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Food security in Timor-Leste through crop production

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Food security in Timor-Leste through crop production

Proceedings of TimorAg2016, an international conference held in Dili, Timor-Leste, 13–15 April 2016

Editors: Harry Nesbitt, William Erskine, Cesar Jose da Cruz and Anne Moorhead

Seeds of Life
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Foreword

Timor-Leste, with a population of approximately 1.2 million, is a largely agrarian society and agriculture accounts for one-third of the gross domestic product (GDP). Approximately 64% of the population is engaged in agricultural activities, with a majority relying exclusively on low-input/output subsistence farming. Broad-based economic growth, inclusive of agriculture, is essential to ensure sustainable reductions to the current high rates of poverty, particularly in rural areas.

Food security is an ongoing country-wide problem. Although the amount of food consumed for each individual has steadily increased since 1996, it remains well below that in neighbouring countries and malnutrition remains unacceptably high. Many families experience a ‘hungry season’ of up to 4 months per year. One of the biggest challenges faced by the nation is to increase production of the main staple crops. While a range of factors contribute to the low productivity (for example use of low yielding varieties, poor agronomy, and high postharvest losses), making available improved varieties with higher yield potentials is where the most immediate and significant gains can be obtained.

In collaboration with the Australian Department of Foreign Affairs and Trade (DFAT) and the Timor-Leste Ministry of Agriculture and Fisheries (MAF), the Australian Centre for International Agricultural Research (ACIAR) has played a key role in the Seeds of Life project, which is working towards a sustainable national seed system for Timor-Leste. The project has improved food security through the introduction, testing and initial distribution to farmers of improved germplasm of the major food crops: sweetpotato, maize, cassava, peanut and irrigated rice.

The *TimorAg2016 Conference* was held in Timor-Leste in April 2016 and was a celebration of the conclusion of the 16-year Seeds of Life project. The theme for the conference was ‘food security in Timor-Leste through crop production’ and discussions were held around factors affecting crop production in Timor-Leste and the success technical advances have made to improving productivity. Two days of oral papers and posters were delivered across a number of sessions focusing on food security, elements for agricultural development in Timor-Leste, crops and their environments, reaching a food surplus, and communication of agricultural innovations. On day three, delegates went into the field to see the results in action, including a visit to a commercial seed producer in Liquica, and to the Loes Research Station. There were 260 registered participants and the conference was conducted in both English and Tetum, with simultaneous translation.

These proceedings describe the progress made by the Seeds of Life project and other partners and stakeholders in improving crop production, nutrition and access to food for households in Timor-Leste over the past 16 years. They provide a valuable contribution to the discussion on further advancing the country’s agriculture sector to achieve food security in Timor-Leste.

Nick Austin
Chief Executive Officer
ACIAR

Contents

Welcome address

It is my great pleasure to welcome you to TimorAg2016. Given the challenges associated with food security in our country and the work being done to improve the national food security situation, I believe that this is an opportune time for us to review and reflect on what has been done in this area and hopefully identify potential actions that we can apply to improve the well-being of the people of this country.

As Minister of Agriculture, I know that strengthening Timor-Leste's agricultural sector and increasing agricultural production is fundamental in this task. I am also fully aware that this alone will not be sufficient to achieve our goals. Increased production only addresses problems on the supply side. To really make a difference we also need to pay attention to such things as the distribution and accessibility of the food produced and ensuring that our population has the purchasing capacity to buy needed food in the market. This is why I am gratified to note that this conference provides a forum for learning about a range of critical interventions that impact access to and utilisation of healthy and sufficient food in national households. Over the next few days we will learn about efforts not only in agricultural production but on such diverse topics as nutrition, agricultural marketing, extension, savings and loans initiatives, storage, agricultural rituals, communication and capacity building for agriculture. All papers will demonstrate and communicate the experience that the Ministry of Agriculture and Fisheries has gained working in collaboration with a range of development partners to ensure that no one in Timor-Leste needs to go hungry.

I hope you will use this opportunity to actively share and exchange ideas that will result in the creation of more ideas, information and knowledge for the achievement of food security in Timor-Leste. I am aware that this is a huge task but every small step will lead to bigger things.

I wish you all an enjoyable and stimulating conference.

Estanislau Aleixo da Silva
Minister of State, Coordinating Minister of Economic Affairs and
Minister of Agriculture and Fisheries

Section 1: Food security

Global food security and Timor-Leste

Tony Fischer[1]

Abstract

This paper highlights the role of crop yield increase in meeting growing global food demand over the last 55 years, as reflected in generally declining real grain and food prices, declining price being a major, but not the only driver of improved world food security. While recent yield increase continues along a remarkably linear path, relative yield growth has slowed to around 1% p.a., except for maize at 1.5% p.a. With the four major staple crops, dissecting the sources of this growth reveals a significant contribution from yield gap closing (from improved agronomy and varieties on farm) as well as a somewhat larger contribution for potential yield increase (mainly from breeding as seen in optimally managed field trials). Both drivers of farm yield increase are expected to continue at around current rates, which should be enough to keep the real world prices of grain and other foodstuffs, to 2025 or beyond, close to or below current (2015) moderate values. This is good news for food importers like Timor-Leste, but does not reduce the urgency of comprehensive programs to lift productivity of its majority poor subsistence farmers, and of smart policies so the farmers already producing food surpluses for the local market are not prejudiced.

Introduction

Food security has always concerned government, non-government and international organisations concerned with health, agriculture and sustainable development, but global food security returned to the popular media as a hot issue with the grain and food price spikes of 2008. Even developing country politicians had to take notice as their people took to the streets in response to these price hikes.

Food security is usually defined in terms of the availability, access or affordability, stability of supply, safety and nutritive value of food per person (FAO et al. 2015). Approximately 19% of people in the world were food insecure in 1990, while in 2015 this was down to 11%, being 790 million people out of the world's population of 7.35 billion then; this absolute number of hungry is declining only gradually (about 1% per year) (Figure 1).

The connection between food price and food security is not perfect, and the Food and Agriculture Organization of the UN (FAO) records many other statistics relevant to food security (FAO et al. 2015), but I take the view that in an increasingly urbanised world, whose food has to be purchased on interconnected national and world markets, lower real food prices are a major factor favouring food security. Besides, the prices of food and its components are reasonably reliably monitored and are available. Price generally reflects the balance between supply and demand—in fact, price determines this balance, although levels of stocks, and market policies and speculation, can play a role, as they clearly did in 2008.

World prices will therefore be a central theme in my presentation on food security. As they buy rice and other foodstuffs on the world market, it is obviously an issue for the consumers and Government of Timor-Leste. For the small but growing number of commercial farmers in Timor-Leste, selling rice and other food products on the local market at import parity prices, it is also a big issue, but with opposite consequences.

I will focus firstly on past changes in crop production and prices, before attempting to look at global prospects, and finally turning briefly to the situation with Timor-Leste.

[1] CSIRO Agriculture, Canberra, Australia

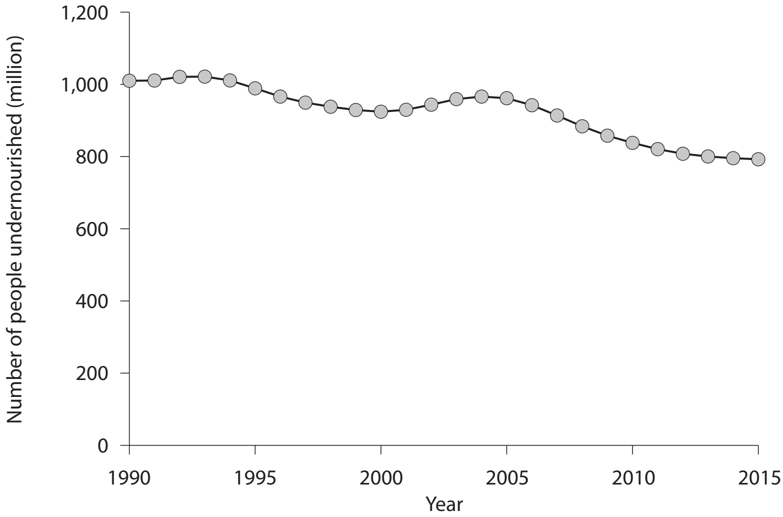

Figure 1. Absolute number of undernourished people in the world over time. Source: FAO et al. (2015).

So what has been happening to world food prices?

World population and hence food demand has increased more than two-fold since 1960. However food production, exemplified by cereal production in Figure 2, has increased at an even greater rate, such that production per capita rose notably. Another consequence was the fact that real prices, notwithstanding periods of peak prices, have generally declined, bottoming around 2000 (Figure 2).

The decline in prices, shown for cereals in Figure 2, was similar for all food prices as seen with the FAO global price index in Figure 3 (see also Table 2), which also shows the changes in real prices of rice on the export market, a product of special interest to Timor-Leste.

The dominant role of crop yield increase

The reasons for production growth since around 1960 are shown in Figure 4. Clearly crop yield has increased at a much faster rate than crop area. And in fact half of the crop area growth has come from intensification of cropping (more crops per year), largely as a result of expansion in irrigation. In other words, the increase in world arable area (land being cropped regularly with annual crops) from 1960 was only about 10%. Thus the yield (and cropping intensity) increases from the adoption of new technology have fed the growing world population with reduced levels of undernutrition, while minimising the net rate of increase in arable area, with all the environmental benefits that this brings. Of course arable land which has been lost (for example through urbanisation or severe degradation) has had to be replaced as well.

While the remarkably linear yield increase in Figure 4 refers to cereals, almost all crops have shown equally strong linear global yield increases over the 55-year period. Generally, yield has more than tripled in this period, but expressing the linear increase relative to today's yield tells a story of diminishing relative progress, with the rate of increase currently around 1.1% p.a. for cereals in Figure 4. These global numbers hide huge diversity within and between crops, and to better understand factors driving yield increase, the global numbers must be disaggregated.

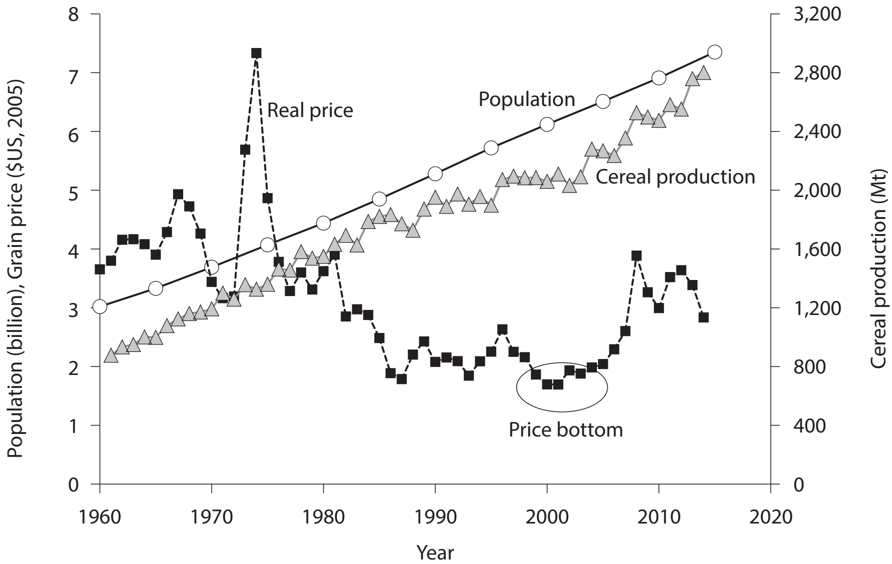

Figure 2. World population, cereal production (all cereals) and average real price of wheat, rice and maize. Source: FAOSTAT (2016); prices from World Bank (2016).

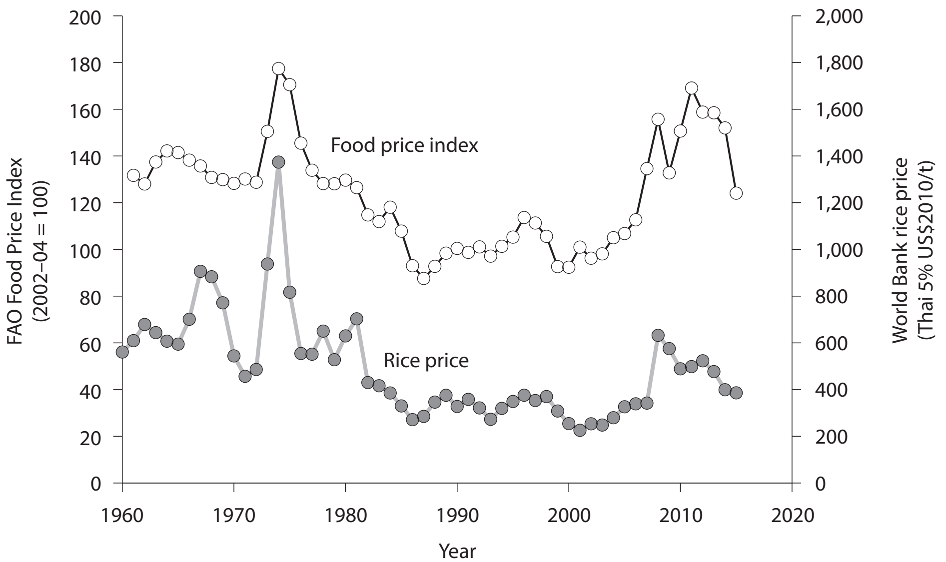

Figure 3. FAO Food Price Index and real price of rice. Source: FAOSTAT (2016) and World Bank (2016), respectively.

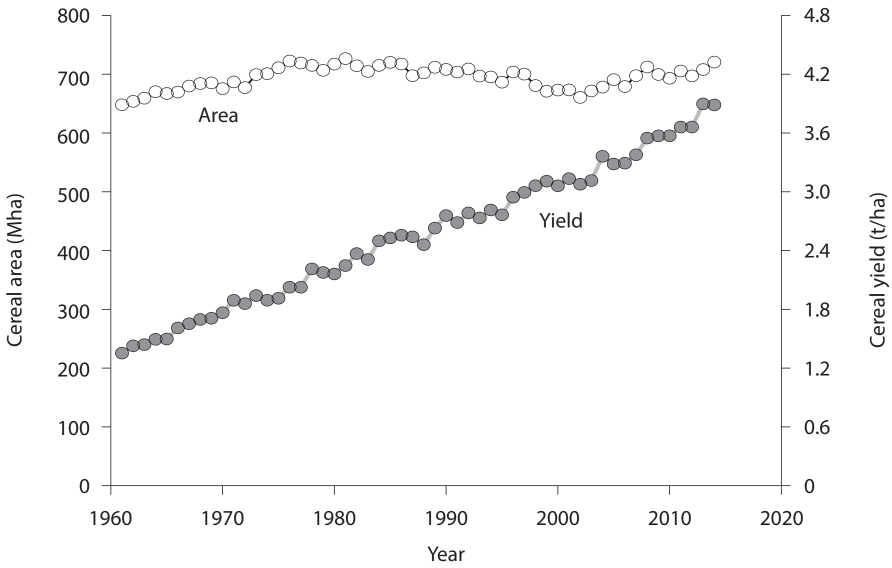

Figure 4. Change in world cereal area (all cereals) and average yield. Source: FAOSTAT (2016).

Disaggregating and dissecting crop yield increase

Factors driving crop yield increase are explored extensively in my recent book, jointly authored with Derek Byerlee and Greg Edmeades (Fischer et al. 2014). For greatest relevance to the future, we have focused on changes in the last 20 to 30 years. We defined potential yield (and water-limited potential yield, PY and PY_w, respectively) as the crop yield that could be reached in optimally managed experiments with the best varieties under full control of biotic and nutrient stresses, but otherwise experiencing the environment of the region of interest (e.g. soil type, weather including temperature and radiation, and rainfall if water-limited). PY increases through breeding, sometimes aided by positive interaction with improved management (e.g. the PY × nitrogen interaction seen in many crops). Actual yield in any region (defined by us as farm yield, FY) is the yield plotted in Figure 4 above, and inevitably lies below PY: the difference between PY and FY is defined as the yield gap, which we express as a percentage of FY. Economic considerations and farmers' risk aversion indicate that the minimum attainable yield gap in situations without price distortions is about 30% of FY. We examined many situations with respect to PY and FY progress across 20 or so key commodities.

The recent history of rice FY in the Cerrado Region of Brazil, a region growing about 1.5 Mha of rainfed upland rice and showing unusually rapid FY progress (2.2% p.a., Figure 5), illustrates our approach. Breeding trials throughout the region across years permitted Breseghello et al. (2011) to estimate PY_w progress at 25 kg/ha/year, or 0.7% of the current PY_w of 3.6 t/ha. These data are also shown in Figure 5, as is the yield gap which in 2010 was 80% of FY, having closed dramatically since 1990 when it was almost 250%. Note that the progress in PY_w as shown was due to breeding, since the main effect of change in agronomy was removed in the statistical analysis of the breeding trials. However the progress in FY and the closing of the yield gap was due to both the adoption of these improved varieties and of improved crop agronomy, such as more fertiliser, etc. The rate of yield gap closing in 2010 (1.5% p.a.) was one of the most rapid seen in Fischer et al. (2014) and reflects the level of sophistication of most of the region's farmers, something very different to Timor-Leste.

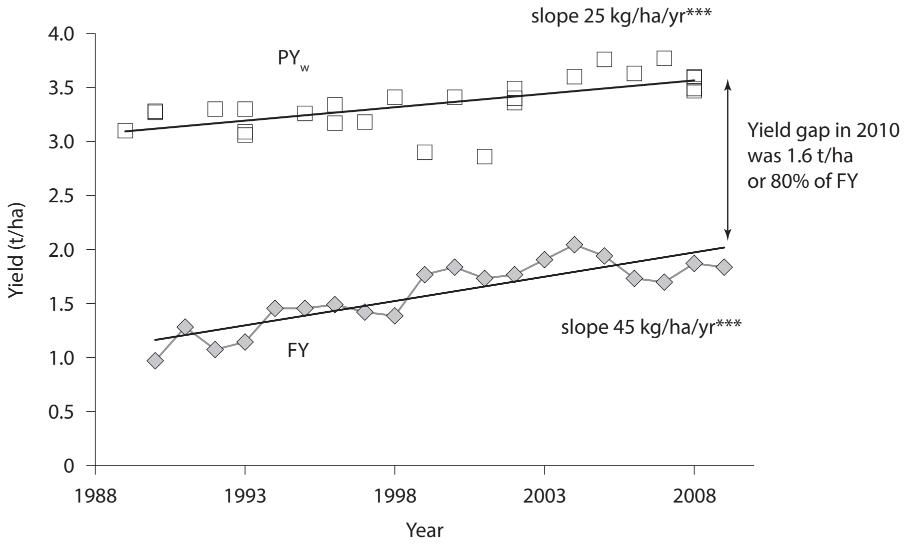

Figure 5. Progress in farm yield (FY) and in water-limited potential yield (PY_w) for rainfed upland rice in the Brazilian Cerrado region. Note PY_w plotted against year of entry of the particular variety in regional trials. *** = significant at 1%. Source: modified from Fischer et al. (2014) and original data from Bereseghello et al. (2011).

Table 1 summarises the data collated in Fischer et al. (2014) for the four most important crops in the world today. Yield gaps vary greatly between crops and especially regions, being generally greater in developing countries and in rainfed systems. Gaps are especially high in Sub-Saharan Africa, ranging from 200% to 400% for maize and 100% to 145% for cowpea and cassava. Also evident is that gaps close only slowly, and more FY progress in the three cereals came from PY increase than from gap closing. Also in these crops, some yield gaps, in developed countries mainly, are getting close to their likely lower limits (30%). On the other hand, PY progress did not vary so much between the four majors in Table 1, but not shown are higher values of progress for cassava (1.5% p.a.) and canola (1.4% p.a.). In no case was there evidence for slowdown in the linear PY progress across the last 20–30 years.

Farm yield progress described in Table 1 was due to the adoption of new technology and has helped drive lower prices while at the same time increasing return per hectare for farmers. As economists will point out, a better description of this progress is that total factor productivity in cropping increased over time, meaning that more crop products were produced per unit of aggregated inputs, whether they be land, labour, capital or variable physical inputs like fuel and fertiliser. While farmers may have been getting more profit per hectare as a result of the changes illustrated above, what has really permitted them to survive (and only some of them) has been the substitution of capital for labour, essentially mechanisation and increase in scale or operational size. Whether cause or effect, this has happened everywhere as development has occurred and national per capita income has risen, although income per capita in the rural sector always lags, especially in developing countries where the necessary consolidation of the operational scale of farms is proceeding only slowly.

Other commonly discussed aspects of the yield progress just described are the implications for natural resource use. There is not space here to deal with this in any depth. Suffice to say that the yield increase associated with modernisation of crop production, although usually requiring more physical inputs per hectare, has almost always led to increased efficiency of use of natural resources, whether it be the quantity of water, nutrients or energy used to produce a unit of food. This positive is in addition to the land-saving effect of yield increase. These themes are developed

Table 1. World farm yield (FY) and relative rate of change, and from case studies, yield gap and potential yield and their relative rates of change in 2010 for wheat, rice, maize and soybean. Note: rates of change refer to the last 20–30 years relative to 2010; range refers to values from the various case studies included in estimating yield gap and PY or PY_w. Source: Fischer et al. (2014).

Crop (n = number of cases)	World FY 2010		Yield gap, % of FY in 2010				PY or PY_w	
	Mean (t/ha)	Annual rate of change (% p.a.)	Mean	Range	Mean rate of change (% p.a.[a])	Range in rate of change[a]	Mean rate of change (% p.a.)	Range in rate of change
Wheat (n = 12)	3.04	1.0	48	26–69	–0.23	–1.0 to 0.8	0.61	0.3–1.1
Rice (n = 12)	4.32	1.0	76	25–150	–0.39	–1.5 to 0.6	0.78	0.3–1.3
Maize (n = 8)	5.15	1.5	104	36–400	–0.61	–1.8 to 0.7	1.08	0.8–1.5
Soybean (n = 3)	2.41	1.0	31	30–33	–0.80	–1.3 to –0.2	0.50	0.4–0.7

[a] Negative change in gap means gap closing.

elsewhere under the banner of 'sustainable intensification' of cropping (Cassman et al. 2003; Fischer et al. 2014).

