized. The process is cost effective and can be implemented at a number of locations involving a large number of farmers evaluating different breeding materials. By selecting different varieties for different locations PPB maintains biodiversity and meets the farmers' needs of having readily available seed best adapted to their farm (Ceccarelli and Grando 2007:350, 353).

Opportunities with indigenous plants have been demonstrated in Africa where progress has been made in domesticating indigenous fruits and nuts; with commercially important traits being developed by farmers (at a relatively small level of investment); and there is growing confidence on the part of institutions and their donors about the merits of agro-diversity and the use of indigenous species in achieving the MDGs (Leaky et al. 2005). While traditional varieties often have the local image of 'poor people's food' – this is changing in Latin America where traditional crops such as yam bean and quinoa have now gained access to international markets and are promoted for their nutritional value (Jacobsen et al. 2013:657).

While research funding in Timor-Leste has focused on the HYVs, about 80% of the seeds farmers use are ones they have saved themselves (LH 2013c). Farmers interviewed regularly spoke of the need to have better access to seeds in general, a better variety of seeds and better storage capacity. The local knowledge and skill developed through the SoL program provides an opportunity to initiate PPB with farmers to address the key issues in seed supply.

Storage

Although the HYVs of maize have capacity to increase national production by 47% without farmers changing their farming practices (Lopes and Nesbitt 2012:15) they are typically more sensitive to droughts and pests and require better storage facilities (Lundahl and Sjoholm 2012:16). Post harvest lost during storage can be as high as 30% (RDTL 2011:124) – and, along with drought sensitivity, can undermine the yield advantages the HYVs have over traditional varieties.

While the NGOs appreciate the availability of the HYVs and the yields that can be realised, they also encourage farmers to plant their own seeds for diversity and to better ensure they get a crop even if there is a problem (e.g., with the season or pests during production or after harvest). SoL also encourage farmers to do this. Outcomes are more likely to be improved by also increasing farmers' capacity for seed selection, saving and storage.

6.2.2.2 Extension

Extension activities that promote SAI are considered an essential investment (Pretty et al. 2011; Tilman et al. 2002). In Timor-Leste the promotion of land management associated with SAI is primarily being carried out by NGOs.

MAF has established approximately 400 suco extension positions but officers are described as inexperienced and under-resourced (Young 2013:15) and operating at the village (rather than suco) level. This is supported by the farmers interviewed, 70% of whom report that they never or rarely see an extension officer or that they gain no assistance from the extension officer. For the 13% who see a MAF officer regularly, it is because the officer lives in the local village. Key informants describe the extension service as having low technical and managerial capacity; and lacking high level coordination with harmonised structures at central and district levels.

Extension officers do not have a package to deliver to the farming community that integrates agriculture and natural resource management. There is no overall vision, for example, of highly diversified farms with climate considerate practices and with animals feeding from local resources that do not result in bare soils on sloping land. Since extension officers are working in isolation long distances from other officers, it is difficult to monitor their knowledge or skills in order to facilitate their work (Tessema 2015).[46]

Oxfam's experience illustrates how the current approach to extension might be described as a barrier to the adoption of SAI - yet reveals an area in which change could provide opportunities for up-scaling.

Oxfam is promoting SRI in Timor-Leste where Integrated Crop Management (ICM) has previously been introduced, focusing strongly on high inputs including chemical fertilizer and pesticides.[47] The ICM model provides a simple set of instructions to extension officers, as "message carriers" to the farmers along with the provision of free inputs. Alternatively, SRI requires both extension officers and farmers to focus on crop management rather than off-farm inputs. It requires understanding the importance of farm practices to, for example, soil health and root development; and it requires extension officers and farmers to be more pro-active participants in the process of gaining new knowledge and skills. Extension officers, farmers and decision-makers are not used to operating in this way (Deichert et al. 2009). Other key informants agree this is typical in Timor-Leste.

This experience is relevant to what Styger et al. (2011) discovered in examining the adoption and diffusion of SRI in Mali. They identified three dramatic outcomes that would be likely to

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[46] For example, farmers interviewed in 2014 (prior to official field work for this research) reported that MAF extension officers visited their farms to promote the use of tractors – when all of their land is steeply sloped. These farmers expressed frustration that MAF was not offering anything to improve their farms.