Global yield prospects

Continuing yield (FY) increase is obviously critical for future global food security. Depending on crop and location, this will involve further yield gap closing and potential yield (PY) increase, or both. Yield gap closing is the obvious way forward where gaps are large, as in Sub-Saharan Africa and in unfavoured parts of Asia and Latin America, while continuing PY increase is critical for most developed world cropping where PY is generally no more than 50% above FY (yield gaps < 50%).

Yield gap closing may seem the easier route, because much of the technology is on the shelf already. However two aspects need to be noted. Firstly a huge effort and investment in rural infrastructure and institutions is a prerequisite for substantial yield gap closing in many poor countries and this would include Timor-Leste: this means rural roads and communications, rural education and health, functioning markets, secure land tenure, agricultural extension, farmer organisation and agribusiness involvement, and community acceptance of law, contracts and regulations. Secondly, new technology and hence research in many areas can facilitate yield gap closing: for example, more robust pest and disease resistance in new cultivars would help close gaps partly arising because of poorly managed biotic stresses, a major cause of yield gaps. This could mean genetically modified (GM) cultivars, as we have seen in their widespread and rapid adoption by smallholder cotton growers in India, China and now West Africa, with large reductions in the yield gap (and improvements in farmer profits) due to better pest control. Because of the resources needed to foster yield gap closing, I expect that it will only slowly gather momentum in developing countries, while slowing further in developed ones: overall if yield gap closing was contributing about 0.5% p.a. to global FY progress in 2010 (Table 1), it could rise to somewhere between 0.5% and 1.0% p.a.

Since PY progress in kg/ha/year appears to be almost always linear (e.g. Figure 5, Table 1), the relative progress, which currently lies between 0.5% and 1.0% p.a. for most crops and situations, is steadily decreasing. This suggests diminishing returns, a notion much reinforced when one considers that investment in crop breeding has undoubtedly increased in real terms over the last 20 years with the growing involvement of the private sector. Many new breeding technologies have helped maintain PY progress (e.g. computing and advanced biometrics, automation, molecular markers, managed field environments). Others appear poised to impact progress, such as exploitation of wider genetic diversity, use of genomic selection, and use of heterosis in new target crops. Often mentioned in this context is also GM for increased yield per se: however to date there is only one example widely deployed in farmers' fields (DroughtGard™ maize from Monsanto in USA) as the task is proving much more difficult biologically than proponents expected. Heterosis in the form of tropical rice hybrids is however starting to have an impact on PY and FY progress in South and South-East Asia, but I do not see other new hybrid crops successes soon. Overall therefore I do not anticipate any breakthroughs on these fronts to lift the rate of PY progress, but also I do not see any sign of approach to biological limits, which will be driven either by the underlying efficiency of use of light or water in leaf photosynthesis. At best PY progress should continue at current rates of around 0.75% p.a.

PY progress as it is measured here is not impacted by climate change, but all yield levels including FY progress are thus impacted, positively in the case of CO_2 increase, at least for C_3 crops like rice, and negatively by temperature increase in most locations of the world. Up to 2050 these effects on yield are likely to counterbalance one another, and/or are likely to be small enough averaged across the globe to neglect (Fischer et al. 2014).

Global crop price prospects

While crop yield looks set to continue to increase into the future at similar rates to those measured in 2010 (1.0% to 1.5% p.a.), or at slightly improved rates, at least to 2030 and maybe further, a gradual crop area increase (around 0.2% p.a.) is also expected. Price of course is driven by balancing the growth in supply against that in demand. Demand for crop products grows with population and income per capita, as well as with growth in other uses of crops, in particular biofuel. Maize planted for ethanol in the USA boosted demand and maize prices, with knock-on effects to other crops, in the first decade of the new millennium (Figures 2 and 3), but increased plantings for biofuel in the future seem unlikely, as is also the case with sugarcane for ethanol (e.g. in Brazil) and oil-palm for biodiesel (e.g. in South-East Asia).

In 2010 the world population was growing at 1.15% p.a.; this will fall to 0.75% p.a. in 2030 and 0.50% in 2050 to give a total then of 9.4 billion (US Census Bureau 2016, estimates made on 1 July 2015). Real income per capita is another driver of the amount and composition of food demanded, and this is also increasing: values up to 2050 are 1–2% p.a. per capita in OECD nations but 2–5% p.a. in other countries. This growth is converted into growth in food demand by a multiplier, income elasticity of food demand (increase in demand relative to increase in income), which generally lies between 0 and 0.5, being higher for processed foods than staples, and higher for developing countries than developed ones. This all means demand for crop products will exceed population growth, but by how much and with what consequences for prices is a somewhat complicated issue, resolved by economists with equilibrium modelling. Major modelling efforts are summarised by Fischer et al. (2014) and point to modest real

Table 2. Real[a] world prices in 2006, 2008, 2012 and 2015 and projected to 2025 in 2010 US$ for commodities of importance for Timor-Leste. Source: World Bank (2016).

Commodity	Unit	Real price (2010 US$ per unit)				
		2006	2008	2012	2015	2025
Rice, Thai 5%	tonne	339	632	523	365	329
Maize	tonne	136	217	277	161	176
Coffee, Arabica	kg	2.80	3.00	3.82	3.34	2.81
Sugar	kg	0.36	0.27	0.44	0.28	0.30
Palm oil	tonne	532	922	929	589	642
Chicken meat	kg	1.70	1.81	1.93	2.39	1.76
Wheat US HRW	tonne	214	317	291	192	217
Crude oil, average	barrel	71.50	94.32	97.60	48.0	66.3

[a] The World Bank used inflation indices of 105.7 (2015) and 124.7 (2025) relative to 100 (2010) to link real and nominal prices.

food price increases up to 2050, relative to the price bottom around 2006. Needless to say, price increases were quite sensitive to assumptions regarding yield increase. Perhaps the best bet for the shorter term, when population growth still remains high, is the figures of the World Bank for 2025 shown in Table 2.

The projected real price of all key commodities in 2025 is no greater than in 2006, with the exception of higher prices for maize and palm oil, commodities in high demand as incomes grow, and lower prices for sugar. This is good news for global food security, but what is not clear is to what extent subdued world economic growth, as has been the case since 2008, and recovery one day, presumably, is part of the result. For example crude oil sits at close to US$30 per barrel in January 2016. This growth slowdown is something not considered in the 2050 modelled projections referred to earlier.

What about Timor-Leste and its farmers?

World price of course is not everything when it comes to food security, especially in a country like Timor-Leste. But Timor-Leste is buying food items on the world market (especially rice but also meat, wheat and sugar products, and vegetable oil). And being a small country, with local production thus very subject to weather variation, Timor-Leste will always need access to food imports to meet demand in poor years. So declining world food prices relative to the peaks of 2008 and 2010–12 are good news in this respect. But a low import parity price (world price adjusted for exchange rate and tariffs and port costs) for foods is not good news for those farmers in Timor-Leste who produce a food surplus for sale. The situation with food is therefore complicated; Figure 6 is an attempt to present the complexity in a simple form.

The total available food (excluding coffee) in milled rice equivalents is about 200,000 tonnes, or about 170 kg/capita/year, but less than half of this amount if imports are excluded. These numbers also exclude all locally produced animal products, with meat estimated to be about 32,000 t (Young 2014), or 25 kg/capita/year, an important part of the diet but small in terms of calories. These numbers suggest barely adequate total food, and needs someone to pay for the food import costs (about US$30 million annually net of coffee sales). Of course food distribution

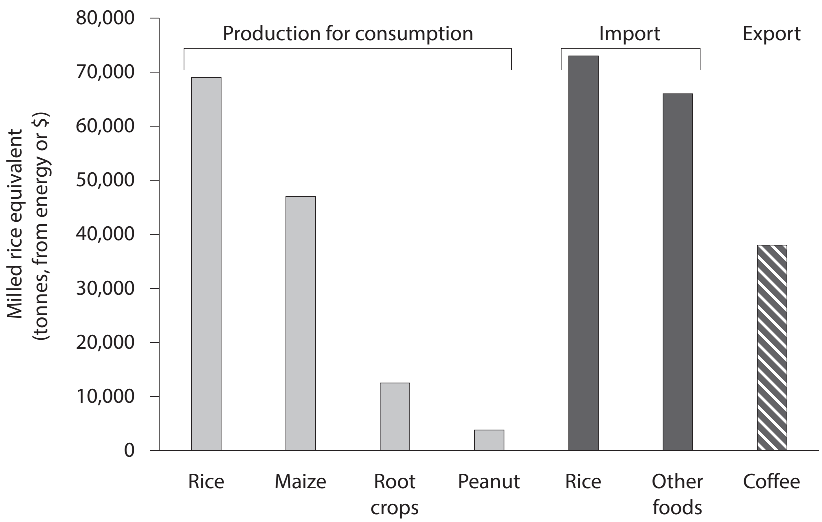

Figure 6. Annual crop production, import and export amounts for major crops in Timor-Leste for 2011–13 expressed as tonnes of milled rice equivalent (conversions done at US$400/t milled rice, or on energy basis). Source: FAOSTAT, Young (2014), and author. Note: 'other food imports' excludes alcoholic beverages and tobacco products but includes imported animal products.

and nutritional quality, as well as purchasing power, are additional considerations for food security for all, and I am sure we will be hearing more about this.

An additional vital consideration for this meeting is—where does Timor-Leste have a comparative advantage and opportunity to boost local food production? As an outsider I should not say much but I remind people that in a predominantly agricultural country like Timor-Leste, increased agricultural productivity is an engine of economic development, as it has been throughout Asia (e.g. Hazell et al. 2007). Also I think it is useful to distinguish within the 180,000 or so rural households, those farmers producing food surpluses and the majority, as I understand, who are subsistence farmers. No greater impact on the food security of poor people can be achieved than by lifting production in the subsistence farm sector to self-sufficiency, or even surplus production at least in most years. Their environment is usually not the best, due both to a poor natural resource base especially because of highly sloping lands, and to poor infrastructure and institutions. But the potential of the new varieties, combined with better management, to achieve this is clear. Thus lifting the subsistence sector through better cropping (and animal production) and better infrastructure and institutions must be pursued notwithstanding costs, because of its direct food security impact.

Where does this leave the smallholder commercial crop sector, the farmers who tend to have flatter lands, deeper soils and better access, and whose paddy rice and maize yields (FY) seem to sit around 2–3 t/ha (Young 2014)? Both trials and modelling (R. Williams personal communication; Bacon et al. 2016) suggest that the potential yield (PY) is more than double this yield, meaning a yield gap of >100%. The technology exists to markedly close the rice and maize yield gaps: it involves fertilisers, legume cover crops, simple zero-till drills and herbicides, along with microcredit, and applied agricultural research and extension. The question is what is the economic or attainable yield, that to which the best farmers would aspire under the current economics? As mentioned earlier, under 'normal' world economics this is achieved with a PY to FY yield gap of about 30%, but developing country cropping rarely shows such a narrow yield gap (Fischer et al. 2014) for a host of reasons, including sometimes an unfavourable economic environment at the farm gate (e.g. fertiliser prices several times world prices in much of Sub-Saharan Africa). It would be unwise for Timor-Leste to pursue food self-sufficiency through policies which heavily subsidise this sector, but it does make sense to remove or counterbalance some of the economic constraints or distortions, the largest of which seems to be the minimum cost of labour (measured for example as kg rice at farm gate per day), running for example at twice that in Indonesia or three times that in Vietnam. There may also be a role initially for targeted input subsidies, but they should not become a permanent feature of the system, as for example has been the case in India and China. A far better investment is more applied agricultural research and local agricultural extension, microcredit, and the infrastructure and institutions already mentioned.

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The nutrition situation in Timor-Leste

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Abstract

Since the signing of the Comoro Declaration in 2010, the Government of Timor-Leste has made a commitment across all relevant sectors to improve food and nutrition security for all its citizens. Despite significant progress being made to combat undernutrition, results from the 2013 Timor-Leste Food and Nutrition Survey indicate that undernutrition (in particular, stunting, underweight, anaemia and other micronutrient deficiencies) in women and children continues to be a major development issue, across all municipalities, in urban and rural areas and across all wealth quintiles. In addition, the prevalence of overweight and obesity is increasing in the population raising concerns of an emerging double burden on the health system. Global evidence concludes that comprehensive, coordinated cross-sectoral actions are required to address the immediate and underlying causes of malnutrition and break the intergenerational cycle. While there is strong momentum within the government for coordinated action to improve nutrition and food security, much work is still needed to improve integrated programmatic responses, including nutrition-sensitive agricultural programs, to ensure improved utilisation of year-round nutritious foods to meet the nutritional needs of all household members.

Introduction

Globally, the evidence is clear that improving nutrition outcomes of populations is crucial to improving economic development and productivity. Long-term nutritional deprivation leading to stunting has intergenerational impacts, including poor cognitive capacity (Prado and Dewey 2014), low school performance, reduced productivity, lost economic opportunities and reduced gross domestic product (Hoddinott et al. 2011).

The immediate and underlying drivers of malnutrition are multifactorial and multidimensional, requiring coordinated action across sectors to ensure sustained impact (Figure 1). Efforts to tackle malnutrition cannot be managed by one sector alone. Cross-sectoral collaboration and accountability, together with an enabling policy environment promoting coherence and convergence of interventions, are essential.

Combating malnutrition has been a national priority for the Government of Timor-Leste for over a decade, as evident from the following: the signing of the Comoro Declaration in 2010 declaring a commitment to ensure all Timorese citizens have access to quality nutritious food (GoTL 2010); development of the National Council for Food Security, Sovereignty and Nutrition (KONSSANTIL); signing up to the Global Zero Hunger Challenge in 2014; developing the cross-sectoral Zero Hunger Action Plan for a Hunger and Malnutrition Free Timor-Leste (PAN-HAM-TL); and actively supporting the adoption of the Sustainable Development Goals (SDG) including SDG2 'End hunger, achieve food security and improved nutrition, and promote sustainable agriculture' (UN 2015).

Despite recent progress Timor-Leste, with a population of just 1,167,242 (GoTL 2015), still experiences some of the highest rates of undernutrition in the world, with 50% of children less than 5 years of age suffering chronic malnutrition (stunting) and over 60% of children aged 6– 59 months suffering anaemia. Although rates of overweight and obesity remain very low in children, the prevalence of

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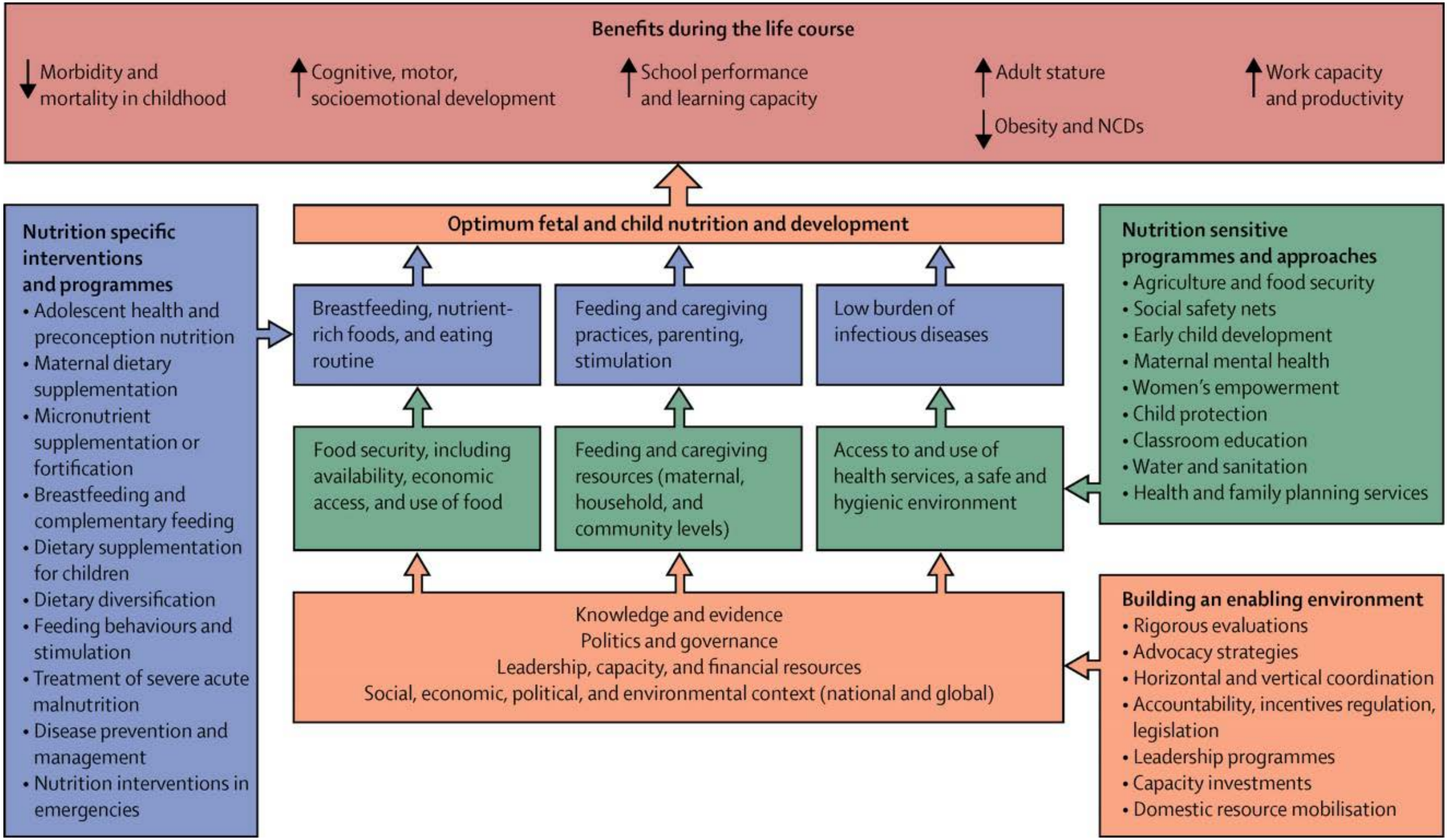

Figure 1. Framework for actions to achieve optimum foetal and child nutrition and development (from Black et al. 2013).

overweight and obesity in women is on a rapid rise, increasing almost fivefold from 3% in 2003 to 17% in 2014, taking into consideration the different age brackets across surveys (MoF 2010; MoH 2015; WHO 2014). While undernutrition still remains the major issue, these data represent early warning signs of the double burden of malnutrition where over- and undernutrition coexist within the same population, and an increased burden of non-communicable diseases (NCDs).

While chronic undernutrition (stunting) is more prevalent in rural areas, data indicate that malnutrition in all its forms is widespread across all municipalities at levels representing a public health problem (WHO 2010), across urban and rural areas and across all wealth quintiles.

Anthropometry of children under 5 years

Stunting

Stunting (height/length for age Z score < –2) is an indicator of chronic nutritional deprivation resulting in impaired skeletal growth and height. Being stunted increases the risk of delayed cognitive development and reduced intellectual capacity (Prado and Dewey 2014), affecting income-earning ability and economic productivity later in life (Hoddinott et al. 2011). A stunted child is more likely to become a stunted adult (<145 cm). Women of reproductive age with short stature are at greater risk of maternal mortality, dystocia (obstructed labour) and delivering a low birth weight or a premature baby (Black et al. 2013). This in turn contributes to the intergenerational cycle of undernutrition apparent in Timor-Leste, where the average height of women of reproductive age is 151 cm and the prevalence of short stature is 13% (MoH 2015).

The prevalence of stunting in children under 5 has decreased eight percentage points from 58% in 2009–10 to 50% in 2013 (MoH 2015), however the prevalence of stunting across every municipality still remains 'very high' (≥40%; WHO 2010; Figure 2). Data from the Demographic and Health Survey 2009–2010 (DHS; MoF 2010) and the Timor-Leste Food and Nutrition Survey (TLFNS) in 2013 (MoH 2015) demonstrate that stunting is more common in boys, in rural areas, and in children of mothers who have a low body mass index (BMI < 18.5 kg/m^2), are in the lowest wealth quintiles and who have completed fewer years of education (MoF 2010; MoH 2015). Both surveys demonstrate that stunting is apparent in children less than 6 months of age, and the DHS reports that stunting is more common in children who were reported to be small at birth (<2,500 g) than normal birth weight babies (MoF 2010), supporting the intergenerational nature of undernutrition in Timor-Leste. Given the intergenerational and economic burden of stunting, combating this issue must remain a priority for the Government of Timor-Leste.

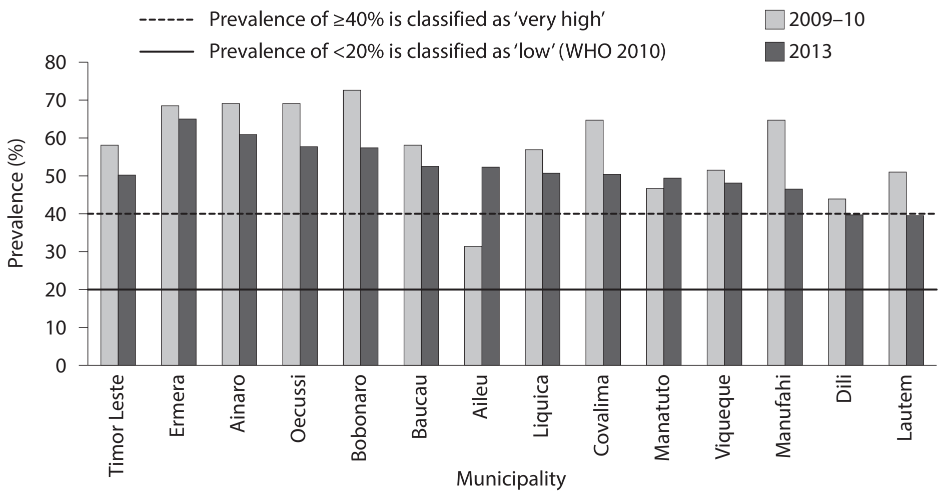

Figure 2. Prevalence (%) of stunting in children under 5 by municipality.

Wasting

Wasting (weight for height/length Z score < –2) is a sign of acute malnutrition and a consequence of infection and/or poor nutrition. It is most common in children aged 6–24 months. Severe wasting increases a child's risk of dying of infections such as pneumonia and diarrhoea by 5- to 20-fold (Black et al. 2013), and increases their susceptibility to infectious disease and the duration and severity of the infection (Black et al. 2013).

In non-emergency situations, where endemic malnutrition is common such as in Timor-Leste, moderate wasting often coexists with stunting in the same child (Bhutta et al. 2013).