[47] Both ICM and SRI are promoted in the Strategic Plan (RDTL 2011:124) despite the fact that the systems, as practiced in Timor-Leste, are in contradiction to one another. This typifies the ambiguity regarding the direction of agricultural development.

impact on future agricultural innovation and change: i) that the process introduced a paradigm shift in agriculture from emphasising plant breeding and external inputs to better utilization of local resources and better skills; ii) it impacted on farmers' and technicians' thinking about the need to be more pro-active in the process of learning and adopting new practices – as compared to relying on existing assumptions and/or other people; and iii) it demonstrated the powerful force of innovation by farmers.

There are opportunities for such a paradigm shift in Timor-Leste. Both FAO[48] and WV spoke about the enthusiastic change in farmers who are beginning to understand the science of sustainable practices. NGOs and other groups regularly invite MAF to participate in training and field days in order to promote more sustainable practices. World Vision liaises with MAF's crop protection department to tap their expertise in the identification and knowledge of crop pests. WV is working to develop safer, locally produced pesticides[49], and liaising with MAF as work in this area progresses.

The lack of clear direction from national level impacts on farmers' capacity to increase productivity and manage natural resources, and on the capacity of extension officers to assist them in the process. However, there is potential, with MAF and the NGOs working together to build the interactive knowledge networks between farmers and scientists that is recognised as an effective instrument in developing SAI (IAASTD 2009). The view of the NGOs is that Government must take the lead and NGOs can help carry this out with technical support where needed.

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[48] FAO, who are promoting Conservation Agriculture (CA) in Timor-Leste, say that in the first 18 months they've worked with 900 farmers and many are happy with the changes. Farmers see they initially have to work a bit more to get the same or more yield - but that the approach also protects the natural resources and is practiced without the use of herbicides. The most 'pro-active' farmers have come into the FAO Dili office to look at soil micro-organisms under the micro-scope and are making the connection between their farm practices and the productive potential of their land.

[49] World Vision is testing *Titonia diversifolia* (which grows prolifically as a weed in Timor-Leste) for the purpose of fertilisation, pest control and weed suppression. WV is also testing *Pyrethrum*. They have distributed seeds to grow in higher altitude areas and are hoping the *Pyrethrum* can provide Timor-Leste farmers with safer, low-cost, locally-available pest control; as well as potentially being an export product.

6.2.3 Facilitating market entry by smallholders

The need to fund infrastructure development is widely recognised as a key factor in promoting smallholder SAI (World Bank 2007; McIntrye et al. 2009).

The lack of infrastructure in Timor-Leste (including small-scale irrigation[50]; storage[51] and processing facilities; and feeder roads and transport systems) is a barrier to smallholder market entry.

The majority of farmers interviewed commented that the distance they had to travel to market was a disincentive to growing more crops. Many walk for between 30 minutes and two hours, carrying their produce for sale. This is consistent with findings of Lundahl and Sjoholm (2012).[52] If farmers use local transport the cost is $1.50 which accounts for both themselves and the produce bags they are carrying. If they don't sell their produce, the return trip is also $1.50. Even the single trip is a significant cost; for many, representing more than an average day's income.

While work is progressing on infrastructure[53], a prominent CSO reports that the bulk of expenditure is aimed at mega projects that are not associated with significant employment opportunities, some of which the viability remains unclear, and carry risks of negative social and environmental impacts (La'o Hamutuk 2014a; also see RDTL 2014c:35).

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[50]The need for small-scale irrigation was discussed in section 6.1.3.2. Farmers lack capacity to store water on farm and are concerned about future water stress and lack of an agreed water management plan.

[51] Inadequate or non-existent storage of post-harvest food crops has been a long term problem in Timor-Leste (FAO 2003:6). There are indications of improved food security after the government provided 5000 silos to farmers' groups between 2007 and 2011. The distribution of 43,000 grain storage drums was to be funded by IFAD commencing in 2012; although 600,000 drums are required to store all harvested maize in Timor-Leste (Lopes and Nesbitt 2012 cited by Da Costa 2013:91); and warehouse storage remains a problem.

[52] In Timor-Leste the feeder roads are seasonally affected secondary and tertiary networks. This limits the capacity of villagers to access markets and increases their costs. Lundahl and Sjoholm report that "Markets exist in towns and larger villages but a major problem is lack of transportation to markets…80 percent of all farmers have to walk on foot to the nearest market which is located two hours away on average" (2012:18).

[53] The government is addressing infrastructure needs through its Program for Decentralised Development (PDD), a partnership of the private sector, government and community to construct over 800 small to medium infrastructure projects including roads, bridges, health care and sanitation facilities, schools, water supplies and flood control (RDTL 2011:110).

In combination with the required infrastructure, policies and the lack of local development support also influence smallholder market participation (IAASTD 2009; Studwell 2013). In Timor-Leste, most key informants commented on the importation of rice, and its sale at a subsidised price, as a disincentive to local production; a view that is supported by a study commissioned by MAF (Young 2013). The study found that it is more expensive to grow rice than import rice[54] because investment is skewed towards the 'hardware' of irrigation infrastructure with river diversion, while the 'software' (such as farmer extension) is not developed and not likely to be available in the foreseeable future - primarily because MAF and the Ministry for Commerce, Industry and Environment (MCIE) have insufficient funds to fulfil their mandates. The overall impact of current policy is that farmers in Timor-Leste are not earning the $53 million spent on importing rice (Young 2013).

Where programs have targeted smallholder participation they have gone straight to the market end of development – without first ensuring adequate support and preparation. One example is the 'people plant - government buys' program which was launched with an established table of prices the government would pay for a range of commodities. Farmers initially responded to the program with enthusiasm and increased their plantings but not everyone was paid or able to sell their produce because finance regulation had not been operationalised; accessing districts was difficult due to the roads; a lack of warehouse storage; and insufficient supply (Key informant, MAF).

The Strategic Plan indicates that the private sector will be relied upon for development services, particularly in the agribusiness area (RDTL 2011:113). It is unclear whether this will provide the needed coordination and support.

An example of the coordination, technical support and adaptive responses that are needed in working from the bottom up to bring smallholders into the economy is provided by BRAC, a large NGO in Bangladesh. BRAC's contribution to the poultry industry involved providing microfinance, training farmers, developing a feed industry from local ingredients, resolving

[54] Rice imports cost $53 million/year ($660/Mt for 80,000 Mt). Under the current agriculture environment emphasising larger scale irrigation infrastructure, growing the equivalent amount of rice in Timor-Leste would cost $160 million/year ($2,000/Mt). If more efficient and cheaper irrigation systems were used (e.g., using tube wells and small pumps) then the economic cost of growing rice would be less than the cost of importing, approximately $440/Mt (Young 2013).

technical problems, value-adding and developing the market chain (Smillie 2009).[55] This level of support is unlikely to be available through the private sector alone.

In Timor-Leste, bottom-up change is being provided on a small scale by Mercy Corps who are developing a low cost and simple cold-store box for the purpose of distributing fish for sale (Figure 6.4).

Figure 6.4 Mercy Corps' simple, scalable and sustainable 'cold chain' transport system (van Duijn 2014).

Due to the unavailability in many areas of coolers and ice, the selling capacity of fish traders is limited. By developing simple cold-chain transport systems it is expected that fish farmers and traders will be able to market more fish and serve a broader area. Mercy Corps is working with 17 local blacksmiths across the country to design, test and produce storage systems with a Styrofoam box (available locally) inside a customized metal box that can attach to a motorcycle (Mercy Corps et al. 2013:20-21).

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[55] BRAC's poultry program started in the 1970s. It established three feed mills producing 40,000 tons of poultry feed in 2006; six hatcheries that in 2007 produced 12.8 million day-old chicks; a trucking network to service 350 local dealers supplying day-old-chicks and feed; the development of more productive varieties of maize as a component of the feed; a seed processing plant; and tissue-culture and disease diagnosis laboratories. BRAC's poultry program involves more than 1.9 million women (Smillie 2009; Sajjad 2011).

Mercy Corps is also working to develop the value-chain for inland aquaculture and facilitating training in business and financial literacy. The process will involve a training-the-trainer approach so that knowledge is retained locally. The Consortium emphasises that "the programme will do this through an approach that relies less on provisioning inputs and more on providing knowledge that can be transferred, and facilitating linkages that can be maintained" (Mercy Corps et al. 2013:25).

6.2.4 Land ownership

Egalitarian land reform increases smallholder security and results in maximum returns to labour (Studwell 2013). Security of land rights is important for farmers wishing to make longer-term investment in their property.