With the exception of Bobonaro, Oecusse and Covalima municipalities, the prevalence of wasting in children under 5 has declined from 'critical' levels (above 15%) in 2009–10 (MoF 2010) to 'serious' (10–14%) in Liquica, Manatuto and Dili and 'poor' (5–9%) in the remaining municipalities. Lautem has the lowest prevalence (5.4%) while the highest prevalence is in Oecusse where nearly one in five children (19.8%) suffers acute malnutrition (MoH 2015; Figure 3).

Anthropometry of women of reproductive age

Underweight

As well as delayed growth and development (MoH 2015; WHO 2013), being underweight (body mass index (BMI) < 18.5 kg/m²) has several immediate and long-term health risks for women of reproductive age. These include decreased learning ability and educational attainment (Dewey and Begum 2011; Grantham-McGregor et al. 2007), increased risk of non-communicable diseases such as heart disease, hypertension and diabetes (Delisle 2002), and increased risk of pregnancy complications (Black et al. 2013) including increased risk of maternal mortality (Christian et al. 2008), obstructed labour (Black et al. 2013) and having a preterm or low birth weight infant (Black et al 2013) or one born with congenital malformations (De-Regil et al. 2010).

Similar to trends in other countries in the region, the prevalence of undernutrition in women of reproductive age is slowly decreasing in Timor-Leste, from 38% in 2003 to 25% in 2013 (MoH et al. 2004; MoH 2015). The WHO Stepwise Approach to Surveillance

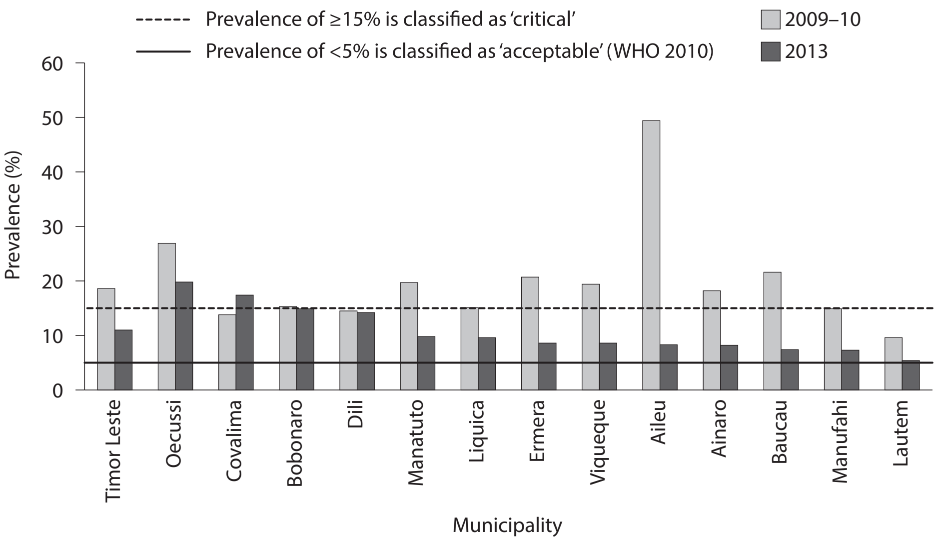

Figure 3. Prevalence (%) of wasting in children under 5 by municipality.

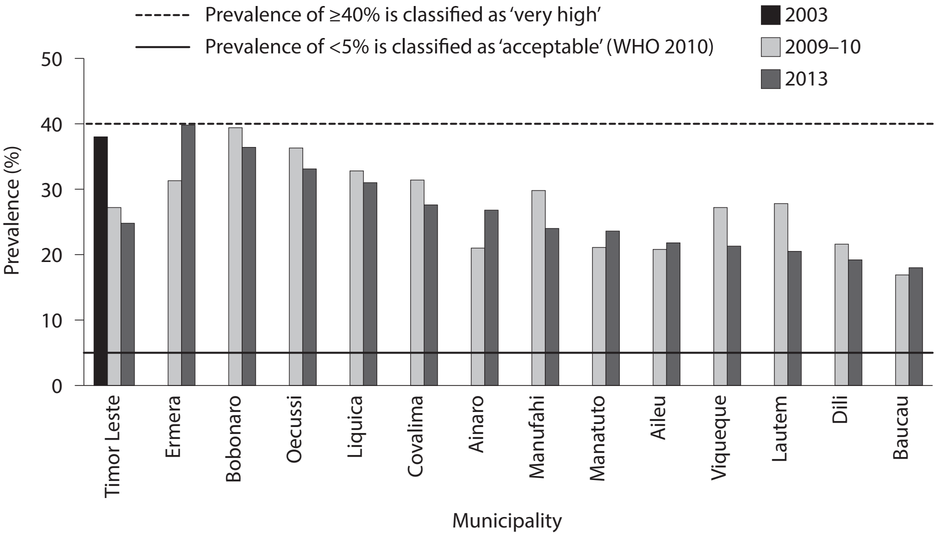

Figure 4. Prevalence (%) of women of reproductive age who are underweight (BMI < 18.5 kg/m^2) by municipality.

(STEPS) survey (WHO 2014) indicates that the prevalence of underweight in women (aged 18–69 years) is 31%. There are some municipalities where the prevalence has increased since 2009–10 (namely Ermera, Ainaro, Manatuto, Aileu and Baucau; MoF 2010; MoH 2015; Figure 4).

Overweight

On the contrary, and following a similar trend to other low–middle income countries (LMIC) in the region, the prevalence of overweight (BMI ≥ 25 kg/m^2) in women of reproductive age is increasing across all municipalities in Timor-Leste (MoH 2015). Two in every ten women in Dili are overweight and the national prevalence has increased by over fourfold from 3% measured in the DHS conducted in 2003 (MoH et al. 2004) to 17% in 2014 (WHO 2014). This is raising concerns of the double burden of malnutrition where under- and overnutrition coexist within the same population and there is a related rise in the prevalence of diet-related non-communicable diseases, now common in many other LMICs (Shrimpton and Rokx 2013; Figure 5).

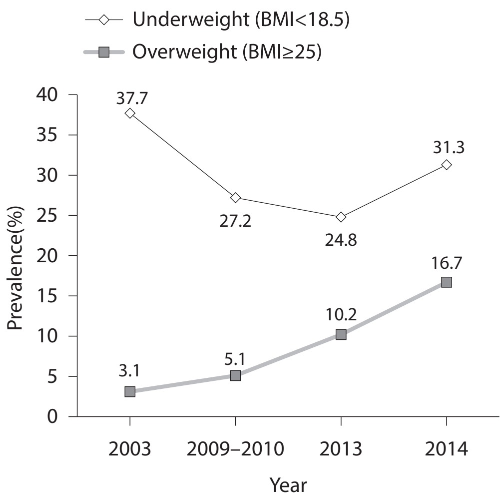

Figure 5. Changes in the prevalence (%) of underweight and overweight in women of reproductive age in Timor-Leste. (Note different age ranges in surveys (2003, 2009–10 DHS: 15–49; 2013 TLFNS: 14–60; WHO 2014: 18–69).)

Micronutrient deficiencies

Until recently, with the exception of iron deficiency anaemia, national data on the prevalence of micronutrient deficiencies were limited. The first nationally representative data on zinc, iodine and vitamin A deficiency were collected during the 2013 TLFNS.

Anaemia

Anaemia has direct consequences on learning and cognitive development (Prado and Dewey 2014), as well as adverse impacts on maternal and neonatal outcomes including increasing the risk of maternal mortality from post-partum haemorrhage (Rush 2000), low birth weight (Steer 2000) and preterm birth (Allen 2000).

Anaemia (Hb < 110 g/L adjusted for elevation) in children aged 6–59 months has increased in all municipalities except Manatuto (MoH 2015), with prevalence levels classified as 'critical' (>40%) (WHO 2010) in all municipalities (Figure 6). Anaemia is more prevalent in boys than girls, higher in children 6–23 months of age, and more prevalent in urban areas (MoH 2015).

Nationally the prevalence of anaemia (HB < 120 g/L) in women of reproductive age is 39%, an increase of 18% since 2009–10 (Figure 7). In all municipalities, again except Manatuto, the prevalence of iron deficiency anaemia in women of reproductive age has increased since 2009–10 (MoH 2015).

Vitamin A deficiency

Vitamin A deficiency is the leading cause of preventable blindness, and increases the severity and duration of illness from common infectious diseases such as diarrhoeal disease and measles. Vitamin A deficiency may also increase the risk of maternal mortality (Faisel and Pittrof 2000). While the prevalence of Vitamin A deficiency in children aged 6–59 months is 8%, classified as a 'mild' public health problem (WHO 2010), in women of reproductive age the prevalence is 13.5%, classified as a 'moderate' public health issue (WHO 2010; Figures 6 and 7).

Zinc deficiency

Zinc is essential for normal growth and development including optimal immune function. According to MoH (2015), 34% of children aged 6–59 months have clinical signs of zinc deficiency (serum zinc < 8.7 μmol/L), with children in rural areas have a higher prevalence than children living in urban areas (42% versus 18.6%; Figure 6).

Iodine deficiency

Iodine deficiency in pregnancy increases the risk of congenital malformations in infants (De-Regil et al. 2010) and has a direct effect on cognition and learning ability (Prado and Dewey 2014). While the median urinary iodine levels among women aged 14–60 years is 170 μg/L, falling within the range classified as 'optimal prevalence' (100–199 μg/L; WHO 2010), the prevalence of iodine deficiency (urinary iodine < 100 μg/L) is 26.7%, with women aged over 35 years with no education and living in rural areas more vulnerable to iodine deficiency (MoH 2015; Figure 7).

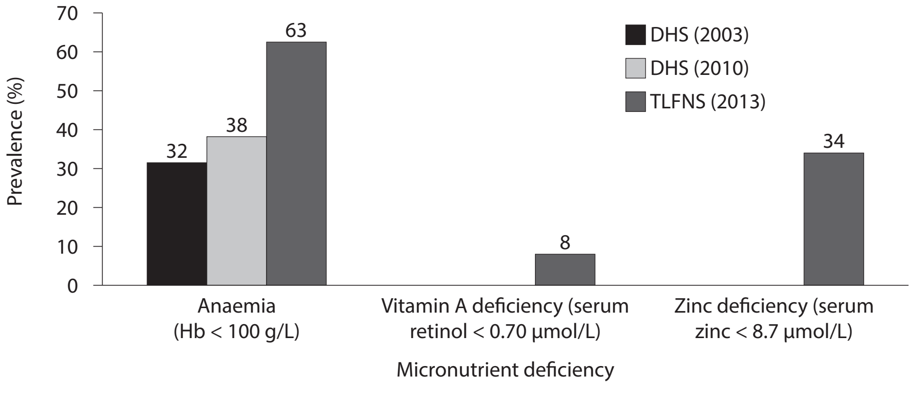

Figure 6. Prevalence (%) of micronutrient deficiencies in children aged 6–59 months in Timor-Leste.

Caring practices

Breastfeeding practices

The World Health Organization (WHO) recommends initiation of breastfeeding within 1 hour of birth, exclusive breastfeeding until 6 months, and continued breastfeeding until 2 years or more (WHO 2002). The protection, promotion and support of breastfeeding is one of the package of top ten nutrition interventions calculated (when scaled up) to reduce child mortality by nearly 15% (i.e. 1 million lives saved worldwide; Bhutta et al. 2013).

Early initiation of breastfeeding

Breastfeeding a newborn within 24 hours of birth is associated with a 44–45% reduction in the relative risk of all-cause and infection-related neonatal mortality among live births, and the earlier the initiation the lower the risk. Breastfeeding within the first hour of birth is estimated to prevent 22% of all neonatal deaths (Edmond et al. 2006). Timor-Leste has one of the highest rates of early initiation of breastfeeding (within the first hour of birth) in the region (UNICEF 2015) and since 2003 rates have increased from 47% to 93% in 2013 (MoH 2015; MoF 2010; Figure 8).

Exclusive breastfeeding

Breastfeeding exclusively is all an infant requires for the first 6 months, before complementary foods are introduced at 6 months. Among other benefits, including protection against obesity and some NCDs later in life, exclusive breastfeeding to 6 months reduces the incidence of and mortality associated with infectious disease (Horta and Victora 2013).

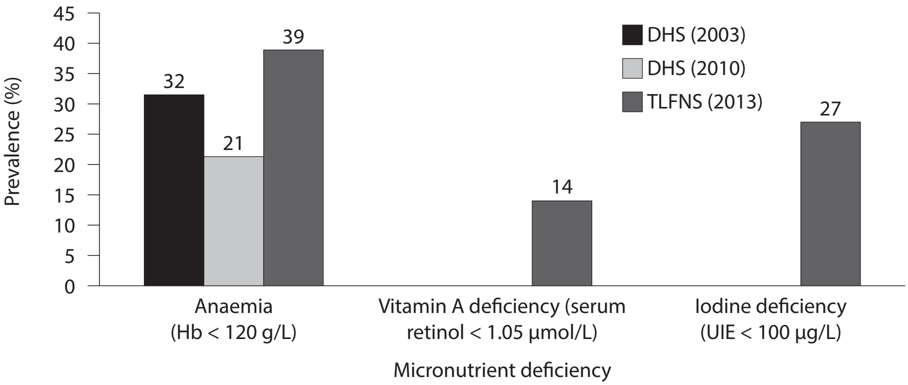

Figure 7. Prevalence (%) of micronutrient deficiencies in women of reproductive age in Timor-Leste.

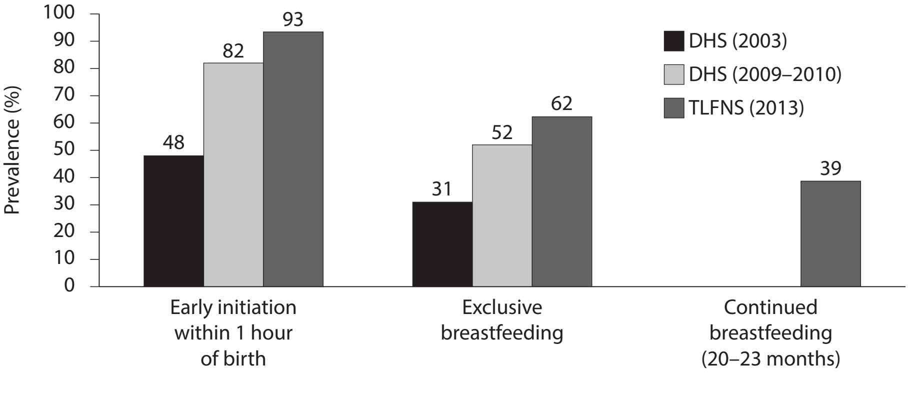

Figure 8. Percentage of women following optimal breastfeeding practices in Timor-Leste.

In 2013, 62% of children under 6 months were exclusively breastfed in Timor-Leste, indicating an improvement of 10% since 2009–10 and similar rates to other countries in the region (UNICEF 2015). However, by the age of 5 months the prevalence of exclusive breastfeeding is only 37.6%, indicating that complementary foods are still being introduced too early for many children (MoH 2015).

Continued breastfeeding

In addition to the timely introduction of complementary foods at 6 months of age, WHO recommends continued breastfeeding to at least 2 years of age. One-third of a child's energy requirements may be derived from breastmilk from 12 months of age and breastmilk continues to provide protection against infections such as diarrhoea and pneumonia. Recent evidence from Brazil also suggests that children who are breastfed for longer have improved IQ capacity (Victora et al. 2015). While nearly three-quarters (73.9%) of all children aged 12–15 months are still breastfed, the percentage drops significantly by age 20–23 months when only 38.7% are still being breastfed. Compared with other countries in the region this is low (UNICEF 2015).

Complementary feeding practices

Complementary feeding refers to the timely introduction of safe, nutritious foods in addition to breastmilk from age 6 months to 23 months and beyond. Appropriate complementary feeding practices protect against stunting. Data from 11 countries used to create a dietary diversity score based on seven food groups showed that improved dietary diversity was positively associated with reduced prevalence of stunting in nine of the 11 countries (Airmond and Ruel 2004). Similarly a study of 14 DHS datasets from low–middle income countries showed an association between improved dietary diversity and reduced risk of both stunting and being underweight, whereas improved meal frequency alone was only associated with a lower risk of low weight for age (Marriott et al. 2012).

Results from the TLFNS (2013) indicate that 37.2% of children aged 0–23 months are stunted, and by 26–59 months, when the damage of chronic undernutrition is difficult to reverse, 63.5% of children are stunted (MoH 2015). The period of exclusive breastfeeding and then establishment of complementary feeding (0–24 months) is the 'window of opportunity' to improve infant and young child feeding practices to prevent delayed linear growth and the long-term and irreversible effects of stunting. The TLFNS indicates that grains and roots and tubers make up the bulk of the diet, with 99% of children receiving these frequently. A total of 79% of children aged 6–23 months met the minimum meal frequency, whereas only 27.5% met the minimum dietary diversity. Overall, only 17.6% of children aged 6–23 months in Timor-Leste met the requirements of a minimum acceptable diet (MoH 2015; Figure 9). Only 14.9% of children from rural areas met the criteria compared with 24.8% in urban areas. This is an area requiring substantial improvements and an important entry point for nutrition-sensitive agriculture programs.

Nutrition knowledge, practices and attitudes

Data on household nutrition behaviours, attitudes and practices are limited to several small studies and

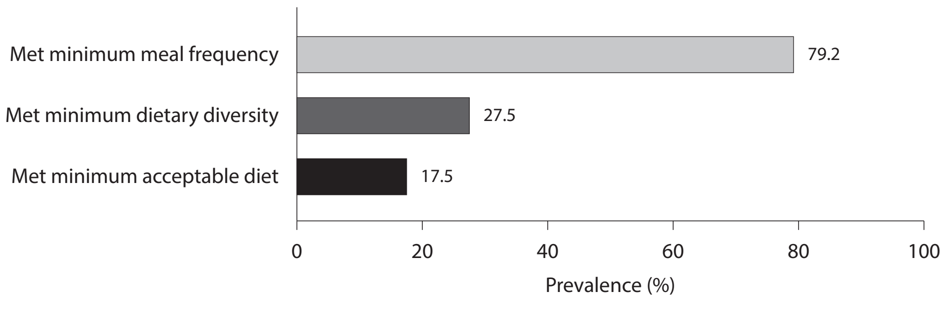

Figure 9. Percentage of children aged 6–23 months who met the requirements of a minimum acceptable diet (frequency and diversity; MOH 2015).

program evaluations. In 2013, Care International conducted a study on food habits in three villages in two municipalities (Liquica and Ermera). The study was conducted to understand the social factors (including traditional and cultural practices, behaviours and beliefs) that affect nutritional status. Key results included the perception that a full meal is a large quantity of rice and the finding that rice has a much higher status than other staple foods such as maize; the consumption of meat is reserved for traditional ceremonies; the scientific value of foods is poorly understood; and food choices are determined by food taboos and convenience (Castro 2013).

Similarly, the results of the 2007 Timor-Leste Asistensia Integradu Saude (TAIS) community consultation on child health (TAIS 2007) revealed that the most common complementary food is watery plain white rice porridge (*sosara*) because it is 'easy for children to eat' and that non-scientific beliefs influence infant and young child feeding practices, for example beliefs that dark green leafy vegetables cause diarrhoea in children, breastfeeding should cease during illness, and nutritious foods are more expensive and difficult to prepare. A survey conducted in 2014 on poverty and agricultural households in Timor-Leste found that for poorer families (in the bottom and fifth income deciles), increased income does not improve household utilisation of food, and when more cash is available in higher income households more money is spent on a greater range of foods other than staple foods (Inder et al. 2014). Further supporting these findings, the COMPAC-TL baseline study across six municipalities found that higher incomes do not guarantee food security or improved dietary diversity (Hivos and Mercy Corps 2014). The study also found that during periods of food shortages, the most common coping mechanisms were reducing meal size, consuming less preferred foods and reducing the number of meals.

Discussion

Improving food and nutrition security is a global priority requiring multifaceted approaches based on nutrition-sensitive landscapes including but not limited to nutrition-sensitive agricultural programs.

Malnutrition impacts on the health and physical and cognitive development of children with long-term effects on health, education and earning capacity of adults. In Timor-Leste, improving nutrition is key to improving economic development and productivity. If not addressed, nutritional deprivation leading to chronic undernutrition will continue to intergenerational impacts, including poor cognitive capacity (Prado and Dewey 2014), low school performance, reduced productivity and lost economic opportunities leading to reduced GDP (Hoddinott et al. 2011).

Despite increases in agricultural production and progress in other nutrition-sensitive sectors (e.g. water sanitation and health) in Timor-Leste, undernutrition still remains a significant issue with the prevalence of stunting classified as 'very high' and the prevalence of anaemia in children under 5 classified as 'severe' (WHO 2010) in all municipalities.

While the evidence for agricultural interventions improving nutritional status of children is limited, this cannot be attributed to the inefficacy of the interventions but rather the lack of power and/or the design of the studies to detect any impacts (Massett et al. 2011). In Timor-Leste, well-designed targeted agricultural programs designed to boost production and increase incomes can improve nutrition outcomes through several pathways (Ruel and Alderman 2013): increasing year-round access to a greater range of foods; providing a source of income to improve purchasing power; and enhancing the social status and empowerment of women, which in turn can improve women's access to and control over resources and assets and give them greater decision-making power over intra-household allocation of food and access to other nutrition-promoting resources and behaviours such as secondary schooling for girls and health care.

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Improving food security through agricultural development in Timor-Leste: experiences under 13 years of democratic government

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Abstract

Improving food security in a nation that is emerging from conflict is difficult, particularly when the new government is working in a vacuum of previous administrative experience. Such were the constraints on the first democratically elected government of Timor-Leste when it was established in 2002. Government ministries were formed to address these issues, with the Ministry of Agriculture, Forestry and Fisheries (MAFF) assigned the task of promoting the cultivation and marketing of food crops, livestock and fish to address the supply side of food security. As in all post-conflict situations, there needed to be a multi-dimensional focus on improving farmers' access to seed, livestock, fishing and forestry stock and inputs; the development of a system allowing these to be either multiplied, manufactured or imported; and for production to be marketed. And above all else, national agricultural production needed to increase in a sustainable manner. This paper describes the post-independence establishment of the formal agriculture sector in Timor-Leste and discusses the varied investments the new government made to raise production and improve productivity over the first 13 years of its existence. These investments and studies have provided options for further development in the agriculture sector.