Land access in Timor-Leste is determined by a traditional system of land tenure, with modern notions of ownership rights emerging slowly. There are several different, partly conflicting, law systems governing land ownership: i) land claims based on traditional rights and not by any written laws; ii) Portuguese titles, the bulk of which were lost in 1999; and iii) claims based on Indonesian titles. In addition, there are claims made by people based on occupation resulting from voluntary or forced displacement by the Indonesian administration. Many landholdings have several claimants (Lundahl and Sjoholm 2012:19). Despite the complexity, all farmers interviewed seemed secure with respect to land ownership.

One key informant stated that farmers do seem secure but that there is no basis for this security; and a decision by the state to use an area of land may well come as a complete surprise. In a survey[56] cited by Cryan and Martin, "72% of people ranked 'state land grab' as their biggest land problems in 2011" (2013:8). A Real Estate Fund is to be used to compensate individuals for land that the Government expropriates from private or community use (LH 2013d:1).

The government is making title services available for farmers "willing to pay". They consider this important for farmers who are "progressive"; but maintain that it will "not pose problems for subsistence farmers" (RDTL 2011:112). How the land laws and claims will be negotiated and whether there will be a net benefit in providing land security for farmers is not yet clear. It is not clear who decides which farmers are 'progressive' or wish to remain subsistence; or whether there is a system in place for those who are 'willing to pay' but do not necessarily have the required cash flow to do this.

[56] Matadalan ba Rai: Community Voices on Land, Haburas Foundation 2012.

6.3 Conclusion

Generally speaking, the barriers to adoption and scaling-up smallholder SAI in Timor-Leste are consistent with international experience. They include the lack of infrastructure and adequate support for research and extension related to sustainable agriculture and targeted at smallholders; and a lack of policies and local development support to enhance smallholder competitiveness. There are also questions about the security of land rights. The inconsistencies of the Strategic Plan make it difficult to assess how the government views the role of smallholders and multifunctional agriculture in the country's development. Potentially, this is the over-riding barrier to SAI adoption in Timor-Leste. In drawing this research to a conclusion, the next chapter briefly reviews the findings of the research before identifying opportunities to improve food security in Timor-Leste by supporting and scaling-up smallholder adoption of SAI.

Chapter 7: Conclusion

Over the last four to five decades the international response to the global problem of food security has focused on increased food production with the use of high-cost inputs of the GR. While production increased dramatically, millions of people in developing countries did not get their share of the bounty. As the decades progressed, the agricultural practices had an alarming and negative impact on the environment and the world's continuing capacity to produce food.

Growth in crop yields is now stagnating and cannot keep pace with a rising world population as well as new competition for diminishing resources from changing diets and demands for biofuels (Appendix B). Agricultural systems are needed that will increase food production without expanding further into natural ecosystems, and both adapt to and mitigate against climate change. The framework in which the new agriculture occurs needs to be more inclusive than past approaches in order to provide livelihoods and greater access to food for the millions of people who remain poor and malnourished.

The circumstances have drawn attention to SAI which proponents maintain is best suited to repair the mistakes of the past and meet the demands of the future. Because SAI is less prescriptive than the GR and must be adapted to local biophysical and socio-economic conditions, its adoption and diffusion needs to be customised at the country level.

This research examined the capacity of SAI to serve the multiple functions of agriculture; and its application to Timor-Leste. This concluding chapter briefly reviews the findings in response to the three key questions posed:

1. What is the capacity of SAI to serve the multiple functions of livelihood, nutrition and natural resource management – in general and in Timor-Leste?
2. To what extent does smallholder sustainable agriculture provide a framework for rural development in Timor-Leste?
3. What are the obstacles and opportunities associated with scaling-up SAI in Timor-Leste?

7.1 The capacity of SAI

The literature (presented primarily in Chapter 2 but also in other chapters) shows that the practices and science underpinning SAI have been honed in projects across the world demonstrating its capacity to significantly increase production while protecting natural resources and building greater biophysical capacity – producing both food and sustainability; despite having been largely neglected by research and development.

Importantly, it is being effectively adopted and adapted by small-scale farmers collaborating with scientists, NGOs and others. This directly targets the livelihoods of those who are poor and most food insecure while at the same time greasing the gears of economic growth with more wide spread distribution of income and building human capacity with improved access to nutrition, knowledge and skills.

Chapter 5 described the farmers in Timor-Leste, who are adopting SAI, with respect to their ownership of land, livestock and farming equipment; a rough estimate of their income and household food security; and how their circumstances compare to farmers nationally. It described the practices adopted and both the farmers' expectations of SAI and early indications that expectations would be achieved. Farmers' expectations related to the multifunctional roles of agriculture (the farmers' livelihoods, household food security, and natural resource management). The case studies and evidence from other SAI projects in Timor-Leste show that farmers are beginning to embrace these methods. The early experiences of farmers who have adopted SAI practices are encouraging with respect to its potential to improve livelihoods, household nutrition and natural resource management. According to the comparisons presented, there is no apparent reason why, with suitable support, SAI could not be successfully adopted by farmers throughout Timor-Leste.

7.2 SAI and rural development in Timor-Leste

Chapter 6 presents the applicability of SAI to Timor-Leste in terms of the critical role of agriculture in development; the value, in particular, of targeting smallholder development; and the need for improved natural resource management. The extent to which smallholder adoption of SAI plays a role in the development framework is assessed by exploring key instruments recognised as effective for this purpose. The chapter concludes that the promotion of smallholder SAI is not well-embedded in national policies, infrastructure funding decisions, education, research or extension – all of which contribute to increased and stable production, community capacity building and market readiness. Consequently, attempts to facilitate smallholder market entry have been problematic.

The UN Special Rapporteur on the Right to Food argues that "Major shifts in food security policies are being discussed in most countries. Yet the best options are simply not being promoted sufficiently" (De Schutter 2011:2). This was determined to be the case in Timor-Leste. The problem seems to be that in the rush to catch up with the 'modern' world, Timor-Leste turns a blind-eye to the failings of the GR. Increasingly over the last couple decades scientists around the world, along with policy-makers, international institutions, CSOs and others have recognised the shortcomings of the GR and have actively pursued more sustainable farming systems – and building development around sustainability and inclusive participation. With its emphasis on HYVs and off-farm inputs, it is as though Timor-Leste wishes to leap frog into the future, without realising that it is jumping into the past.

7.3 Obstacles and Opportunities

Given the significant development challenges in Timor-Leste it's not surprising that numerous barriers exist to the adoption of SAI. Many of these relate to practical infrastructure. However, a key obstacle to adoption is the lack of clear direction from the national level to support and guide research, extension, funding commitments and food security decisions in ways that support and promote smallholder adoption of SAI and market entry.

Timor-Leste is just beginning to develop its education, research, and extension capacity. The country still benefits from donor support and oil income. Now is the time to build the required infrastructure and a sustainable system from the bottom up. The more the state does this, the less farmers rely on the state as both the initiator and provider in the future.

Opportunities to scale-up SAI in Timor-Leste are largely associated with the existing working relationships between MAF and NGOs and other organisations promoting SAI systems to build a coalition to:

- align agricultural education at secondary and tertiary level to smallholder livelihoods, nutrition and natural resource management;
- prioritise infrastructure and research needs and advance budget allocations for this purpose;
- more deliberately integrate the training and resourcing of extension officers into projects promoting sustainable agriculture;

- review how the objective to produce cash crops can best be integrated with agro-diversity on existing small farms and with a goal of diversity at the landscape scale;
- review policies and change those that act as a disincentive to increased and sustainable domestic production; and
- use the existing farmer groups and proposed cooperatives (RDTL 2011:110-111) as a means of farmer-to-farmer training as well as a network to provide a flow of services and market information (Rossett et al. 2011; IAASTD 2009).

Scaling up will be most effective if innovation is institutionalised (Styger et al. 2011) nationally and supported by donors. That means embedding SAI in national policies and across relevant ministries and departments; and creating stronger links between international research and development institutions and NGOs on the ground - building interactive knowledge networks between farmers and scientists (IAASTD 2009). Many farmers interviewed talked about insect pests and the need for improved crop protection. World Vision has started working on this and their work could provide an excellent point at which to formally initiate network collaborations.