Introduction

The Democratic Government of Timor-Leste was formed in May 2002 and began efforts to bring economic stability to the country. Its main concern was to ensure food security for the new nation.

The total population of Timor-Leste was estimated to be 1,283,592 in January 2015, and is growing at a rate of approximately 2% per annum (http://countrymeters.info/en/Timor-Leste). Most of the population lived in rural areas prior to independence. In 1999, 76% of the population was rurally based and 81% was involved in agriculture-related labour (Table 1). After independence, urban drift steadily reduced the size of the farming community, but more than 70% of the population was still rurally based in 2014.

Food security is an ongoing country-wide problem. Although the amount of food consumed for each individual has steadily increased since 1996, it remains well below that in neighbouring countries (Figure 1) and malnutrition remains unacceptably high at 38.1% in 2013 (SEAMEO 2013). Animal and fish protein provides approximately 27% of the daily requirements of the population.

At independence, it was of upmost importance for the new government to provide an environment in which the majority of the population were able to prosper. This paper describes some of the policies and programs implemented by or encouraged by the government to help the agriculture sector improve the 'supply side' of food security (as defined by the Food and Agriculture Organization of the UN (FAO) 2008). On the basis of these experiences, the potential for future agricultural development to improve food security in Timor-Leste is discussed.

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Timor-Leste and its agricultural capacity

The nation of Timor-Leste is composed of the east half of the island of Timor and the enclave of Oecusse in the west (Figure 2). Approximately 275 km long and less than 100 km wide at its widest point, its total area is approximately 1,500 km^2. A spinal mountain range divides the north and south, and with 44% of the slopes at 40% or more, the amount of arable land is limited (Barnett et al. 2007). Arable land area is estimated to be 160,000 ha (11% of total area; Table 2). The mountainous terrain also influences the climate, with rainfall increasing from north to south.

Table 1. Rural population and labour force in Timor-Leste (data from FAOSTAT: http://faostat3.fao.org/home/E).

	1999	2004	2009	2014
Rural population (as % of total population)	76.1	74.2	72.5	70.6
Labour force in agriculture (as % of total labour force)	81.3	80.7	79.9	78.8
Females working in agriculture (as % of labour force)	44.3	44.5	45.0	45.2

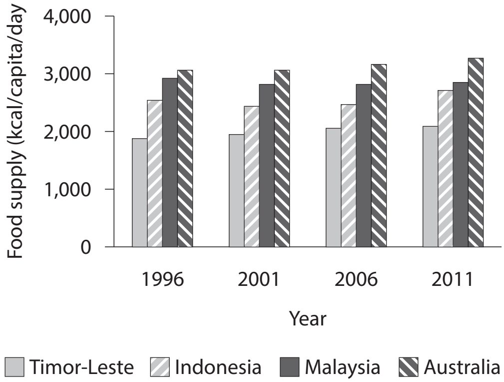

Figure 1. Food supply in Timor-Leste compared with neighbouring countries (data from FAOSTAT: http://faostat3.fao.org/home/E).

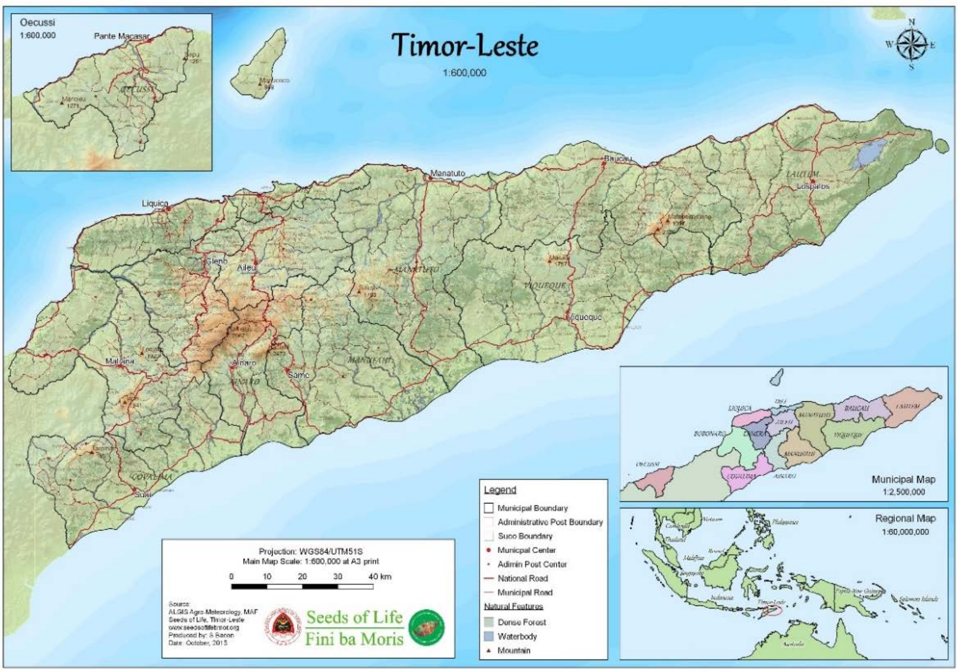

Figure 2. Map of Timor-Leste including enclave of Oecusse.

The farming community exists on subsistence agriculture with only a small proportion of production sold on the open market. Low agricultural productivity is a result of variable rainfall (and small areas of irrigation), poor soils (and low use of inorganic fertilisers), low (but increasing) use of higher yielding varieties, high labour costs (and associated shortage of labour at critical periods), little cash to purchase inputs, low knowledge of new agricultural practices at the farm level (but improving each year), and a risk-averse farming community who are primarily subsistence farmers. The small population size, small farm size and undeveloped marketing infrastructure also reduce the potential for marketing surplus production.

As a result of all these factors, agriculture in Timor-Leste lags behind its neighbours. Yields of the major food crops, rice and maize, are well below those of Indonesia and Malaysia for example (Figure 3). Coffee production, Timor-Leste's only major agricultural export, has been steady over the last 20 years (Table 3). Timber production is small and declining as a result of diminishing forest cover and increasing government deforestation control (Tables 2 and 4). The number of large animals in the country increased after independence but has levelled off recently, although chicken numbers have increased significantly (Figure 4). Marine fish production remains at subsistence level, providing 95% of total national fish production at 3,000 t/year. Aquaculture is in its infancy with 5% of production. Approximately 30 t/year of seaweed is also cultivated and exported.

Table 2. Area of land and crops in Timor-Leste from 1997 to 2012 (data from http://www.indexmundi.com/facts/timor-leste/arable-land).

	Area (millions of ha)			
	1997	2002	2007	2012
Total area	1.49	1.49	1.49	1.49
Arable land	0.13	0.14	0.16	0.16
Permanent crops	0.07	0.07	0.07	0.07
Forest cover	0.89	0.83	0.78	0.72

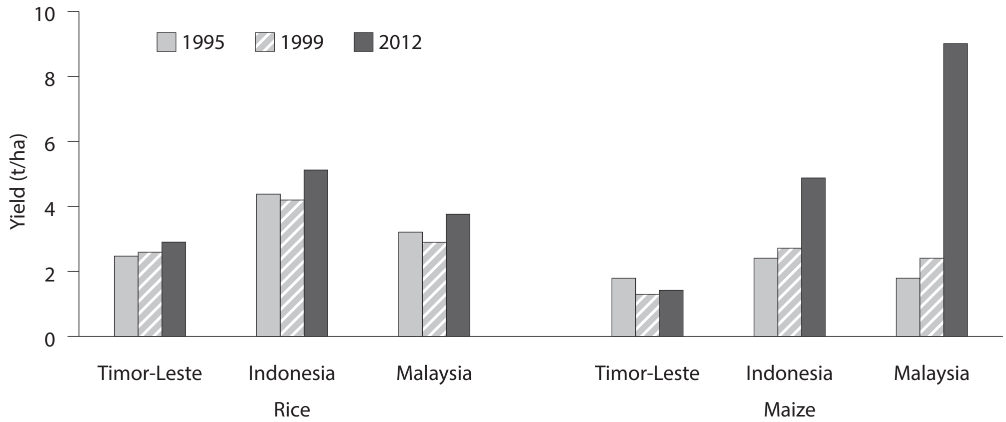

Figure 3. Rice and maize yields in Timor-Leste compared with Indonesia and Malaysia.

Table 3. Coffee production in Timor-Leste.

Year	1996	1999	2006	2008	2010	2012	2013
Production (thousand tonnes)	10.9	12.0	14.0	14.0	12.6	9.0	10.0

Table 4. Round wood production and trade in Timor-Leste (volume, in thousand m³).

	1998	2003	2008	2013
Production	184.72	159.83	130.73	110.40
Imports	NA	0.47	0.08	0.08
Exports	NA	NA	0.51	0.43

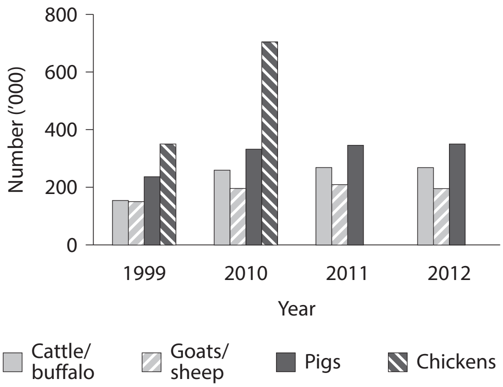

Figure 4. Domestic animal numbers, Timor-Leste 1999–2012.

Evolution of government strategy to improve agricultural productivity

The first democratically elected government of Timor-Leste developed a National Development Plan in 2002 formulating a strategy to address the new nation's development goals (GoTL 2002). As with all new governments, the plan included the establishment of government capabilities, enabling legislation, and the establishment of institutions required to pursue development priorities to reduce poverty. In this plan it was recognised that agriculture was the main source of income for 94% of the *sucos* (villages) at the time, and that support for the agricultural sector would improve the lives of a large majority of East Timorese.

The vision was for the nation to have sustainable, competitive and prosperous agriculture, fisheries and forestry industries by 2020. The Ministry of Agriculture, Forestry and Fisheries (MAFF) was formed to help fulfil this vision, and to address problems and constraints limiting agricultural development. This vision remained in the following IV Constitutional Government Program 2007–2012, and in the current Strategic Development Plan 2011–2030 (GoTL 2011) and the program of the sixth Constitutional Government (GoTL 2015). The MAFF, now known as the Ministry of Agriculture and Fisheries (MAF), also has its own strategic plan, a mid-term operation and investment plan, and develops annual action plans in collaboration with development partners working in the agricultural sector.

The two main areas of constraint are capacity and financial resources, and productivity and product quality. The nation as a whole, and the MAF in particular, have been able to address these issues with varied success.

Capacity and financial resources

It was recognised in 2002 that the MAF would have low capacity to implement programs for development of the agricultural sector with the small number of personnel assigned to work in the ministry at the time. In 2002–2003 there were 350 permanent staff members within the MAF and few of these held university qualifications or were experienced in implementing, managing or monitoring either government or donor-funded activities. As with all ministries, the budget allocated to the MAF was small at US$1.5 million in 2002. During the early years of government, budgetary constraints affected operation of the ministry and also restricted data collection necessary for planning and program development.

The capacity of the MAF expanded in staff numbers from 350 in 2002 to 809 in 2005, 1,823 in 2010 and 2,196 in 2015. Of the 2,196, 18% held bachelor degrees and 1% postgraduate degrees (Abdon unpublished data). Postgraduate scholarships and short-term studies are being offered by foreign governments, and the number of graduates will slowly raise the overall academic qualifications of the ministry over the coming years.

MAF staff implement development programs formulated directly by the government and supported by bilateral and multilateral agencies, NGOs and other members of civil society. The ministry runs a large number of in-house training courses, and has developed laboratories capable of conducting soils analyses, rice quality evaluations, veterinary science, tissue culture and a range of other tests. The research program has also established four fully functional research centres and operates other agronomic and animal research stations.

The MAF budget increased by US$1.5–2 million per year from 2002 to reach US$25,677,000 in 2015. Of this, US$6,504,000 was allocated to salaries and wages and US$14,176,000 to goods and services (https://www.mof.gov.tl/). Goods and services included considerable expenditure on seed and fertiliser. In addition, development partners allocated 12.9% of their total contribution to off-budget grant support to boost activities in the agricultural sector—comprising a total of US$21.4 million. The MAF budget remains a small percentage of the overall Timor-Leste government budget and is not in proportion to the number of persons employed in rural activities nor the number of people living with food insecurity in the rural areas. However, total expenditure on rural development overall has increased and is projected to increase further in the future.

Productivity and product quality

As mentioned above, agricultural productivity in Timor-Leste has remained extremely low in recent years compared with international standards (Figures 2–4 and Tables 3 and 4), and little produce is sold on the open market. Because of the low productivity and small cultivation areas, any surplus produce is of variable quality and expensive to market. There is also no comparative advantage for farmers in Timor-Leste to grow crops for export. Most of the coffee is considered to be organic and can be sold under the fair trade agreement, but often not at an economic advantage.

Low productivity continues into 2016 despite considerable investment in the agriculture sector by the MAF, development partners and private enterprise. These investments are briefly described below.

Agricultural research and extension

The potential for the MAF to plan and implement agricultural research has been enhanced considerably in recent years with the development of a national seed system incorporating varietal research and the release and distribution of higher yield food crop varieties (Borges et al. 2009). Successful research programs for crops (Lacoste et al. 2012), livestock (da Cruz 2003), fisheries (NDFA 2012) and some forestry have also been implemented (FAO 2010). Research stations in the west (Loes Research Centre), south (Betano Research Centre) and east (Darsula Research Station) are also fully functional, and research into crops, livestock, forestry and fisheries is supported by FAO, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), the Australian Centre for International Agricultural Research (ACIAR), the European Union (EU), the Japanese International Cooperation Agency (JICA), Instituto Camoes and a number of international NGOs. Assistance from foreign governments continues to provide capacity building through long- and short-term training programs. A new PhD graduate is now heading the research component of MAF and he is being supported by an increasing number of returning MSc graduates from Indonesia, Australia, Korea, New Zealand, the Philippines and other countries.

The MAF has developed a framework for agricultural extension (MAF 2008). The number of extension personnel increased rapidly after 2008 to ensure one extension officer was posted to each *suco*. There are now 542 agricultural extension officers under the National Directorate of Agriculture, Horticulture and Extension (NDAHE). Support was provided to the *sucos* for extension by various development agencies including the EU and GIZ.

Agricultural input support

The MAF has provided support to the importation of goods to assist agricultural production since 2000. The importation of seed and fertiliser plus pesticides and agricultural mechanisation equipment (see below) has over the years formed a major proportion of the operational materials and supplies portion of the MAF budget. Approximately US$3 million was allocated to the subsidisation of imported seed and fertiliser in 2014. Local production of fertiliser is not possible, but now that the National Seed System for Released Varieties (NSSRV) is operational, the MAF has begun purchasing locally produced maize, rice and peanut seed. For the 2015–2016 season, the MAF is purchasing and distributing 100 tonnes each of locally produced maize and rice seed. Imports over the same period will be reduced to 70 and 53.8 tonnes of maize and rice seed respectively.

Agricultural mechanisation

In countries where labour costs are rising, a shift into agricultural mechanisation is often rapid. In Thailand, for example, land preparation by machinery increased from 20% to 90% in the 1990s. This transformation occurred a decade later in Laos and Cambodia. By the early 2000s only a very small cultivable area in Timor-Leste was prepared by machinery.

To speed this transition, a government budget of US$16 million was made available between 2006 and 2009 to import tractors with cultivation equipment and for the establishment of district agricultural mechanisation centres. The tractors were to remain the property of the MAF, be manned by government-paid drivers, and provide a free service to farmers apart from fuel costs. Maintenance is conducted at the agricultural centres. A total of 311 large and medium sized four-wheel tractors with ploughs and some slashers plus other equipment were imported, and are based out of the centres. In addition, 2,431 hand (two wheel) tractors were distributed to *sucos* with irrigated rice areas. All tractors were 5–6 years old by 2016 and require considerable maintenance. Maintenance will be carried out during the dry season and the tractors will continue to be provided free of charge to farmers for at least the next three years.

Irrigation infrastructure support

Many of the irrigation schemes were damaged during the conflict, and lack of maintenance reduced their effectiveness further after independence. Some experienced rice farmers also abandoned their land at this time. After the new government was formed, it saw the opportunity for boosting the chances of the nation becoming self-sufficient in rice by investing in improved irrigation infrastructure. Damaged schemes were refurbished and upgraded and new ones constructed.

Approximately US$59 million was spent on these schemes between 2011 and 2014 (Table 5; Young 2014). Because of the steep topography and difficult river morphology in Timor-Leste, the cost of construction is high at approximately US$5,000 per hectare (and up to US$21,000 per ha) and the schemes are very expensive to maintain. The schemes also only deliver water in the wet season with few irrigating two crops per year. The return on investment is therefore low compared with schemes elsewhere in Asia, with all the schemes in Table 5 generating negative economic internal rates of return.

Table 5. MAF’s investment in major irrigation development (hectares and thousand $) (source: https://www.mof.gov.tl/a-joint-mof-and-world-bank-report-on-timor-leste-public-expenditure-review-infrastructure/).

Scheme name	ha	2011	2012	2013	2014	Total	$/ha
Raibere Irrigation System Rehabilitation	225			$2,175	$2,620	$4,795	$21,311
Maukola Irrigation System Rehabilitation	2,916			$2,750	$5,479	$8,229	$2,822
Beikala Irrigation System Rehabilitation	1,547			$2,500	$5,612	$8,112	$5,244
Oebaba Irrigation System Construction	2,263		$1,000	$2,200	$5,332	$8,532	$3,770
Tono Irrigation System Construction and Supervision	1,717	$975	$849	$2,750	$4,537	$9,111	$5,306
Bulolo Irrigation System Construction	1,371			$3,496	$3,000	$6,496	$4,738
Galala Irrigation System Construction and Supervision	216			$1,540	$1,940	$3,480	$16,111
Larisula Irrigation System Construction	347			$1,500	$1,980	$3,480	$10,029
Dardau Irrigation System Construction	356			$1,200	$1,208	$2,408	$6,764
Bebui Uatalari Irrigation System Construction a/	1,090	$960	$1,335			$4,795	$4,399
Canal Protection Works in Tono Agricultural Zone b/							
Canal Protection Works in Tono Agricultural Zone b/							
Detailed Design Studies for Irrigation Works			$1,000				
Totals	12,048	$1,935	$4,184	$20,111	$31,708	$59,438	$4,933

However, irrigation remains a key component of the government's attempts to raise agricultural productivity, and rehabilitation of existing schemes will continue. The MAF is implementing a program with the support of JICA to both increase the area under irrigation through the rehabilitation of existing irrigation schemes, and the installation of new dams at strategic sites. Production will also be increased by encouraging farmers to adopt more intensive cropping systems (JICA 2015). The implementation of groundwater pilot projects is also part of the national strategic development plan (GoTL 2011).

Agricultural policy and legislation

Laws for the control of fertilisers and pesticides, seed quality, quarantine and sanitary control, forestry and environmental management have been drafted by the government but are currently not enacted. Policies have however been developed to guide agricultural development. For example, a seed policy was drafted by government and non-government representatives in collaboration with seed producers and this policy is currently being considered by the new government. The government is also discussing a forestry management plan in Parliament to promote reforestation and sustainable land management practices in Timor-Leste.

Poor transport, communication, marketing and processing infrastructure

At the beginning of 2002, farmers were poorly connected to markets by rural roads, the telephone system was limited and expensive, and few government workers were assigned at the *suco* level. Thus, communication between farmers, extension workers and markets was poor. Should any surplus produce come onto the market, processing infrastructure was almost non-existent for value adding. The development of infrastructure in the rural areas of Timor-Leste has escalated in recent years with the installation of a national telephone system, a national electricity grid and a network of rural roads. Information exchange has improved and cheap electricity has enhanced the economic viability of pump irrigation for crop production, animal raising and aquaculture. The construction of animal feed production facilities, a cassava starch factory and plans for a brewery in Timor-Leste also demonstrate that markets for agricultural products are improving.

Land tenure

Part of the reason that farms are undeveloped can be attributed to a lack of clarity about land tenure. A framework providing some security for investors in commercial agricultural development or access to the land needs to be developed. A draft land law was developed for public consultation in 2008.

Forest degradation

The forests in Timor-Leste were originally rich in sandalwood and timber species and were harvested over hundreds of years. Indigenous cropping systems based on shifting agriculture and firewood collection degraded the forests further. Although forest covered 89% of the country in 1997 (Table 2) the area of quality forest was diminishing quickly and the issue needed addressing by the new government. The government is developing a forestry management plan and national bamboo policy and marketing strategy to improve the sustainability of forestry and wood products.

Agriculture statistics

One of the main causes of MAF's planning and reporting problems is poor statistics on which to work. Data collection systems are currently being updated to estimate crop areas for national seed requirements and for other food security issues. FAO is also assisting with other crop and animal data collection and reporting.

Future directions

The MAF will continue to support development of the agriculture sector in Timor-Leste through formulation of relevant policies, regulation, quality control and the provision of extension through its large network of agricultural officers. Development partners will be approached to support research, capacity building and operational support of its non-administrative programs.

There is potential for increasing productivity in crops, livestock, fisheries and forestry. Of particular concern to the government in 2016 is the poor utilisation of irrigation facilities and low agricultural productivity. An inventory of irrigation schemes is being compiled and their constraints analysed. An expansion of irrigated crop production will be encouraged through the rehabilitation of irrigation schemes and more intensive cropping. Analysis of the economics of groundwater supply will also be conducted using the new grid electricity to guide water utilisation for crop, animal and fish production.

The Government will continue to support crop cultivation by providing tractors free of charge.

Improving livestock production through hand feeding programs and by expanding the use of improved pastures and food trees will be encouraged. Coastal fishing will be promoted, particularly in the exclusive economic zone, and aquaculture expanded. In the forestry sector, forestry legislation will be developed to improve land tenure to support a sustainable forestry management plan and degraded forest areas will be revegetated.

Capital expenditure in coffee, candle nuts, cloves and other tree species is expected to increase with government and development partner support.

Government subsidies to the seed sector, particularly of food crops, will continue in the near future with seed being sourced from within the country rather than being imported. The MAF will nurture the NSSRV to support local production. Agronomic research may also expand into plant nutrition and soil improvement.