Finally, key informants expressed different views regarding the uncertainty about the direction of agricultural development. One is that various stakeholders are thinking along different lines and the result is incoherent policy direction. Another is that there is genuine commitment to sustainability but the commitment suffers from the lack of high level coordination and expertise about how to operationalise this. Consequently, decisions are exposed to the dynamics of development politics – new ideas enter and what people focus on changes. This situation requires having people in place that can cope with those dynamics and consistently be part of the conversation. These views are not mutually exclusive. In either case, the ambiguity that exists creates a risk of policy running off the tracks. This emphasises the need to more precisely articulate the direction of agricultural development and to establish clearly defined goals – with relevant indicator baselines and targets, and a transparent process by which indicators are measured and evaluated.[57]

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[57]Relevant indicators include measures that demonstrate: achievement against the Millennium Development Goals; the protection of agricultural land for farming; the adoption of sustainable practices; farmer access to information and training; access to low-cost inputs; the value of food outputs in terms of nutrition, employment and distribution of income; soil health; water use efficiency; empowerment of women in decision making; better storage; improved processing, transport and markets that facilitate participation of poor households; and the level of competition in the food industry (production, processing and marketing).

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Appendix A

Questions for farmers

Prior to the interview I will walk around the farm to observe crops and livestock; soil quality; land condition and production methods.

1. Interviewee/Farmer: Name ___________________________; gender M/F; interviewee code________; date_________2015;
   location of household/farm (district; suco; aldea)________________________________.

2. Livelihood assets:

Asset	Size/number	Owned	Cultivated/ raised	For home (H) or sale (S)	Remarks
Paddy land					
Upland crops					
Home garden					
Agroforestry plot					
Forest plot					
FMNR plot					
Number of ponds					
Total pond area					
Fish					
Cattle/buffalo					
Pigs					
Chicken/ducks					
Sheep/goat					
Horse					

3. Where land is not owned: how secure are you that you will farm here as long as you like? Does lack of ownership affect your land management decisions?

4. Vegetable production:

Crops grown	Did you grow one or more of these vegetables during 2013 or 2014?	Number of species	Total production	Main reasons for growing this crop	Remarks
Pumpkin, carrots, squash, chayote, and other yellow coloured vegetables	Yes/no			1. Easy to grow 2. For household consumption 3. To sell 4. Others, specify	
Sweet potato, Potato, yam, taro, and other root /tubers	Yes/no			1. Easy to grow 2. For household consumption 3. To sell 4. Others, specify	
Leafy vegetables: spinach, Kale, lettuce, mustard and other leafy vegetables	Yes/no			1. Easy to grow 2. For household consumption 3. To sell 4. Others, specify	
Fruit vegetables: Brinjal, chilli, okra, gourds	Yes/no			1. Easy to grow 2. For household consumption 3. To sell 4. Others, specify	
Legumes (beans)	Yes/no			1. Easy to grow 2. For household consumption 3. To sell 4. Others, specify	
Vitamin A rich fruit (papaya, tomato, other coloured fruit)	Yes/no			1. Easy to grow 2. For household consumption 3. To sell 4. Others, specify	
FRUIT: mango, orange, coconut, banana, avocado, pineapple	Yes/no			1. Easy to grow 2. For household consumption 3. To sell 4. Others, specify	

5. Are you satisfied with your vegetable production; if not, why?

6. Do you have market challenges/risks? If so, what are the challenges?

7. Where is the market and how do you get there?

8. How often do you sell (e.g. in the last 12 months: weekly; monthly; seasonally; irregular)?

9. Do you think crop diversification would help in minimizing market risks? If so, how?

10. Is there good potential for a local market (i.e., would there be buyers or bartering available locally)?

11. Farm practices:

Method	Used (U) or Not Used (NU)	Are you familiar with this practice?	How satisfactory is the result as compared with modern(chemical) methods	Where/when did you learn about this practice? (e.g., traditional, neighbours, NGO, government)
Tillage/ with what?		Yes/ No		
Burning land				
Clearing land				
Compost				
Mulch				
Green manure crop or cover crop				
Intercropping				
Terracing				
FMNR				
Agroforestry				
Chemical Fertilisers				
N-fixing plants (e.g., pigeon pea; beans)				
Other				

12. What are your expectations about adopting this change(s) (FMNR/aquaculture/BRACCE) on your farm? Prompts: How do you think this change will affect you/your family (e.g., production level; consumption; increased income; other advantages/disadvantages)? How will it affect your farm land or water?

13. Are you satisfied at this point that your expectations will be met?
Is there any evidence?

14. What has been most difficult about this change (FMNR/aquaculture/BRACCE)?

15. Is it difficult to get information about farming?

16. When you have questions about farming, who can you ask?

17. What kind of questions do you have?

18. How often do you speak with/see government extension officers? Could you see them more often if you had questions?

19. Are there learning opportunities (e.g. to meet with other farmers, workshops, get written info from government or other groups)?

20. Where do you get water for your crops – is there enough?

21. Can you grow crops in the dry season? What crops? For household consumption only? How is water managed?

22. What crop pests do you have and how do you control these?

23. Where do you get your seeds? Are there any problems with seeds?

24. Household food security: At any time during the last 12 months did any of the following situations apply to your household?

	1/2/3	No. of months
Householders ate meals without vegetables		
All three main food categories (cereal, beans, vegetables) were not available		
Not everybody got enough food to satisfy their appetite		
Householders consumed only one meal a day		
Householders could only afford to consume food provided by the government or others		

1 = yes; 2 = no; 3 = don't know

25. What strategies did you use to cope at these times?

26. What are the most frequent climate risks you experience?

27. How often you experience major climate events?

28. Would you like to make other comments that you think are important to farming and food security?

29. How do you think the project (aquaculture/ FMNR/ BRACCE) can be improved?

30. Would you like to ask me any questions?

Appendix B Related issues

This appendix includes comments on three topics: changing diets, biofuel production and the use of genetically modified organisms. At this time, the topics are not directly related to food security in Timor-Leste. The topics have been included for comment here in recognition of their importance to food security in general; their potential to affect food security in Timor-Leste in the future; and in the case of GMOs – because it is a point of debate amongst proponents of SAI.

Changing diets

Increasing meat consumption will put greater pressure on agricultural resources. Meat consumption as a share of dietary energy more than doubled between 1992 and 2014, from 7% to 16.9% (FAO 2014:56). Per capita consumption of meat is predicted to increase further, from 32 kg today to 52 kg by the middle of the century; increasing the global cattle population by around 70% and the global goat and sheep population by nearly 60% by 2050 (GOS 2011:14, 53).

Rising demand for meat and animal products has changed livestock production from a system of extensive grazing to intensive stall-fed animals. This has increased the demand for feed grains and oil seeds, representing 28% of grain consumption in developing countries in 2005. More recently, livestock are being fed other feedstuffs such as oilseed meals and cassava (World Bank 2007:59-60).

Increasing consumption, particularly of grain-fed meat, has large implications for land use and natural resource management. Current livestock production (through grazing and growing feedcrops) accounts for 70% of global agricultural land; including 70% of previously forested land in the Amazon now occupied by pastures, with feedcrops covering a large part of the remainder (FAO 2006b:xxi).

Climate change will be impacted by further land use change associated with increased livestock and livestock feed production. This will result from carbon release from soils; fertiliser manufacturing and use; on-farm fuel use; methane from enteric fermentation and animal manure; and emissions from processing, refrigeration and transport. There will be increased demand on water resources for feed production; and water pollution resulting from erosion-based sediment loads and runoff of nutrients, pesticides, antibiotics and heavy metals. Loss of biodiversity occurs from deforestation, desertification, pollution, and overfishing for fishmeal production. The IUCN identifies livestock as one of the threats to 1,699 endangered species (FAO 2006b; Stienfeld et al. 2006).

This system is unsustainable and inefficient with respect to macro-nutrients. Livestock consume protein that could be used for human nutrition, converting 77 million tonnes of human-edible protein into 58 million tonnes protein in livestock products (FAO 2006b270). The conversion efficiency of intensive production varies with livestock type; 2-3 kg of feed are required to produce one kg of poultry meat and 10 kg of feed are required to produce one kg of beef (World Bank 2007:59-60). This calls for greater awareness and education about the impact of high meat consumption, grain-fed meat in particular, and the design of agricultural and environmental policies (such as eliminating subsidies and implementing liability and payment of externalities) in the context of social, environmental and health objectives (FAO 2006b).

Competition between food and fuel

The production of biofuels can compete with food production with respect to use of resources, pushing up the price of foods and increasing environmental pressures.

Competition between food and fuel is real: "The grain required to fill the tank of a sport utility vehicle with ethanol (240 kilograms of maize for 100 litres of ethanol) could feed one person for a year" (World Bank 2007:71).