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Advances in food availability in Timor-Leste

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Abstract

Does Timor-Leste have a reliable and consistent source of quality food, either self-produced or imported, to feed its people? This paper seeks to answer this question by looking at five underlying questions, drawing on the results of agronomy and social science research conducted by the Ministry of Agriculture and Fisheries and by other researchers. The agronomy research shows that the food crop varieties which the Ministry of Agriculture and Fisheries has released since the mid-2000s are more productive than traditional varieties. The social science research shows that Timorese farmers have increasing access to these improved varieties, that the improved varieties are grown intensively by the farmers, and that farmers who grow the improved varieties are by-and-large more food secure than farmers who do not grow these. For the country as a whole, it appears that rice production is increasing despite a declining trend in the area under cultivation, and maize production also shows an increasing trend.

Introduction

As a new nation, Timor-Leste faces many problems. One of these problems is hunger and malnutrition. The 2015 Global Hunger Index score for Timor-Leste was 40.7, making it the fourth lowest ranked country (with Zambia, Chad and the Central African Republic having lower scores), and one of only three countries where more than 50% of children under five suffer from stunting (Grebmer et al. 2015).

The Strategic Development Plan 2011–2030 of the Government of Timor-Leste mentions specifically that "a thriving agricultural sector is needed to reduce poverty, provide food security and promote economic growth in rural areas and our nation as a whole" (GoTL 2011). The Government is working across ministries to improve food security. Specifically for agriculture, the Program of the Sixth Constitutional Government, 2015–2017, lists promoting the use of high yield varieties identified by the Ministry of Agriculture and Fisheries (MAF) as a key measure towards improving the country's food security (GoTL 2015).

Over the past 15 years, Timor-Leste has put considerable effort into improving the productivity of food crop production in the country. In the first years after independence, the focus was primarily on testing and identifying more productive varieties of the common major food crops. Starting in 2007, MAF released well-tested varieties which were gradually taken up by Timorese farmers. Accessibility of the improved varieties increased rapidly over the period 2011–16, with seed multiplication mainly through the involvement of community seed production groups and commercial seed producers.

The question to be asked is—has the productivity of major food crops increased, and has this resulted in improved food security for rural households in Timor-Leste? To answer this question, this paper addresses a set of sub-questions, and demonstrates that food security has improved overall, even though much remains to be done. The sub-questions are:

- Are the released food crop varieties more productive?
- Do farmers have access to the improved varieties?
- To what extent do farmers grow the improved varieties?

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- Are farming households more food secure than before?
- How has overall food availability evolved in Timor-Leste?

The World Food Summit Plan of Action, 1996, states that "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food for a healthy and active life". Consequently, there are four dimensions of food security: access, availability, utilisation and stability. This paper does not attempt to discuss food security in Timor-Leste in its totality (Andersen et al. 2013); instead it focuses on the availability dimension. The paper thus investigates whether Timor-Leste has a reliable and consistent source of quality food, either self-produced or imported for its people.

Are the released food crop varieties more productive?

In the first years after independence, hundreds of varieties of maize, rice, peanut, cassava and sweetpotato were evaluated by MAF (SoL 2007; Williams et al. 2016), first on research stations and subsequently in farmers' fields. Some varieties proved less promising than first thought; others were too susceptible to disease, or did not score well in taste tests with the farmers. The hundreds of varieties that were tried on research stations dwindled to tens that were evaluated in farmers' fields.

On-farm variety trials, including local varieties for comparison, were carried out by farmers in the same manner as they grew their own crops, i.e. with the same level of weeding and without the use of fertiliser or pesticides. The acceptability to farmers for taste, ease of food preparation and storage were also factors that were taken into account by MAF's variety release committee. Ultimately only a few of the many varieties that were tested were considered good enough for official release by the ministry (Lacoste et al. 2012; Williams et al. 2012a, b, 2013).

The yield advantages of the released varieties over local varieties are in the order of 50% for maize, 24% for rice, 47% for peanut, 15–46% for three cassava varieties, and 90–130% for three sweetpotato varieties (MAF 2014a). The higher productivity of the improved varieties was confirmed in country-wide surveys. In the 2011 and 2013 surveys, 88% of the farmers growing improved varieties stated that these were more productive than local or traditional varieties (SoL 2013).

Do farmers have access to the improved varieties?

In 2010, there were an estimated 116,426 households in Timor-Leste involved in crop production (63% of all households in the country; NSD 2011), in both rural and urban areas. For some, especially in the urban areas, crop production was (and remains) a secondary activity (for example, it can be limited to a fruit tree in a backyard, or a very small plot with some vegetables), but for the majority of the nation's households agriculture is still the sole or most important livelihood activity. The Timor-Leste Labour Force Survey 2013 found that of a total of 392,133 working persons, more than 42% were subsistence foodstuff producers. Also, among those engaged in agriculture, 62% were subsistence foodstuff producers while the rest produced very little surplus (MoF 2015). The Timor-Leste Food and Nutrition Survey 2013 also confirmed the predominance of agriculture. In that year, 68% of households in the country made a living from the production and sale of agricultural crops (MoH 2015).

Food security starts with seed security, and this is especially so for subsistence farmers. A seed system security assessment conducted in 2013 showed that more than 90% of the farmers in Timor-Leste sowed seed originating from informal seed systems. This included seed from their own stocks retained from the previous year's harvest (72% of seed sown); seed purchased in a local market (12%); or seed obtained from relatives, neighbours or acquaintances (7%). The remainder was free seed distributed by the government, the UN Food and Agriculture Organization (FAO) or non-governmental organisations (NGOs) (USAID 2013).

It is estimated that between 2008 and 2013 close to half of the population received seed aid in one form or another on average 1.6 times during that period (USAID 2013). The farmers appreciated receiving quality seed for free, but stated that they usually only got a small amount of it, and it always arrived late (USAID 2013).

The challenge was for MAF to improve the seed distribution system to expand farmers' access to quality planting material of improved varieties. During the second half of the 2000s, the approach was to contract selected and qualified farmers to grow good quality seed and cuttings under close supervision, and distribute that planting material to farmers before the onset of the growing season. NGOs and bilateral aid organisations were often involved in both multiplication and distribution of this material. The Seeds of Life program (SoL) within MAF assisted with varietal evaluation, seed and planting material multiplication, and their distribution (Table 1).

In 2009, it became clear that it would take a long time to achieve a substantial uptake of improved varieties by Timorese farmers by relying on seed growing by contract farmers and distribution of seed through MAF and NGOs. Based on a seed replacement rate of 33%, the estimated annual demand for maize seed is 750 tonnes (Young 2013). This compares with a total of 32.5 tonnes of yellow maize seed being distributed to farmers in 2010–11 (Table 1).

MAF therefore opted for a different approach, one which had been piloted in 2008–10 by CARE in two districts where seed multiplication by farmers' groups proved successful. Such groups could meet the demand of their group members for improved seed, and the groups were able to share surplus seed locally with relatives and neighbours. In 2011, the ministry started to support 280 community seed production groups in 70 *sucos*, and this activity expanded year-by-year to reach 1,208 groups in 363 *sucos* in early 2015.

The distribution of improved varieties by MAF, FAO and NGOs, and the increased availability of improved varieties through community seed production groups, has accelerated the spread of improved seed and cuttings. Country-wide surveys conducted in 2011, 2013 and 2014 show an increasing percentage of adoption of the improved varieties by Timorese farmers. In 2011, 18% of food crop farmers grew one or more improved varieties, in 2013 this had increased to 25%, and by 2014 to 33% (SoL 2014).

The change in distribution and accessibility of improved varieties can be illustrated by a set of histograms that show what percentage of the respondents in each of the sample *sucos* in the 2011, 2013, 2014 and 2016 surveys were growing improved varieties (Figure 1).

As can be seen in the figure, the percentage of sample *sucos* where no respondents were cultivating improved varieties became smaller over the years (35% in 2011, 24% in 2013, 17% in 2014, and 2% in 2016). At the same time, the average adoption rates in the *sucos* where improved varieties were already being grown also increased (27% in 2011, 29% in 2013, 39% in 2014, and 47% in 2016). Overall, farmers in Timor-Leste have increasing access to improved varieties.

To what extent do farmers grow the improved varieties?

To assess the impact of the cultivation of improved varieties, it is insufficient to consider if farmers have access to the improved varieties; one must also know to what extent farmers grow these varieties on their plots. Table 2 shows that in 2013 the maize, peanut, cassava and sweetpotato farmers who cultivated the improved varieties had more than 85% of their crop areas planted with these varieties. The majority of the farmers also only grew the improved varieties. Rice farmers seem to opt somewhat less wholeheartedly for Nakroma. More than half of the Nakroma-growing farmers continued growing other rice varieties.

In 2013, 15.7% of all maize areas were planted with improved varieties, 11.1% of all rice areas were planted with Nakroma, and 12.5% of all peanut areas were planted with Utamua.

Table 1. Seed and cutting distribution to farmers in Timor-Leste, 2008–11.

Variety	Seeds and cuttings distributed			Share of uptake over the 3 years		
	2008–09	2009–10	2010–11	Ministry	NGOs	SoL*
	t (no. farmers)			Percentage		
Nakroma	14.6 (1,654)	52.7 (5,268)	50.3 (5,027)	88	5	7
Sele	11.4 (8,813)	18.1 (14,274)	32.5 (4,826)	45	27	19
Utamua	4.5 (489)	16.0 (1,051)	16.8 (871)	45	23	32
	Cuttings (no. farmers)			Percentage		
Hohrae	120,293 (2,406)	43,435 (869)	24,280 (486)	37	13	50
Ai-Luka	1,150 (23)	29,798 (597)	19,995 (400)	2	32	66

Source: SoL 2011.
*For on-station and on-farm trials, and as source seed for contract growers.

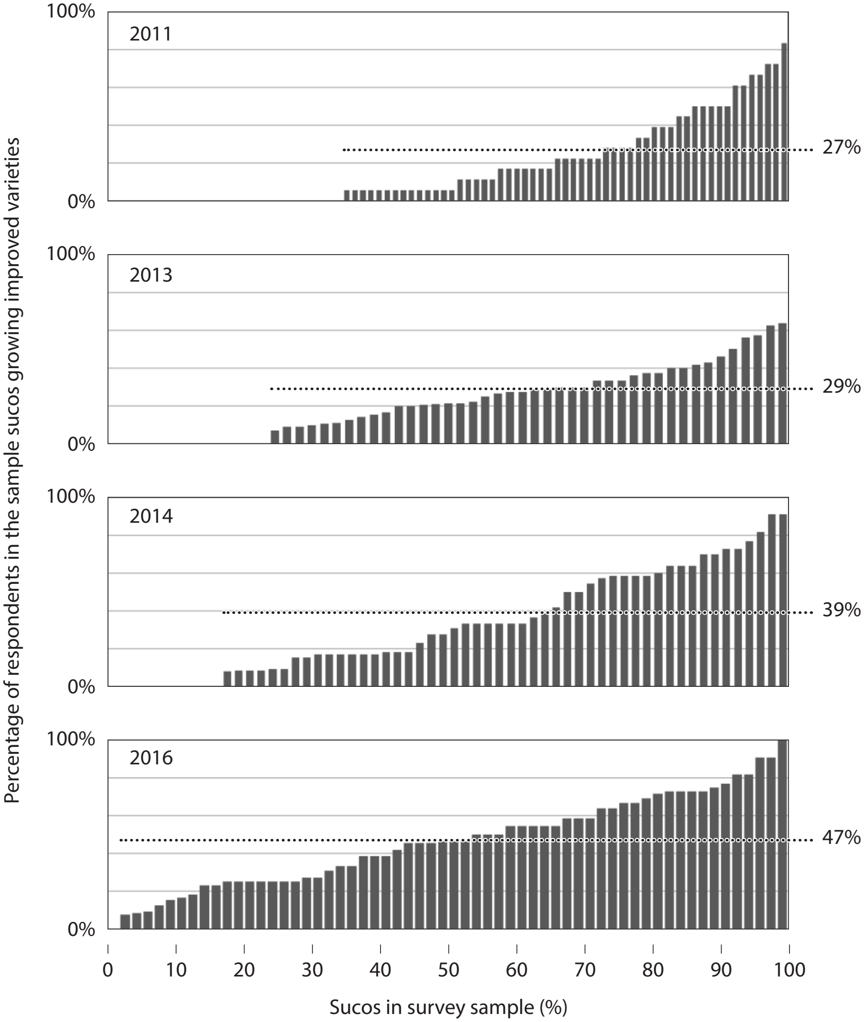

Figure 1. Percentage of respondents in the sample *sucos* growing improved varieties.

Table 2. Areas grown with improved varieties by adopting farmers.

Variety	Average area under improved variety (ha)	% of variety adopters growing only the improved variety	Average % of crop area grown under the improved variety
Sele	0.5	55%	85%
Noi Mutin	0.8	93%	95%
Nakroma	0.8	45%	43%
Utamua	0.3	89%	94%
Ai-Luka	0.6	79%	86%
Hohrae	0.3	76%	86%

Source: SoL 2013.

Are farming households more food secure than before?

From the above decisions by farmers to replace local seeds, it is clear that the improved varieties are more productive than the traditional ones, that farmers have increasingly greater access to these varieties, and that the improved varieties are being grown relatively intensively. But are farming households therefore more food secure than before?

In the 2013 and 2014 nationwide surveys, respondents were asked if, in the 12-month period prior to the interview, they had experienced hunger, and, if yes, in which months this had occurred.

The results indicate that farmers growing improved varieties were more food secure than farmers who did not grow them (Figure 2). In 2013, 23% of the farmers growing improved varieties did not experience hungry months over the period June 2012 to May 2013, whereas 14% of non-adopting farmers did not experience hungry months during the same period. In 2014, the figures were 26% of adopters versus 13% of non-adopters who had not experienced hungry months between August 2013 and July 2014.

Conversely, in the group of farmers who experienced hunger, fewer farmers growing improved varieties than those who did not grow such varieties indicated that they had lacked food (Figure 3). Especially during the peak of the hungry season—November to February—proportionally fewer of the farmers growing improved varieties experienced hunger than farmers who did not grow such varieties.

Growing improved varieties clearly contributes to greater food security for Timorese farmers. This opinion is also shared by the farmers who are growing the improved varieties. In the 2014 survey the adopting farmers were asked to what extent they agreed or disagreed with certain statements related to the impact of growing improved varieties (Table 3).

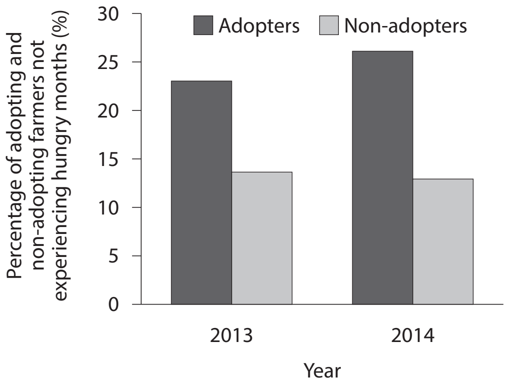

Figure 2. Percentage of adopting and non-adopting farmers who did not experience hungry months in the 12-month period before the survey.

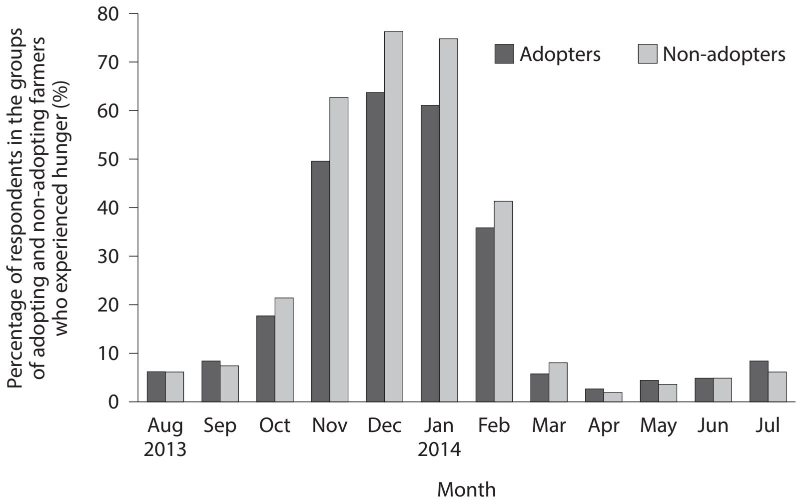

Figure 3. Improved variety adopting and non-adopting farmers who experienced hunger, August 2013 to July 2014.

The majority of the adopting farmers agreed that growing improved varieties has helped them to grow more food, and that they were less hungry than before. On the question whether the farmers growing improved varieties had become less poor, the answer was less clear.

How has overall food availability evolved in Timor-Leste?

The goal of agriculture is not only to meet the food requirements of the farmers themselves, but to contribute to food availability in the country as a whole, by growing a marketable surplus. To assess this we look at the national availability of rice, maize and cassava.

Figure 4 shows the reported production figures for maize, rice and cassava in Timor-Leste over the period 2001–15 (FAO 2015; MAF 2012, 2014b, 2015a, b, c; Rangel 2013). If the low production figure of maize in 2011 (when agricultural production was severely affected by La Niña conditions) is omitted, the general trends for both maize and rice production appear to be increasing.

For rice, the increasing trend in production is despite a declining area under rice cultivation during the period 2005–15 (Figure 5). As stated in a public expenditure review of infrastructure conducted jointly by the Ministry of Finance and the World Bank, "From an economic cost perspective, in Timor-Leste, it is much cheaper to import rice (at an average cost of US$660 per metric ton) than to grow rice ($1,000 per metric ton), and there are few incentives for farmers to increase domestic production" (MoF and WB 2015).

Over the period 2005–13, the annual rice balance showed an average deficit of 74,719 t, ranging from a deficit of 57,195 t in 2012 to a deficit of 91,697 t

Table 3. Results of the 2014 survey of farmers growing improved varieties: responses of 225 farmers.

Growing improved varieties…	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	No answer
…has helped me to grow more food		3%	7%	66%	22%	3%
…has reduced the number of months during which my family experienced hunger		5%	17%	54%	22%	3%
…has helped us to become less poor	4%	19%	26%	31%	16%	5%

Source: SoL 2014.

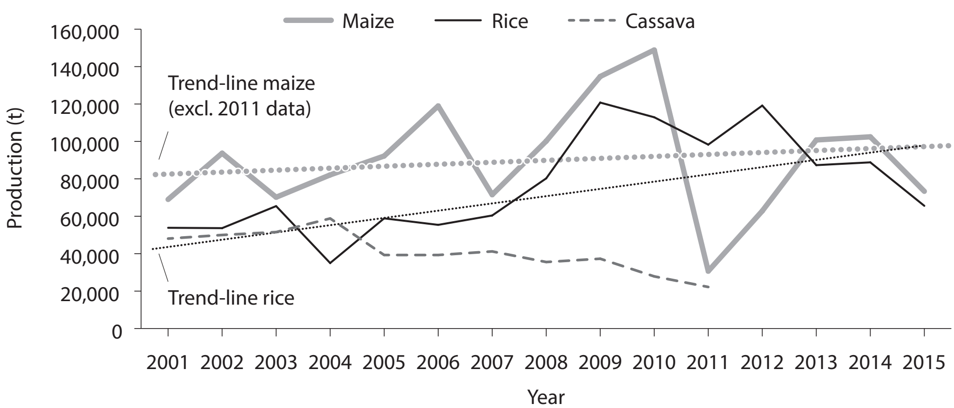

Figure 4. Maize, rice and cassava production, 2001–15. (Data from FAO 2015; MAF 2012, 2014b, 2015a, b, c; Rangel 2013.)

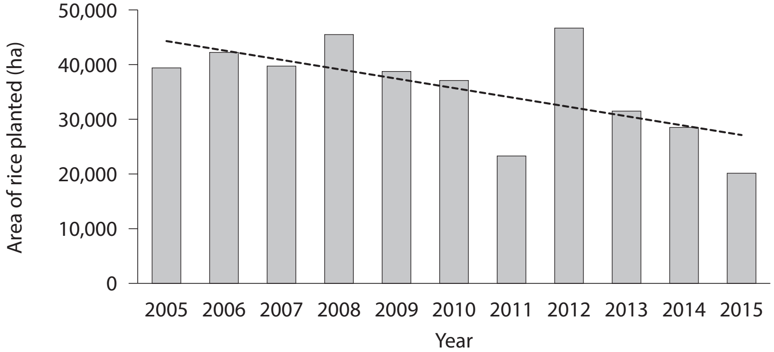

Figure 5. Area of rice planted, 2005–15. (Adapted from MoF and WB 2015, and MAF 2015a, c.)

in 2011 (MoF and WB 2015). These deficits have largely been met with rice imports; e.g. between April and December 2014, a total of 199,631 t of rice was imported (MAF 2014).

The fact that rice purchases are widespread, and that is it cheaper to buy rice than to grow it, was also confirmed in the surveys of 2011 and 2013. In 2011, virtually all farmers (99.6%) stated that they had bought rice in the previous 12 months, and 62% of the respondents bought rice every month (SoL 2012). In 2013, 94% of the respondents had bought rice in the previous 12 months, and 65% of respondents purchased rice every month, on average 32 kg per month. Of the rice farmers who also bought rice, 85% said that they did so because their own production was not enough to meet their needs (SoL 2013).

Conclusion

Improving food security of Timorese farmers is a major objective of the Government of Timor-Leste. The paper has shown that—provided the reported production figures are reliable—progress has been made in improving self-sufficiency in maize; and even rice production increased until 2009, although it has declined since 2012.

Compared to 2011, farmers in Timor-Leste have improved access to more productive varieties of their major food crops, and farmers who have adopted these varieties grow them intensively on their plots. As a result, these adopting farmers are better able to meet their food needs through self-grown crops than farmers who do not yet grow improved varieties.

A challenge for the country is to find a balance between making agriculture profitable for farmers, and keeping agricultural products affordable for the population at large.

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Section 2: Elements for agricultural development in Timor-Leste

The role of international germplasm exchange in agricultural development

Eric Huttner[1] and Julie M. Nicol[1]

Abstract

The Timor-Leste Ministry of Agriculture and Fisheries has supported the introduction of improved crop varieties since its establishment in 2002. This work provides an excellent example of the contribution of germplasm exchange to agricultural development. This paper discusses the role of genetic resources and the regulations covering genetic resources and plant varieties. No country is fully autonomous for genetic resources so plant breeders around the world need to access and utilise global genetic resources. Genetic resources formally belong to their country of origin and their international exchange is now regulated under the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources for Food and Agriculture. The movement of genetic resources is recorded and the recipient of a particular genetic resource commits to share the benefits of its application with the original owners under specified conditions. Successful plant breeding programs release improved plant varieties. In Timor-Leste, the released varieties are in the public domain and the farmers using them obtain all the economic benefit of this innovation. In many countries where plant breeding has become a private economic activity, varieties are protected by intellectual property rights, mostly plant breeders' rights. In principle, these rights reward the breeders for having developed a new variety: they obtain part of the benefit of the innovation. In practice, it will be crucial for the ongoing improvement of crops that genetic resources continue to circulate globally with the lowest possible barriers.