Increased biofuel demand contributed 30% of the weighted average increase of global grain prices between 2000 and 2007 (Funk and Brown 2009:37). This demand pushed up the price of maize by 23% in 2006 and 60% in the following two years; and contributed to a decline in grain stocks to a low level. Similar price increases have occurred for vegetable oils (World Bank 2007:70).

For a variety of reasons (such as changes to land use and the impacts of different feedstock production methods) the environmental benefits of biofuels cannot be assumed. For example, to grow one ton of maize in the U.S. requires 160 litres of oil; under traditional farming methods in Mexico one ton of maize can be grown using only 4.8 litres of oil (WB 2007:66).

Genetically Modified Organisms (GMOs)

Amongst organisations and individuals promoting SAI, there is general agreement on the importance of genetic diversity, but less agreement regarding the use of genetically modified organisms (GMOs). Some reject the technology (Altieri 2012; Rossett et al. 2011); some voice significant concerns (IAASTD 2009) and others have a more positivist view (Royal Society 2009; Godfray et al. 2010). In general, skepticism and concern is based on: i) the impacts of genetic engineering on the environment and the potential for scaling-up SAI; ii) that GMOs do not serve the interests of the majority of poor farming families and detracts attention and resources away from more sustainable technologies; iii) the concentration of agro-industry ownership and reduced agro-diversity associated with the development of GMOs; and iv) the narrow scope of GMO research and development independent of the context in which this R&D occurs.

I. GMOs have been promoted on the basis of reduced pesticide use. However:

   1. More sustainable methods also reduce pesticide use (Pretty 2011).
   2. The approach fails to recognise the complex ecological systems on which agriculture depends and reduces farmers' capacity to rely on these mechanisms. For example, Bacillus thuringiensis (Bt) is a naturally occurring bacterial disease of insects. Its use is acceptable by organic farming standards because Bt is considered safe to non-target species and to people. This safety to non-target species is critical to maintaining a biological balance between pest and predators within the crop field. In order to avoid pest resistance to Bt, organic (and other sustainable) farmers only use acceptable sprays such as Bt when pest populations are at a level that is not otherwise being controlled. The genetic engineering of Bt into plants means that Bt is permanently present, which increases the likelihood of pests developing resistance – thereby eliminating the effectiveness of the GMO crop as well eliminating a key pest management strategy of sustainable farmers.
   3. In the USA, corn rootworm has developed resistance to the Bt toxin; and in China Bt crops are now requiring increased pesticide use against secondary pests (Jacobsen et al. 2013).

II. GMOs have been promoted on the basis of being required to feed the hungry. However:

   1. Soybeans account for more than 50% of GM crops globally and are mostly used as high-protein animal feed (Jacobsen et al 2013).

2. Poor farmers can't afford the high-cost of inputs required for GM crops (Jacobsen et al. 2013).
3. The yield of some GMO crops is highly variable – 10-33% gains in some places and yield decline in others (IAASTD 2009:8).
4. Many other factors that contribute to food insecurity including the lack of education and extension services; post-harvest losses; lack of credit, infrastructure, and distribution channels that support increased participation of poor farmers in the marketplace; and equitable access to foods produced – all of which are discussed elsewhere in this thesis.

III. The development and marketing of GMOs has concentrated ownership[58] of agricultural seeds globally; shifted public and private research toward the most profitable proprietary crops and away from improving varieties that farmers can easily replant (Howard 2009); and reduced crop and livestock diversity, increasing genetic vulnerability and erosion (FAO 2007; Gepts 2006 cited by Jacobsen et al. 2013).

IV. The narrow-scope of vision within which GMOs are developed and utilized limits realizing their potential value. For example the development of drought-resistant crops could make a positive contribution to food security. While such development will become increasing important, the value of drought-tolerant plants is limited unless broader climate-smart agricultural techniques are adopted and actions to mitigate climate change are also taken. Another example is the focus on increased production without putting commensurate efforts into maintaining the capital on which future production relies.

These are serious and major concerns that require recognition, deliberation and resolution if genetic engineering is to make a substantial contribution to global food security.

[58] Monsanto, DuPont and Syngenta now control nearly 70% of global seed sales. Monsanto has control of 95% of the Indian cotton seed market and this near monopoly has resulted in greatly increased prices (Jacobsen et al. 2013).