Introduction

Improved varieties are a powerful innovation to increase food production in food-insecure countries. Of course much more is needed than just improved varieties for farmers to produce more food sustainably. First, the improved varieties need to work well in farmers' fields, to fit well with their production systems, to reduce their risk, and to produce a desirable product appropriate for local tastes and preferences. Then, farmers need timely access to affordable seeds of the improved varieties. Last, any new input required to capture the full benefit of the improved varieties (labour, fertiliser, water) has to be compensated by increased production and profitability.

Of all innovations aiming at increased production, improved varieties of traditional crops are one of the easiest to adopt. The innovation is contained within the seed. While timely production and dissemination of quality seeds has many challenges, the Seeds of Life (SoL) program within the Timor-Leste Ministry of Agriculture and Fisheries (MAF) has shown how these challenges can be met, even in a difficult environment such as Timor-Leste. Improved varieties introduced to Timor-Leste are the starting material that could lead to a food production increase. This paper describes the role genetic resources play in improving crops, and how their global exchange is organised. It then covers intellectual property rights issues relevant to improved varieties.

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Genetic resources: what they are and why they matter

Wild relatives, landraces and improved varieties constitute the genetic resources which are the raw material of crop improvement. Some genetic resources are directly usable as an improved variety. Indeed, the varieties released under the Timor-Leste National Seed System for Released Varieties (NSSRV) were obtained from various plant breeding organisations overseas. However the majority of genetic resources are used as a source of improved traits to breed new varieties.

The genetic basis of cultivated varieties is very narrow in some crops such as groundnut, chickpea (Varshney et al. 2013) and most pulses. There is increasing recognition of the importance of expanding the genetic diversity used in breeding, making access to genetic resources very important (McCouch et al. 2013; Mir et al. 2012). Landraces, wild relatives and older varieties have been the source of traits required by new improved varieties to cope with biotic and abiotic stresses or to increase their nutritional content (Gamuyao et al. 2012; Khazaei et al. 2013; Upadhyaya et al. 2014). Recent improvements in DNA analysis methods, such as DNA sequencing and genome-wide genotyping, have revolutionised our understanding of the genetic diversity available in genetic resources.

The international research centres of the CGIAR hold some of the world's largest gene banks. They are now analysing the genetic resources they hold by phenotyping and genotyping in parallel most of the accessions in the collections (Sehgal et al. 2015). A good description of the approach is given by the Seeds of Discovery project based at the International Maize and Wheat Improvement Center (CIMMYT) (http://seedsofdiscovery.org/). The information generated by projects of this kind will allow breeders to select useful and relevant accessions and then harness the traits, genes or alleles they contain to obtain improved varieties faster (Xu et al. 2012). While this approach is not new, the new DNA tools increase the chance of success and make the breeding of new varieties faster and more precise. Technological progress is thus facilitating the productive use of genetic resources and increasing their usefulness and potential value. The development of genome editing techniques (Jacobs et al. 2015) is likely to provide a new path to applying the information (the association between a DNA sequence and a trait) to the accelerated breeding of improved crops.

Ownership of, and access to, genetic resources

The United Nations Convention on Biological Diversity (CBD; https://www.cbd.int/convention/) is the only international instrument comprehensively addressing biological diversity. It entered into force in 1993 and has been ratified by 196 countries including Timor-Leste. The convention's three objectives are: the conservation of biological diversity, the sustainable use of its components (i.e. the genetic resources), and the fair and equitable sharing of benefits arising from the utilisation of genetic resources. Under the CBD, genetic resources belong to the countries where they are found. Access to these genetic resources requires prior informed consent from the owners: in practice this proved difficult to implement. The Nagoya Protocol to the CBD on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (www.cbd.int/abs/doc/protocol/nagoya-protocol-en.pdf) entered into force in October 2014. Recognising that the practical implementation of the CBD in terms of access and benefit-sharing had been limited, the Nagoya Protocol attempts to advance the third objective of the CBD by providing practical guidance for the CBD access and benefit-sharing provisions. The Protocol also explicitly includes the recognition, preservation and reward of traditional knowledge associated with genetic resources. The implementation of the Nagoya Protocol relies on each country passing appropriate legislation. This may take many years. It is difficult at this stage to predict how the Nagoya Protocol will be applied in practice, and what its consequences will be for the circulation of germplasm. At the end of 2015, Timor-Leste had not ratified the Nagoya Protocol.

The CBD applies to all genetic resources, covers all uses, and is a bilateral mechanism: the party requesting access and the country owning the resources must agree. However, for a limited list of plant species, and limited to the use of genetic resources for food and agriculture, a special multilateral system applies: the FAO International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA; www.planttreaty.org), referred to as the Treaty.

Multilateral system

The Treaty covers the use, for food and agriculture purpose only, of genetic resources for 35 crop genera and 29 forage species. The list, known as Annex 1, contains most of the world's staple food crops and their relatives. Notable exceptions include vegetables such as tomato, capsicum and cucurbits, important cash crops such as groundnut (peanut), coffee and cocoa, industrial and feed crop soybean, and fibre crops such as cotton and flax (despite soybean oil, cottonseed oil and flax seeds being food). The Treaty also covers all genetic resources held in trust by the ex situ gene banks of the 15 centres of the CGIAR and other similar centres. These are considered to be held in trust for the whole of humankind and not belonging to any country. Access to genetic resources covered by the Treaty is administered by a multilateral system under FAO and involves specific provisions for access and benefit-sharing. One hundred and thirty seven countries have ratified the Treaty, not including Timor-Leste. The provisions of the Treaty only apply to exchanges with these countries and the CGIAR centres. For all other countries, the CBD provisions apply.

The Treaty is the most common instrument covering germplasm exchange for food security in developing countries, except for species not part of Annex 1 and not available through the ex situ gene banks of the multilateral system. The multilateral system operates as a clearing house and keeps a record of all germplasm transferred under the Treaty. The benefit-sharing provision under the Treaty reflects the way traditional plant breeding has been operating: a financial benefit-sharing obligation applies only to users of genetic resources who prevent further use of the resource, for example by releasing an improved variety under patent, as opposed to the further breeding allowed with varieties released under plant breeders' rights.

Moving genetic resources

Compliance with the various treaties governing access to genetic resources requires the recording of the movement of germplasm between providers and recipients. This is done in practice through a material transfer agreement (MTA). Under the Treaty (the multilateral system), a standard MTA is used (a copy can be found at http://www.planttreaty.org/content/what-smta).

The requirement to document germplasm exchange can be seen as a burden for plant breeders. Under the Treaty, an integrated information system under construction will facilitate the exchanges. The international centres' gene banks have in place the infrastructure required to process requests. Therefore in practice, the operation of the Treaty does not create an excessive obstacle to germplasm exchange for the purpose of plant breeding and food security, especially in the context of public breeding programs operating in developing countries. These programs release improved varieties, free for all to multiply, disseminate and use for further breeding in the public domain and as a private business. As an example, the MAF/SoL varieties of sweetpotato Hohare 1, 2, and 3 were imported to Timor-Leste from the International Potato Centre (although their importation pre-dated the entry into force of the Treaty).

The situation is less clear for the implementation of the Nagoya Protocol, since national laws will have to be passed and each case will be different. The national implementation of the Protocol could be a concern to private plant breeders, operating in developed countries but also increasingly in developing countries. The requirement of keeping track in perpetuity of all applications of the genetic resources acquired under MTAs is seen as onerous, and could actually go against the well-established breeder exemption where anyone is free to use previously released germplasm for further breeding. In a press release from August 2014, Ms Stephanie Franck, president of the German Plant Breeders' Association (BDP: http://www.bdp-online.de/en/Homepage/), says: "The EU Regulation leads to abundant red tape, restricts access to plant genetic resources in particular for plant breeders—meaning: [it restricts their] utilization in breeding—and by far exceeds the principles laid down in the Nagoya Protocol itself… The exact documentation on the utilization of genetic resources as required by the EU Regulation is practically not feasible." As explained on the IPKat blog (http://ipkitten.blogspot.com/2014/08/german-plant-breeders-challenge-eu.html): "according to the BDP and many plant breeders, real benefit sharing will only take place if and when plant breeders actually use the resources, i.e. as long as access is not prevented by excessive bureaucratic hurdles. Plant breeding needs a special approach, since utilization of a genetic resource in plant breeding is not comparable to other forms of utilization, as e.g. in the pharmaceutical industry. The plant breeder can only uncover the value of genetic resources during the long breeding process, and therefore the direct exploitation of genetic resources is not [a] given. The CIMMYT wheat variety Veery for example is a product of 3,170 crossings between 51 different parental lines originating from 26 different countries. Such a plant variety has been developed over many generations and by many different plant breeders."

Benefit-sharing obligations also open issues such as identifying the owners of the resources used, including the traditional knowledge attached to them. Users of genetic resources will have to manage the risk of having to deal with conflicting claims of ownership, for example when multiple countries, ethnic groups or communities claim the material and its associated traditional knowledge.

Users will also have to balance the costs with the benefits of accessing the resources. In many instances, a genetic resource will contain a single gene (or locus) conferring a useful trait to new varieties (for examples in rice, see Bailey-Serres et al. (2010) and Gamuyao et al. (2012)). Fairly sharing the benefits of the resource with its original owners will require the fair evaluation of the financial contribution of this single gene to the overall value of the improved variety, which may be the result of 5–10 years of plant breeding.

Realising the benefits of improved varieties

Open-pollinated and self-pollinated varieties and clones

Improved varieties planted by farmers provide them economic or livelihood benefits. Such varieties can be in the public domain as in Timor-Leste. In this case the full benefit of the improved variety is obtained by the farmer and the price of the seeds reflects only the cost of producing quality seeds and the demand (market premium) for these seeds. A premium of 60–100% over the price of ordinary grain is frequently observed, and justified by the care and effort underpinning quality seeds. In Timor-Leste, the NSSRV has so far released only open-pollinated, pure line or clonal and conventionally bred material (Williams et al. 2016). These varieties, all in the public domain, can be reproduced by farmers. Their decision to save some of their grain or clonal material as seed for the next crop or to purchase new seed will be based on their assessment of the expected benefits of using new seeds and the costs of buying them. Farmers decide to buy new seed for a range of reasons:

- to access a new variety: replacing part of their crop with a higher performance variety;
- to ensure genetic purity: for example in open-pollinated maize, grains harvested from non-isolated crops will be genetically heterogeneous so a farmer may prefer to procure homogeneous seed from a reliable supplier;
- to ensure seed quality: for example in mungbean, storing the seed is difficult and farmers without good storage may prefer to sell their entire crop after harvest and rely on a better equipped producer to supply them with seeds at planting time.

Hybrid varieties

Farmers using hybrid varieties cannot use their grain as seed since a hybrid does not breed true. The higher performance of hybrids, provided the correct agronomic practices are used, makes it worthwhile for farmers to purchase the seeds each year. If this is not the case, farmers do not use hybrids. In developing countries hybrids are mostly used for high-value crops such as vegetables and industrial crops (for example tomato, cotton). However the use of hybrid rice and maize is rapidly increasing in India, Bangladesh, Indonesia and other similar countries. A recently released hybrid of pigeonpea is being rapidly adopted in India (Saxena et al. 2013), showing the future prospects of hybrid varieties for smallholder crops in developing countries.

Reward system for breeders

In many developed countries, and increasingly in developing countries, improved varieties of open- or self-pollinated crops such as wheat, barley, rapeseed or rice are developed mostly by private organisations. The developers of such varieties invest time and resources in the development and are motivated by the profit they expect to derive from farmers using the improved variety. Plant breeders' rights (PBR) attempt to secure this reward for breeders, while not excluding others from using the released material for further breeding. Seeds of a variety protected under PBR can be sold only by the holder of the rights or by her licensees. The price of the seed therefore reflects an assessment by farmers of the value of the improved variety over and above other varieties. Under PBR, farmers can use their grains as seeds, so they do not have to buy seeds every year. This places a practical cap on seed prices. Preventing farmers from replanting their own grain would be difficult in practice for most common open- and self-pollinated crops. The Australian system of end-point royalty (EPR) collects a levy based on farmers' production rather than farmers' purchase of seeds. In this case, the breeder and the farmer share the production risk since the royalty is lower when production is low (for example due to a poor season). The system works well for wheat, barley, oilseeds and grain legume crops in Australia but requires an organised formal grain delivery system to record the production and the varieties delivered, and to collect the corresponding royalty for remittance to the plant breeding companies. This would not readily apply to developing country situations where informal trade of grain is the norm.

Conclusion

The continuous genetic improvement of crops has been one major source of productivity and livelihood improvement for farmers. This is dependent on access to genetic resources. The flow of genetic resources between countries is now regulated, to promote conservation and use of the genetic resources and to ensure that their benefits are shared with their original owners. This paper has provided the landscape for these regulations in the limited context of food and agriculture. The paper identified practical implications of these regulations. Their complexity, the difficulty in identifying precisely the original owners, and the transaction costs of implementing the regulations could threaten the ongoing improvement of crops. In parallel, recent genetic analysis methods will increase the utility of genetic resources as a source of traits, while making it less important to access the actual seeds. The value of knowledge and information per se will increase and may make the current system less relevant. Improved varieties benefit farmers only if they can be easily and cost-effectively accessed and deployed. MAF-SoL successfully established the Timor-Leste NSSRV, thereby allowing farmers to access improved varieties. As the farming sector grows and matures, we can expect the seed system to evolve towards an array of small businesses, motivated by the rewards they obtain by providing high-quality seeds from high-performance varieties to their customers.

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Theory, practice and results of food crop variety evaluation and release in Timor-Leste, 2001–16

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Abstract

From 2001 to 2016, the Timor-Leste Ministry of Agriculture and Fisheries accelerated the process of Timorese farmers selecting and choosing new varieties of staple food crops. During this period, more than 500 varieties of 13 species were evaluated in joint research/farmer trials, resulting in the national release of 18 improved varieties. Introduced varieties were first evaluated on research stations along with the best available local varieties, and then rigorously tested with farmers in their fields. On-farm testing of a small number of elite varieties was conducted in farmer-managed trials using their current level of technology and with no additional inputs. More than 4,000 on-farm trials were conducted between 2005 and 2015. Two principles governed plant introductions: all selected varieties had to be suitable for use by subsistence farmers, and introduced material needed to be free intellectual property. All tested varieties were either open pollinated (no hybrids), pure line or clonal and conventionally bred (no genetically modified material). No varieties were released to farmers that could not be shared freely with family, neighbours and across generations. The first varieties were released in 2007, and for the next 8 years their adoption was relatively rapid compared to other variety release programs, with one in three farming households growing at least one released variety by the end of 2014. It is estimated that the use of these improved varieties increased the farm gate value of food produced by approximately US$4.4 million that year.

Introduction

Agriculture in Timor-Leste is dominated by small households planting a wide diversity of crops. Most people have access to seed through informal seed systems, where seed is held by the household from year to year, and exchanged or bartered between households. However, farmers have limited access to novel or different varieties or sets of genes of these crops. Sharing of varieties between households or buying seed at markets is the most common strategy to increase diversity, but as a nation there are limits to the diversity available to farming families. For example, although most households grow two or three types of cassava, nationally there may be only 20 cassava clones in total to choose from (Reinhardt personal communication). In the case of rice, even if every *suco* (village) had a unique rice, the total would be approximately 420 varieties. This is much less than the 127,000 accessions and wild relatives stored in the International Rice Research Institute (IRRI) gene bank. For Timor-Leste farmers to access a wide range of diverse genetic material, they need access to varieties that are currently only available overseas.

The limited diversity of most of the crops in Timor-Leste is the result of previous introductions of

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narrow samples of genetic diversity. Each food crop (e.g. rice, maize, cassava etc.) has a geographic centre of origin associated with its diversity; globally there are eight primary centres of crop diversity (Vavilov 1935). The centre of diversity for each species is where that species was initially selected from wild relatives and grown by farmers. The island of Timor is not the centre of diversity for any of its major food crops, and the genetic diversity of each crop is therefore restricted by the variability introduced. All new world crops currently grown in Timor-Leste were introduced after the Portuguese arrived some 500 years ago. These crops include maize (*Zea mays* L.), cassava (*Manihot esculenta* L.), sweetpotato (*Ipomoea batatas* L. (Lam.)), chili (*Capsicum* sp.), tomato (*Solanum lycopersicum* L.), potato (*Solanum tuberosum* L.), pumpkin/squash (*Cucurbita* sp.) and peanut (*Arachis hypogea* L.), all of which originated in the Americas.

Historical sources of crop diversity

Prior to European contact with Timor, farmers had a very limited range of food crops available to them. Human occupation of Timor-Leste started some 40,000 year ago (O'Connor 2007) and the early population relied heavily on sea produce (shellfish etc.) and tree crops for subsistence. Fruit from the Arecaceae family, such as betel nut (*Areca catechu* L.), black fibre palm (*Arenga pinnata* Merr.), sugar palm (*Borassus flabellifer* L.), coconut (*Cocos nucifera* L.) and sago (*Corypha utan* Lam.), were targeted for harvest and consumption (Oliveira 2008). Some remnants of Job's-tears (*Coix lachryma-jobi* L.) were found in an archaeological dig within a soil layer dated at 15,000 BP (Glover 1972), but it may have been used for decorative purposes and not necessarily as a food.

About 3,500 years ago another group of people—Austronesians—arrived in Timor, and they brought with them some new food crops including upland rice (*Oryza sativa* L. ssp. *indica*), foxtail millet (*Setaria italica* L.), yams (*Dioscorea* spp.), sesame (*Sesamum indicum* L.) and taro (*Colocasia esculenta* L. Schott). In addition they introduced domestic animals (pigs and dogs) and pottery (Fox 2003). However, there is very little evidence that people's plant resource use changed until the arrival of the new world crops (Oliveira 2008).

There were occasional plant introductions prior to 500 years ago through trade with the Chinese. As early as 1255 AD, Chinese traders were buying sandalwood from Timor and presumably bringing plants such as cotton, mungbean, pigeonpea, sorghum, citrus and possibly coffee (Fox 2003).

The arrival of maize and other new world crops caused an agricultural revolution in Timor. Maize was introduced to the west of the island of Timor between 1540 and 1650 (Hägerdal 2012). By 1699, William Dampier noted that Indian corn (maize) was a staple food for the islanders in west Timor. Maize quickly spread eastward into East Timor (Fox 1988); Dampier commented from the Oecussi region: "What other grain they have besides corn, I do not know" (USDA 2016).

It is unclear how quickly maize became dominant across the whole island, but when the capital of Timor-Leste was moved to Dili in 1769, maize grain was often used to pay tax (finta) to the Portuguese. By the late 1850s Timor-Leste exported maize (Shepherd and Palmer 2014).

Agricultural development in Timor has been dependent on farming families having access to new crops, and being able to select seed and other planting material from these crops for themselves and to trade with others. Over the centuries a large number of crops have been collected and evaluated, resulting in rural and home gardens being very species-rich. Present-day Timorese households cultivate on average more than 10 species of field crops and collect products of many other plant species from the wild (da Costa et al. 2013; Erskine et al. 2015).

Targeted plant introductions

There has been a long history of targeted plant introductions into Timor. Many are not documented, and their history has been lost. However we do know that in 1900, under the government of Celestino da Silva, the first agricultural experimental stations were established in Portuguese Timor. Among the more important new crops grown at the time were Liberian coffee (*Coffea liberica* Hiern), robusta coffee (*Coffea robusta* L. Linden), African oil palm (*Elaeis guineensis* Jacq.), tea (*Camellia sinensis* (l.) Kuntze), rubber (*Hevea brasiliensis* Müll. Arg.), cacao (*Theobroma cacao* L.), lipstick tree (*Bixa orellana* L.), quinine tree (*Cinchona succirubra* Pavon) and "several varieties of subsistence plants, mainly vegetables" (Cinatti 1964).

Recent introductions

From independence in 2002, the Timor-Leste Ministry of Agriculture and Fisheries (MAF) with the help of one of its development partners, the Seeds of Life (SoL) program, purposefully tested diverse varieties with Timorese farmers, allowing them to choose what seed to keep and grow again. To provide farmers some novel and good varietal options, germplasm collections in international agriculture research centres were accessed to increase the diversity of local genetic resources.

Over the last 60 years, international agriculture research centres have developed and released superior varieties of a wide range of food crops. These include rice from the International Rice Research Institute (IRRI), maize and wheat from the International Wheat and Maize Improvement Center (CIMMYT), potato and sweetpotato from the International Potato Center (CIP), peanuts and pigeonpea from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), cassava from the International Center for Tropical Agriculture (CIAT) and various crops from the International Institute for Tropical Agriculture (IITA). All these centres aim to reduce rural poverty, increase food security, and improve human health and nutrition. Not only do the centres target increased production, they also focus on improving the nutritional value of staple crops and increasing the pest and disease resistance of released varieties.

By testing varieties from international centres, farmers in Timor-Leste have been provided with increased opportunities to source and select productive, nutritious and disease-resistant food crops and varieties for their households. This has included sourcing a small set of varieties from national and international research centres specifically selected to suit climatic conditions in Timor-Leste and testing these on research stations and farmers' fields.

Guiding principles for crop introductions

All introduced crops and varieties were chosen to be suitable for subsistence farmers. Imported germplasm needed to be suitable for farmers to generate their own planting material. To this end, all introductions have been of clonal (potato, sweetpotato and cassava), pure line (rice and legumes) or open-pollinated composites (maize). No introductions were hybrids, and there were no genetically modified (GM) materials.

Crop variety introductions

More than 550 crop germplasm lines were imported into Timor-Leste over a 14-year period (Table 1). Most of the introductions were during 2000–05 and included two tropical cereals (rice and maize), two temperate cereals (wheat and barley), tuber crops (cassava, potato and sweetpotato) and a wide range of legumes. With the exception of winged bean and perhaps pigeonpea, none of these crops were found in Timor-Leste 500 years earlier. It is highly likely that the recent introductions significantly increased the genetic diversity of all cultivated crops within the country.

At each introduction, 50–200 g or a few runners or canes of each test line were imported. The imports were facilitated by an import permit obtained from the MAF Division of Quarantine and Biosecurity. The planting materials were accompanied by a phytosanitary certification and a material transfer agreement (MTA). The MTA states the allowed use of the planting material and the GM status of the material. In all cases the MTA declared the material was not of GM origin, and the seed was free to use.

The newly introduced planting material was maintained in pure form and lines of interest were multiplied for further evaluation on research stations and on farms. Once multiplied, there is no ongoing dependence on seed supply from overseas. At the time of release, most seed would have passed through at least six generations. Very little of the imported material found its way into farmers' fields, with only 18 of the 557 tested lines being released as national varieties (Table 2).

Introductions were targeted at varieties that have a good chance to be adapted to conditions in Timor-Leste. For example, only maize populations resistant to the disease downy mildew—widespread in Timor—were considered for introduction. With peanut, only varieties with a high level of resistance to leaf diseases (late and early blight) were considered. In the latter years, introductions targeted varieties with improved nutritional quality. This included sweetpotato varieties with yellow flesh (high in pro-vitamin A, beta-carotene) and maize varieties with resistance to aflatoxin and high levels of beta-carotene.

In parallel, local germplasm collected within Timor-Leste was also tested through all steps of the evaluation process. Selections were initially made for their superior characteristics. This could be for their large cob size in the case of maize, large roots for cassava, or exceptional taste or storage quality. Some of the local varieties make their way to the final phase of on-farm testing. In 2015–16 there were three local varieties being tested in on-farm trials and under consideration for release (Tables 3 and 4).

Evaluation of introduced varieties

Initial testing

Initial testing and evaluation of germplasm imported by MAF is under strict scrutiny at one or more research stations in Timor-Leste. In this observation phase, each variety is checked for general adaptation to Timorese cropping systems and compared with local varieties. Observations include the plant's growing period, disease susceptibility and overall general suitability. Test lines are discarded if they are late flowering, have extreme sensitivity to a disease complex, are too short, too tall or have a generally poor or unsuitable growth habit.

Replicated trials and taste trials

The second phase of evaluation is to include test lines surviving the observation trials in a series of replicated trials. These trials are replicated across a number of agro-ecosystems depending on availability of suitable research locations. Typically there are four or five locations for tropical crops, one or two for temperate crops, and between two and four for rice. Twenty or thirty varieties are evaluated at each location and trials are repeated for at least two seasons. Replicated trials of a range of species have been conducted since 2000 (Piggin and Palmer 2003). In later research, the nutritional quality was measured as well, for example beta-carotene in sweetpotato (Williams et al. 2013).

Table 1. Number and source of variety introductions by MAF, 2000–14.

Species	Year	Source (institution)	Country of origin	No. of entries
Maize	2000	CIMMYT	India	29
	2005	CIMMYT	Philippines	13
	2010	CIMMYT	Zimbabwe	36
	2012	RICC	Indonesia	1
	2013	IITA	Nigeria	20
Cassava	2000	CIAT	Thailand	46
	2006	CIAT	Thailand	9
Rice	2000	IRRI	Philippines	38
	2006	IRRI	Philippines	60
Rice (dryland)	2000	IRRI	Philippines	12
	2006	IRRI	Philippines	90
Pigeonpea	2005	ICRISAT	India	9
Peanut	2000	ICRISAT	India	15
	2006	ICRISAT	India	45
Sweetpotato	2000	CIP	Indonesia	16
	2006	CIP	Indonesia	16
Potato		CIP	Indonesia	12
Mungbean	2000	ILETRI[b]	Indonesia	6
Mungbean	2007	HRC[c]	Australia	15
Soybean	2000	ILETRI	Indonesia	6
Soybean	2014	ILETRI	Indonesia	1
Cowpea	2000	ILETRI	Indonesia	2
Wheat	2007	HRS	Australia	30
Barley	2007	HRS	Australia	30
Total				557

RICC = Indonesian Research Institute for Cereal Crops; ILETRI = Indonesian Legume and Tuber Crops Research Institute; HRC = Hermitage Research Centre (Australia); all other abbreviations are given in the text.

In addition to yield data, farmers' taste preferences are measured. This evaluation is conducted soon after harvest and involves a number of local farmers (about 30) scoring the acceptability of the food products made from the different varieties. After tasting, farmers score each variety for taste and desirability. At the end of the evaluation, farmers are asked to choose two varieties they would like to grow. Farmers' preferences and taste evaluations are used to define the preferred variety and to record their overall preferred attributes for further varietal importation and evaluation (Borges et al. 2009). Gender preference is particularly noted at this stage. Individual preference is recorded, and analysed to discern differences between women's and men's taste/preference. Very rarely have there been gender differences in preference, and none consistent over time and across locations (SoL 2013).

For some species there are very clear taste preferences. For example, red rice or fragrant rice is always preferred to non-fragrant rice. Preference for red and fragrant rice is consistent across years and locations. For sweetpotato, taste preferences changed depending on the group. At some locations the evaluators liked cooked sweetpotato that crumbled in the mouth and was suitable for eating at breakfast with coffee (SoL 2013). Other groups preferred a wetter sweetpotato with a texture more like boiled pumpkin. With cassava, some farmers rejected any bitter-tasting varieties, while others preferred this type because it stores better and has good animal eating qualities.

In response to diverse taste preferences, the MAF has released a range of varieties to suit a range of preferences. For example, at least one white and one yellow maize has been released. In cassava varieties, one bitter and two sweet varieties have been released. In sweetpotato, the released varieties include yellow- and white-fleshed varieties, as well as different eating textures.

On-farm testing

The third and final phase of variety evaluation is on-farm testing. In this stage, between one and four test varieties are compared with local varieties by farmers in their fields. The hypothesis tested in this phase is whether the varieties that performed well on research stations will also perform well and be acceptable to farmers when grown under local conditions. Farmers are in control of the experiment, deciding the time to plant, planting density, level of weeding and other agronomic factors. The new varieties are planted on 5 × 5 m plots, next to a plot the same size of the current local variety to facilitate observations between varieties. Because local agronomic practices are used, less than 1% of the testing locations had any fertiliser added and there were no additional inputs at this stage.

Not all farmers are interested in testing new varieties. However, more than 80% of farmers approached participated in the on-farm testing between 2000 and 2015. For those who chose not to participate, the main reasons were that the amount of seed they were given was not enough, or they were content with their current varieties.

At harvest, the researcher and farmers compare the varieties. Production from the plots belongs to the farming family and they can use it as they choose. At a small number of on-farm testing sites, a field day was conducted with neighbouring farmers attending to contribute their opinions on the test varieties. Where possible, the different varieties were cooked and eaten to evaluate the taste and acceptability of varieties. The best local variety was always included for comparison.

After two years of positive testing with farmers, varieties can be considered for release. Both quantitative and qualitative data obtained from the on-farm testing are essential for the evaluation of the new varieties. For example, when sweetpotato Hohrae 1 and Hohrae 3 were first tested by farmers in 2005, a number of farmers reported selling the tubers and earning more than $20 from the 25 m^2 plot. This gave the variety release committee confidence that Hohrae 1 and Hohrae 3 were very acceptable in the market. Similarly, more recently farmers in Venilale reported earning more than $50 selling fresh winged bean in the local market, based on just three varieties and plots of 25 m^2.

On-farm testing provides sufficient data to decide on varieties for release, and also gives an opportunity to explore the effect of agronomic practices on yields. In the case of peanuts and maize, the results of the on-farm testing were used to produce recommendations on best agricultural practices in 2012 (Williams et al. 2012a, b).

Thirty-five varieties were evaluated in on-farm trials in more than 4,000 experiments over the 11-year period from 2005 to 2016. Of the 35 varieties tested, 18 were released, 12 were discarded and 5 were under evaluation during the 2015–16 wet season (Tables 2 and 3). All varieties under test by farmers were sourced from local or introduced varieties. In the 2015–16 testing cycle three of the varieties under test were sourced within Timor-Leste—one red rice, a purple sweetpotato and a high-yielding peanut.

Table 2. Maize and rice varieties tested in on-farm experiments, 2005–16.

Species	Test name	International name	First year of OFDT testing	Year of release	Varietal name
Maize	M03	LYDMR	2006	2007	Sele
	M01	Suwan5	2006	2007	Suwan 5
	Har05	DMRSSyn024/DMRSSyn021	2007	Not released	
	Har12	V036=PopDMRSRE(MOZ)F2	2007	Not released	
	P07	CMU Var12	2008	2012	Noi Mutin
Rice	PSBRC54	PSB RC 54	2006	2007	Nakroma
	PSBRC80	PSB RC80	2006	Not released	
	PSBRC82	PSB RC 82	2013	Not released	
	Matatag 2	Matatag 2	2013	Not released	
	Angelica	Angelica		Not released	
	M17	PR26645-B-7	2014	2016	Nakroma 1
	N02	NA (local)	2014	Under test	

OFDT = on-farm demonstration and trial.

Table 3. Non-cereal varieties tested in on-farm experiments, 2005–16.

Species	Test name	International name	First year of OFDT testing	Year of release	Name
Sweetpotato	CIP 1	B0053-9	2006	2007	Hohrae 1
	CIP 6	AB96001.2	2006	2007	Hohrae 1
	CIP 7	BB9702.1	2006	2007	Hohrae 1
	CIP 4	AB94078.1	2009	Not released	
	CIP 8	BB96110.8	2009	Not released	
	CIP 83	CIP440001		2016	Darasula-CIP
	Baucau purple	NA (local)	2014	2016	Sia-LT
	CIP 72	CIP440429		Not released	
Peanut	Pt 05	ICGV 88438	2006	2007	Utamua
	Pt 14	ICGV 96165	2009	Not released	
	Pt 15	ICGV 97128	2009	Not released	
	Pt 16	ICGV 98378	2010	Not released	
	Pt 142	IGCV 99174	2015	Under test	
	Local boot	n.a. (Local)	2015	Under test	
Cassava	Ca 15	OMM 90-03-100	2008	2009	Ai-Luka 2
	Ca 26	MLG 10169 / Gading	2008	2009	Ai-Luka 4
	Ca 107	Rayong 72	2012	Not released	Ai-Luka 1
Red bean	Mwirasi	Mwirasi	2014	2016	Fleisha-RW
	RWV1384	RWV1384	2014	2016	Ululefa-RW
Mungbean	Delta	Delta	2014	2016	Kiukae-AV
	Merpati	Merpati	2014	2016	Lakateu-AV
Soybean	Anjismoro	Anjismoro	2015	Under test	
	Orba	Orba	2015	Under test	

Released varieties

Eighteen improved crop varieties identified by the research program were released by MAF by mid-2016. The initial seven varieties were released by the variety release committee on 8 March 2007. These are two yellow maize, three sweetpotatoes, one rice and one peanut. All released varieties had undergone evaluation under on-station conditions over the period 2000–05 and in later years.

Two cassava varieties were released by MAF on 27 August 2009 and multiplied in 2009–10 for distribution to seed producers. These varieties were released as Ai-Luka 2 and Ai-Luka 4. A third, bitter cassava variety for starch production, was released in May 2014. This variety, named Ai Luka 1, is being extensively promoted by Cooperative Café Timor (CCT) as a second cash crop for farmers.

A high-yielding white maize variety evaluated from 2009 to 2012 was released on 27 July 2012 with the name Noi Mutin (white darling).

A further seven varieties were released on 7 April 2016. These included two sweetpotatoes, two mungbeans, two climbing beans and one rice variety.

Adoption

The level of adoption by farmers after 3 years of on-farm testing was measured in 2009 (Lacoste et al. 2012). This survey showed that 80% of farmers grew the new varieties in the following year, but the number reduced in each subsequent year. After 3 years the adoption rate was about 50%. Lack of seed of the desired varieties was the most common reason for dis-adoption. Surprisingly frequently, farmers had a crop failure, or lost stored seed of the desired varieties. The development of village seed production groups has resulted in many more farmers having access to planting material of the new varieties (Kunwar et al. 2016).

By 2014, the national-level adoption of the newly released varieties was quite high. A national adoption survey reported that 33% of all farming households were using one or more SoL varieties (SoL 2014). This was measured by a random sample of rural households in all districts. The national level of adoption nearly doubled between 2011 and 2014 (Table 5). This increase is a combination of more seed becoming available over time and a wider selection of available varieties. The rate of adoption is greatest for the yellow maize variety Sele (20% nationally) released in 2007. The release of a white maize variety (Noi Mutin) in 2012 allowed farmers to grow an improved variety based on their colour preference.

Value of increased income

The farm gate value of the extra produce in 2014 was estimated by using data from the adoption survey and yield increase data from the on-farm research. In the 2014 cropping year, MAF-released varieties increased the value of farm production by US$4.0 million (Table 6). This value is spread over 40,957 households, indicating that each adopting household produced just under an extra US$100 of production. This is consistent with adopting households reporting more food production and a short hungry season (Spyckerelle et al. 2016).

Table 5. Adoption of released varieties based on SoL surveys, 2011–14.

Species	Variety	Yield advantage (%)	Adoption rates 2011–14 (%)		
			Base line survey (2011)	Mid-term survey (2013)	Adoption survey (2014)
Any variety			18	25	30
Maize	Sele	50	13	15	20
Maize	Noi Mutin	46	NA	2	10
Sweetpotato	Hohrae 1,2 and 3	131	7	7	9
Peanut	Utamua	54	16	11	12
Cassava	Ai Luka	15–40	3	3	5
Rice	Nakroma	24	11	15	14

Table 4. Details of the 18 improved varieties released by MAF, 2007–14.

Species	Variety	Yield advantage (%)	Suitability	Notes
Maize	Suwan 5	54	Broadly adapted to all maize-growing locations in T-L. Sheath does not always cover cob, resulting in weevil susceptibility	Resistant to downy mildew and stalk rots
Maize	Sele	50	Broadly adapted to all maize-growing locations in T-L	Resistant to downy mildew and stalk rots
Maize	Noi Mutin	46	White maize variety, broadly adapted to all maize-growing locations in T-L	Resistant to downy mildew and stalk rots
Sweetpotato	Hohrae 1	102	Recommended only at elevations above 500 m above sea level	Excellent taste and texture; crumbly texture when boiled
Sweetpotato	Hohrae 2	91	Broadly adapted to all sweetpotato-growing regions in T-L	Excellent taste and texture; a wet texture when boiled
Sweetpotato	Hohrae 3	131	Broadly adapted to all sweetpotato-growing regions in T-L	Yellow fleshed, with excellent levels of vitamin A; moist texture when boiled
Sweetpotato	Darasula-CIP	131	Broadly adapted to all sweetpotato-growing regions in T-L	Yellow fleshed with high levels of vitamin A; dry crumbly texture when cooked
Sweetpotato	Sia-LT	180	Broadly adapted to all sweetpotato-growing regions in T-L	Stunning purple skin and purple flesh. Excellent eating quality, with high levels of antioxidants
Peanut	Utamua	54	Large seeded peanut, good for commercial sale. Resistant to leaf yellowing and early and late leaf spot	Dormancy in seed means no germination during harvest, but needs 3 months between harvest and replanting
Cassava	Ai-luka 1	43	Broadly adapted to all cassava-growing regions in T-L	Bitter taste due to HCN levels. Best used as a source of industrial starch
Cassava	Ai-luka 2	46	Broadly adapted to all cassava-growing regions in T-L	Sweet eating
Cassava	Ai-luka 4	15	Broadly adapted to all cassava-growing regions in T-L	
Rice	Nakroma	24	Broadly adapted to all rice-growing regions	Excellent eating quality due to slight fragrance
Rice	Nakroma 1	29	Broadly adapted to all rice-growing regions. Flowers a few days earlier than Nakroma	Excellent eating quality due to aromatic grain quality
Mungbean	Lakateu-AV	29	Short-season productive variety, requiring one or two harvests	Dull seed coat
Mungbean	Kiukae-AV	30	Short-season variety, very synchronous maturity requiring only one harvest	Shiny seed coat
Climbing bean	Fleixa-RW	54	Long-season variety, able to produce beans over three to four harvests, adapted to areas above 600 m elevation	Purple seed coat, highly desirable for adding colour to meals
Climbing bean	Ululefa-RW	66	Medium season length, producing pods for three harvests, adapted to areas above 600 m elevation	Maturing pod turns red before drying off. Small seeds, red/pink in colour

T-L = Timor-Leste.

Adaptation and local varieties

It is very surprising to many people that varieties from overseas can be adapted to the conditions in Timor-Leste, but this is indeed the case. Of all the released varieties, they appear more adapted to the Timor-Leste environment (physical and cultural) than local varieties. There are a number of reasons for this, such as: (1) the environment in Timor is similar to other environments in the world; (2) imported varieties have been specially bred for broad based adaptation; (3) Timorese food crops probably have a narrow genetic base; and (4) selection pressure on the food crops in Timor-Leste has been inconsistent over time.

The Timorese environment

Located in the tropics (8.5–9.5° S), Timor-Leste experiences a similar climate to many other countries in the tropics. The high-altitude areas (temperate climate) in Timor-Leste are less common in other tropical countries, but they are not unique. The soils of Timor-Leste have derived from similar parent material and by similar processes to other locations, making Timor soils similar to those in other countries (Bob Gilkes personal communication).

Selected varieties are broadly adapted

Modern breeding programs have produced broadly adapted varieties, often with multiple disease and insect resistance. For example, in maize the newly introduced varieties have resistance to the fungal disease downy mildew, as well as to various stalk rots. The stalk rot resistance means that modern varieties are less likely to lodge (fall over) at the end of the season. The maize varieties Sele, Suwan 5 and Noi Mutin all have stalk rot resistance, and are less prone to lodging. The genes for this resistance are not common in local maize populations, and the trait has not been selected for locally.

Narrow genetic base

It is likely that historical crop introductions did not originate from a wide range of locations. Historical crop plant introductions have brought many new crops to Timor, but perhaps not many introductions of each species. Most likely, these almost accidental introductions have been sporadic and have led to a narrow genetic base within Timor. However, even with this narrow genetic base, Timorese farmers have been able to select and choose varieties that survive and produce a yield in their new environment.

Selection pressure in Timor has been inconsistent

During times of population displacement, local seed systems experience massive disruption (Richards et al. 1997). During times of crisis or poor weather, seed carefully curated by Timorese farmers is often lost. The breaks in the seed saving/selecting and replanting cycle have further reduced the genetic diversity available to farmers. During the early years following the Indonesian invasion, many farming families were in hiding in protected areas, and away from their land for up to three years. As a result, much of the local seed that they had carefully selected and stored was lost. When they returned to their lands, they were forced to rely on non-local

Table 6. Value of adopted varieties, 2014.

Variety	No. of households growing SoL varieties[a]	Area farmed per household (ha)[a]	Increase in yield (t/ha)[b]	Price (c/kg)	Value of product (US$)
Sele	22,180	0.3	0.7	35	1,630,234
Noi-Mutin	11,090	0.3	0.4	35	465,781
Nakroma	6,881	0.4	0.75	40	825,703
Utamua	4,386	0.1	0.7	70	214,894
Ai-Luka	5,419	0.2	4	5	216,760
Hohrae	6,805	0.1	5	20	680,524
Total	40,957[c]				4,033,895

[a] Source: Adoption survey (SoL 2014).
[b] Source: OFDT results.
[c] Not an arithmetic total, as some households plant more than one released variety.

seed. One example of this was the village of Hatas in the Maliana district. When the community returned to their farms in 1978, after 3 years in the hills, they had no access to velvet bean seed. It was about 30 years before this seed was returned to them by MAF researchers. Now farmers regularly use velvet bean in a sustainable maize production system, and produce seed that is distributed around the country.

Crop failure for any reason will reduce the diversity of food crops. Drought is a common cause of crop failure, and in the cropping season following the excessively wet year of 2010, the area planted to maize was reduced by 80%. As maize seed cannot be easily stored for two years, many seed populations were lost during that year.

Conclusion

Timorese farming households have always benefitted from introduced crop and animal species and varieties. The historical introduction of new world crops approximately 500 years ago, such as maize, sweetpotato, squash and chilies, changed the diet and cropping landscape of the country. The more recent targeted introductions have improved people's lives, increasing their food security. The common feature of historical and more recent introductions is that farmers have been crucial to the testing and selection of new varieties.

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Seed multiplication and distribution: selecting the best option for Timor-Leste

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Abstract

Planting good quality seed is a key component for improving productivity in all agricultural environments and is especially important in developing countries. The large yield gap between improved seed and farmer-saved seed is due to varietal differences, low seed replacement, poor seed quality and low adoption of good agronomic practices. In Timor-Leste, quality seed of improved varieties has been shown to give 15–131% higher yields than traditional varieties. However, accessing improved seed in sufficient quantities at planting time is a challenge for many farmers. The key problem faced by government agencies in developing countries is the high cost of multiplication and distribution of quality seed. This paper examines two approaches to seed multiplication and distribution implemented by the Government of Timor-Leste's Ministry of Agriculture and Fisheries in the past five years: (a) centralised certified seed production and distribution, which was practised from 2010 to 2011; and (b) decentralised community-based and commercial seed production and distribution, practised from 2012 to 2015. Certified seed produced by specialised contract growers using MAF facilities for processing and storage was found to be 2.3 times more expensive than growing seed commercially with MAF quality control supervision. In just 4 years since adopting the decentralised community-based commercial seed production approach, the seed replacement rate of two major crops (rice and maize) increased fivefold from 4% in 2011 to 20% in 2015. MAF has chosen the latter approach as the most viable option for the future.

Introduction

Seed, fertiliser and irrigation are the three most critical agricultural inputs for enhancing crop productivity in developing countries (SoL 2013). There is a large difference in yield between quality seed and seed from traditional sources (Jaffee and Srivastava 1992). Studies in Timor-Leste have shown that pure seed of improved varieties can increase yields by between 24% and 54% in cereals and legumes and 15% to 131% in cassava and sweetpotato compared with traditional varieties (SoL 2014). Despite the benefits of using improved varieties, availability of quality seed in sufficient quantities is a challenge in developing countries because of the high cost of seed multiplication and distribution.

A strong correlation exists between seed quality and improved crop productivity, with some studies showing up to 100% yield improvement (FAO 2015). Seed should be replaced regularly to maintain seed quality. Deterioration is particularly rapid in cross-pollinated crops because varieties cross in the field generating a high percentage of off-types. Self-pollinating crops may also lose viability as they become mixed over time. For hybrids seed must be replaced annually, while for self-pollinating crops the seed replacement rate (SRR) is approximately every 4 years (i.e. 25%), and for cross-pollinated crops the SRR is 35%.

The SRR is very low in developing countries. In most Asian countries it is less than 20% (Gerpacio and Pingali 2007) and in Africa it is less than 10% (Maredia et al. 1999). The amount of seed from the formal sector is estimated to be below 10% of

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all seed used in Tanzania (Ngwediagi et al. 2009), 7.5% in Uganda (Kabeere and Wulff 2008), 3.5% in Ethiopia (Atilaw and Korbu 2011) and 20% in Kenya (Wulff et al 2006). In South-East Asia the SRR is 10–25% (Gill et al. 2013).

Most countries have released higher yielding varieties and have increased the availability of quality seed to meet the needs of farming households in a cost-effective way (Fischer et al. 2014). However, seed diffusion is often slow. The major reasons for this are the low levels of seed replacement, poor seed quality and low adoption of recommended agronomic practices (Gerpacio and Pingali 2007).

This paper discusses seed multiplication and distribution experiences across Asia and Africa and examines appropriate options for Timor-Leste.

Data sources

A number of sources of data were used for this study, including published reports related to seed sector from Africa and Asia (Atilaw and Korbu 2011; Gerpacio and Pingali 2007; Kaabeere and Wulff 2008; Ngwediagi et al. 2009; Niangado 2010; Ruskie and Eicher 1997; Young 2013; Wiggins and Cromwell 1995; Wulff et al. 2006). National data from Timor-Leste included cultivated areas for the major food crops, seed production, the number of community seed production groups (CSPGs) and commercial seed producers (CSPs), statistics from the National Association of Commercial Seed Producers (ANAPROFIKO) and data from the National Directorate of Agriculture, Horticulture and Extension (NDAHE) within the Timor-Leste Ministry of Agriculture and Fisheries (MAF). Data on the costs of MAF producing certified seed were sourced from a report compiled by an intern from Columbia University (Planicka 2012). Information was also collected from MAF municipal directors, their community seed coordinators, extension staff and chiefs of CSPGs and CSPs.

Seed multiplication and distribution in developing countries

The development of a modern national seed multiplication and distribution system normally involves progression through four stages, as discussed by Douglas (1980), Pray and Ramaswami (1991), Jaffe and Srivastava (1992) and Ruskie and Eicher (1997).

- Stage 1: Farmer selection and supply. In a simple traditional seed system, most farmers save their seed for planting the following season. If a new variety is released by the national research program, seed multiplication is very low and adoption poor. The productivity of farmer-saved seed remains low.
- Stage 2: Introduction of improved varieties. The public sector tests improved germplasm (local and foreign) and releases new varieties. The public sector also produces breeder and foundation seed. Farmers start replacing traditional varieties with improved varieties and achieve improved yields. Use of other agriculture inputs is low but gradually increases over time. The private sector and non-governmental organisations (NGOs) start taking an interest in seed multiplication and distribution of public varieties albeit on a limited scale. Seed productivity is moderate.
- Stage 3: Widespread use of improved public varieties and early spread of private varieties. The private sector dominates the public sector as they play an active role in varietal research and development. The public seed sector supplies breeder seed of self-pollinated and open-pollinated varieties (OPV) of food and minor crops. The private sector focuses its efforts on seed required for niche crops (cash crops), low-volume high-value crops and hybrids that give good profit margins. Seed multiplication and distribution become more diverse and decentralised. There is increased involvement of agro-input dealers in selling seed. Seed producers put certification labels and private brand names on their seed. The private sector becomes involved in certified seed production. Seed productivity is high.
- Stage 4: Advanced seed system. A complex but well-developed national seed system exists with different agencies actively involved (seed companies, seed traders, agro-input dealers, seed producers, seed processors, seed regulatory bodies, etc.). The private sector releases/registers most varieties of cash crops and hybrids including the production of breeder seed. Foundation, certified and commercial seeds are produced by private firms and farmer groups. The public sector limits its research to OPV and minor crops. Seed policy, law and regulations are fully functional. The seed business is fully commercialised. There is widespread use of improved seed among farmers. Seed productivity is continually increasing.

Seed systems of the majority of the countries in Africa and Asia are currently in stages 1 and 2 of development. In most African countries, such as Benin, Bukina Faso, Côte d'lvoire, Ghana, Guinea, Mali, Niger, Nigeria and Sierra Leone, seed is overwhelmingly supplied by the informal seed system, i.e. farmer-saved seed. There are a few exceptions. In South Africa and Kenya, seed from the private sector outstrips that from the public and informal seed sectors. In Senegal, on-farm seed multiplication and seed from the public sector are almost equal (Niangado 2010). There is no significant private seed sector in Bukina Faso, Guinea, Mali, Niger, Sierra Leone and Senegal, but it is gradually emerging in Ghana, Côte d'lvoire, Nigeria, Uganda and Tanzania.

In countries where private agro-input dealers are fairly well-established, donor-supported programs and NGOs promote seed fairs and seed voucher schemes to distribute seed to target groups. Seed fairs are a practical way to distribute seed in post-emergency situations (e.g. after drought, floods, earthquakes, etc.), but as the cost of organising these events is high they tend to happen only in the presence of donor funding. Government agencies rarely organise these activities on their own. Another shortcoming of the seed fair approach is the high travel cost for poor farmers living in remote locations to attend the events. Travel costs are often higher than the value of seed they receive.

The seed voucher approach for seed distribution has been effective in African countries where agro-dealers are prevalent. Through the voucher, the agro-dealers can market their seed and beneficiaries may be well targeted. The seed voucher approach is also expensive and generally implemented by NGOs, rarely by government agencies.

NGOs working in remote and under-served areas promote community seed production, where individuals or groups of farmers are encouraged to produce their own seed, store it for their own use next planting season, and distribute surplus seed to needy farmers within the community (Wiggins and Cromwell 1995). The main objective is to self-supply quality seed. This approach is effective in reaching vulnerable farmers living in remote locations but to remain effective, community-based seed production requires regular seed replacement every 3–4 years.

In South and South-East Asia the seed sector is more advanced than most African countries. There is widespread use of hybrid maize, rice and vegetables, particularly in Korea, Malaysia, Thailand, Indonesia and Vietnam. Seed multiplication is also being carried out by parastatal companies, the private sector and by community seed groups. In India for example, a parastatal company is engaged in seed multiplication and a number of private companies are involved in seed production and marketing. In Indonesia, seed is produced through farmers' cooperatives and selected multinational companies. Forward contract agreements for seed multiplication between seed companies and farmers are common.

In summary, there is no single approach that is popular in both Africa and Asia. Whether the public sector, private sector or NGOs dominate depends upon the stage of development of the national seed system. As the national seed system matures from a simple traditional seed system towards an advanced seed system, the number of organisations involved in seed multiplication and distribution increases. At the beginning of 2011, the MAF in Timor-Leste adopted a balanced approach with involvement of public and private sectors and NGOs in seed multiplication and distribution, thereby emerging from a national seed system previously in stage 1 of development.

Seed multiplication and distribution approaches in Timor-Leste

At the end of 2015, the release of new varieties and multiplication of seed for distribution to farmers in Timor-Leste has many similarities to other parts of the world where the national seed systems are in stage 2 of development. Improved germplasm of different crops is imported and evaluated against traditionally grown varieties. Seed of those lines chosen for release to farmers is maintained as breeder seed by researchers. Plant breeders increase this seed in purified quantities (foundation seed) for further highly controlled multiplication as certified seed. Certified seed may be either distributed directly to farmers or multiplied into greater quantities as commercial seed and finally community seed.

Prior to 2012, the MAF adopted a centralised approach where it was wholly responsible for certified seed production and distribution. In developing the national seed system between 2012 and 2015 it focused on the multiplication and distribution of commercial seed and community seed. The pros and cons of each of these approaches are discussed below.

Certified seed multiplication and distribution

The production of certified seed involves the use of foundation seed and the production, storage and distribution of seed under stringent quality control procedures. This approach also involves developing a contract between MAF and specialised contract seed growers who are subject to supervision and quality control inspection visits by government seed technicians during the growing season and at harvest. Trained MAF staff inspect the crop at least four times during the growing season and select seed at harvest using a previously agreed buy-back price provided the seed meets agreed production standards. When all seed production and quality control criteria are fulfilled by the seed grower, their seed is procured by MAF and taken to one of MAF's purpose-built seed processing centres for further drying, cleaning, grading, testing, packaging, labelling and storage for subsequent distribution as high-quality certified seed of officially released varieties.

In 2010–11, Timor-Leste required an estimated 2,277 tonnes of maize and rice seed to meet the national seed requirement for the following year (Table 1). Since commercial seed was not yet being produced, the distribution of certified seed was the only option for MAF to supply seed to farmers. A total of 82 tonnes of maize and rice seed was distributed that year, equivalent to 4% of the total seed requirement (i.e. SRR = 4%).

The estimated cost of producing maize and rice seed to meet Timor-Leste's certified seed requirement of 721 tonnes, based on seed replacement rate (SRR) of 35% for maize and 25% for rice, during 2011 is presented in Table 2. The seed price of $3.50 per kg includes the cost of production plus processing, storage and transportation of certified seed to each MAF municipal headquarters (Planicka 2012; Young 2013).

A cost of nearly US$2.5 million annually to service its national maize and rice seed requirement is a large expense for a small nation of 130,000 farming families (almost $20 per family). A major portion of this expense is the cost of processing and storage and then transporting the seed to municipal headquarters for distribution to farmers. If certified seed is the sole source of seed servicing Timor-Leste's annual maize seed requirement, other issues must also be considered, as follows.

- Development of specialised seed growers: From Table 2 it is evident that Timor-Leste would require more than 1,000 individual seed growers with at least 4–5 years of experience in quality seed production to fulfil the nation's seed requirements. Developing such professional seed growers poses a challenge in terms of cost, capacity building and in

Table 1. Seed replacement rate (SRR) from distributing certified seed, 2011.

Crop	Area cultivated (ha)	Seed rate (kg/ha)	Seed requirement (t)	Seed supply of improved variety (t)	Seed replacement rate (SRR)
Maize	75,804	20	1,516	32	2%
Rice	38,069	20	761	50	7%
Total	113,873		2,277	82	4%

Source: MAF (2011), SoL (2013).

Table 2. Estimated cost of producing Timor-Leste's total seed requirement in 2011 using certified seed.

Crop	Amount of seed required at 35% SRR for maize and 25% SRR for rice (t)	Total area required to produce seed (ha)*	No. of growers required at 0.6 ha/grower	Seed cost to grower (US$/kg)	National seed cost (US$/kg**)	Total cost of supplying national seed requirement (US$)
Maize	531	531	885	$1.25	$3.50	1,858,500
Rice	190	127	211	$1.25	$3.50	570,000
Total	721	658	1096			2,428,500

Note: * Area required to produce seed assumes 1 t seed produced/ha for maize and 1.5 t seed produced/ha for rice; **total actual cost of producing 1 kg of certified seed including cost of processing, storage and transport to MAF municipal office.

providing the buy-back guarantee for the quantity of seed they would produce.

- Transportation, storage and seed handling: Transportation of seed from the production sites to processing centres and subsequent distribution to farming families living in distant villages is also an issue, especially in light of the existing poor rural transport network.
- Low purchasing power: A majority of the rural population in Timor-Leste are subsistence farmers and have low purchasing power. As long as the price of seed is high, making seed available to farmers will be problematic and diffusion of improved varieties will remain low.
- Implication of distributing free seed: Government distribution of free seed was initially implemented as a short-term measure using imported seed. Distributing free seed to farming families also tends to nurture a culture of dependency which is contrary to accepted development policy and the objectives of the MAF.

Moreover, while the direct cost of distributing either locally produced formal seed or imported seed is high (about \$3.50/kg), the opportunity costs associated with imported seed distribution can be more than three times greater due to poor quality (in terms of seed purity, germination rate and less suitable varieties) and greater likelihood of late distribution and delayed planting (Young 2013).

Commercial seed production and development of community-based seed multiplication

The prohibitively high cost of MAF multiplying and distributing certified seed to farmers encouraged the introduction, in 2012, of a regulated commercial seed component to the emerging national seed system. This additional component of the formal seed sector was a step towards the development of a cheaper, more efficient and more sustainable community-based seed system.

Commercial seed production is a decentralised production, storage, processing and marketing activity implemented by organised groups of farmers operating in their home villages and known as commercial seed producers (CSPs). To be eligible to produce commercial seed for sale, all CSPs have to follow basic seed production procedures set by the seed department of the MAF National Directorate of Agriculture, Horticulture and Extension (NDAHE). These conditions were initially promulgated in National Seed System for Released Varieties (NSSRV) guidelines approved by the National Seed Council.

CSPs must initially request a 5-year registration from MAF and then an annual authorisation to multiply a specific quantity and variety of certified seed into commercial seed. CSP seed production plots and the resulting seed are checked by municipal seed officers or other personnel from NDAHE.

CSPs harvest, process and arrange for their seed to be sampled by MAF personnel and tested for physical purity, germination and moisture content in the NDAHE seed laboratory. The seed is then securely packaged in 5 kg lots in double plastic bags. CSPs market their seed using their own brand name and registration number and a pink label showing seed test results and date (Figure 1). They also market under the 'Fini ba Moris' brand of the NSSRV that assures their seed quality (Kunwar et al. 2013).

To ensure the CSPs were qualified to multiply high-quality seed, they received training from MAF extension staff on seed production, storage, processing and marketing over a 3-year period (2012–15).

Figure 1. CSP members holding packets of their commercial seed ready for sale.

The initial training was followed up with periodic monitoring support from MAF municipal extension staff and NDAHE municipal seed officers.

Nineteen CSPs were established in 2013 following the spirit of the national seed policy. By the end of 2015, 69 CSPs were in operation averaging five per municipality with at least one operating in each municipality including the Oecussi special region (Table 3). Each CSP has an average of 25 members.

The multiplication of seed by commercial seed producers dramatically reduces the cost of seed production. In 2014–15, 295 t of commercial seed of improved varieties of maize and rice was produced and distributed by MAF and its development partners to more than 40,000 farmers. This methodology increased the SRR to 20% from 4% when distributing certified seed (Table 4), and costs were reduced to approximately \$2.30/kg or US\$0.68 million annually (Table 5). From Tables 2 and 5, it can be seen that the market price of certified maize and rice seed is 2.3 times more than commercial seed.

Table 3. Registered commercial seed producers by municipality, 2015–16

Municipality/ region	Number of CSPs	Seed produced
Aileu	5	Maize, rice, peanut
Ainaro	3	Maize and rice
Baucau	12	Maize, rice, peanut
Bobonaro	7	Maize, rice, peanut
Covalima	4	Maize, rice, peanut
Dili	1	Peanut
Ermera	3	Maize and rice
Lautem	6	Maize, rice, peanut
Liquica	4	Maize, rice, peanut
Manatuto	5	Maize, rice, peanut
Manufahi	6	Maize, rice, peanut
Viqueque	8	Maize and rice
Oecussi special region	5	Maize and peanut
Total CSPs	69	

Taking into consideration the reduction in cropping area of rice and maize from 114,000 ha in 2010–11 to 73,000 ha in 2014–15, the savings were large at approximately 50%. These savings were mainly due to the fact that CSPs provided their own labour, used their own facilities (equipment, seed warehouses) and there was less distance and costs involved in delivering the seed to the local MAF municipal office. This approach also enabled MAF to cease distribution of certified seed directly to farmers from 2014, thereby dramatically reducing the need for MAF to produce large quantities of expensive certified seed and significantly improving the sustainability of the national seed system.

Seed from the CSPs (commercial seed) and some certified seed is provided to community seed production groups (CSPGs) to produce 'community seed'. Community seed is then stored for use by group members the following season and any surplus seed is shared, bartered or sold to family members or neighbours in the community. Over the past 4 years, MAF has established 1,207 CSPGs that are producing community seed. These CSPGs were originally MAF farmer groups who were trained in seed production by MAF extension staff. A CSPG is normally composed of 10–12 members. By December 2015 some 15,000 farming households were members of CSPGs and had directly benefitted from community seed production and distribution (Table 6). Neighbouring farmers were also recipients of quality seed of improved varieties produced by these CSPGs.

Table 4. Seed replacement rate distributing commercial seed, 2014–15.

Crop	Cultivated area (ha)	Seed rate (kg/ha)	National seed requirement (t)	Seed supply of improved variety commercial seed (t)	Seed replacement rate (%)
Maize	44,812	20	896	185	21
Rice	28,128	20	563	110	20
Total	72,936		1,459	295	20

Source: MAF NDAHE 2015.

Table 5. Estimated cost to produce Timor-Leste seed requirement as commercial seed, 2014–15.

Crop	Amount of seed required at 35% SRR for maize and 25% SRR for rice (t)	Total area required to produce seed (ha)*	Number of CSPs required at 5 ha/CSP for maize and rice	Cost to grower (US$/kg)	Farm gate seed price (US$/kg)	Total cost of supplying national seed requirement (US$)
Maize	314	314	63	$0.22	$ 1.50	471,000
Rice	140	93	19	$0.32	$ 1.50	210,000
Total	454	407	82			681,000**

* Area required to produce seed at 1 t seed/ha for maize and 1.5 t seed/ha for rice, 2014–15.
** Based on a similar cultivated area to 2010–11, the total cost was approximately $1,063,000.

Table 6. Number of CSPGs established as at December 2015.

Municipality	No. of CSPGs	Type of group			Number of members		Total
		Men	Women	Mixed	Men	Women	
Aileu	81	10	4	67	719	367	1,086
Ainaro	71	12	4	55	653	279	932
Baucau	127	24	1	102	1,044	426	1,470
Bobonaro	113	12	0	101	836	435	1,271
Covalima	148	39	2	107	1,519	451	1,970
Dili	26	0	2	24	190	252	442
Ermera	72	9	6	57	597	365	962
Lautem	137	21	1	115	903	498	1,401
Liquica	62	19	2	41	422	220	642
Manatuto	72	20	1	51	666	147	813
Manufahi	67	22	7	38	623	260	883
Oecussi	99	8	10	81	706	554	1,260
Viqueque	132	30	1	101	1,285	404	1,689
Timor-Leste	1,207	226	41	940	10,163	4,658	14,821

CSPGs generally multiply seed in a single plot approximately 0.2–0.25 ha in area. The plots are managed collectively by the groups. Open-pollinated crops are isolated from other crop varieties. The seed requirement for the following year is collectively stored in airtight containers to maintain seed quality. Neither the crop nor the seed is quality inspected or certified by MAF, but if the group follows seed production protocols including proper drying, grading and airtight drum storage the resulting product is good quality. As seed is primarily produced to meet group members' needs, it is in the group's interest to maintain high production standards. MAF extension staff assist CSPGs to replace their seed with government-certified or commercial seed every 3–4 years for maize and 4–5 years for rice and peanut. Since community seed is not and cannot be quality assured, under NSSRV guidelines CSPGs must not sell their seed in the marketplace.

MAF extension staff provided seed production training to the initial batch of 280 CSPGs established prior to and during the 2011–12 wet season. These groups were trained to produce seed of maize, rice and peanuts and planting material (cuttings) of cassava and sweetpotato. One hundred and eighty-five of these groups successfully harvested maize, rice and peanuts (Table 7). By the 2014–15 crop season, the number of trained groups had increased to 1,207 of which 1,135 were producing seed of improved varieties of maize, rice and peanuts. In 2015, there were three or four CSPGs in each of 363 (82%) of the total 442 *sucos* in Timor-Leste. These produced a total of 191 t of community seed.

Table 7. Seed production by community seed groups in 2011–12 and 2014–15.

Year	Crop	No. of harvested CSPGs plots	Total community seed (t)	Average seed production (kg/CSPG)
2011–12	Maize	90	13	148
2011–12	Rice	55	16	300
2011–12	Peanuts	40	3	68
Total		185	32	
2014–15	Maize	670	104	155
2014–15	Rice	185	75	403
2014–15	Peanuts	280	13	47
Total		1,135	191	

Source: MAF NDAHE 2015.

Discussion

Of the two different seed multiplication approaches implemented in Timor-Leste, the community-based approach was the most successful. This approach was able to produce and distribute high-quality commercial seed to the farming community at approximately half the cost of the centralised certified seed option, while leaving a significant profit margin as a production incentive for the commercial seed producers. As production of commercial maize and rice seed expands to around 400 t/year it is anticipated that the price of commercial seed will reduce to around $1.00/kg (i.e. approx. 100% above the grain price) and agricultural input suppliers will become increasingly involved in commercial seed sale and distribution (e.g. at $2.00/kg).

The major costs incurred in the certified seed approach are seed processing, storage and transport from producers' seed plots to government seed processing and storage facilities. Additional costs include overheads and redistribution of certified seed from the centralised facilities to MAF municipal offices. Community and commercial seed are more widely and readily available across the farming communities at planting time and farmers face less delay in receiving the seed. Commercial seed production not only ensures that a secure supply of quality seeds is locally available to farming families at planting time, it also improves farm family autonomy and independence and encourages transition to commercial agriculture by commercial seed producers and their farm family members.

CSPGs generate their own seed at low cost, but to maintain quality they should systematically replace their parent seed stock with high-quality commercial seed every 3–4 years for maize and every 4–5 years for rice and peanuts. Groups that follow good agricultural practices tend to maintain their seed purity better than those that follow the guidelines less stringently. With experience the groups require less extension support, but continued technical support and connections to a supply of commercial seed (or certified seed) are critical to the ongoing success of the program.

It was observed that confidence among MAF team members working within the national seed system at the national and municipal level has dramatically improved over the past 4 years. For some years to come MAF has committed to locally purchasing its annual seed requirements from CSPs for redistribution to farming households rather than import more expensive, less suitable varieties with less assurance of seed quality. This is great news for CSPs as the market for seed of major food crops in the private sector remains undeveloped, no doubt partly due to MAF distribution of free seed.

Since the seed system in Timor-Leste is currently in its infancy, considerable effort is required to extend the benefits of MAF-released varieties to as many farmers as possible for at least 3–4 more years. This action should further raise awareness of both the benefits of planting quality-assured 'Fini ba Moris' brand seeds and the superior productivity of MAF-released varieties, thereby improving overall market demand for commercial seed.

CSPs multiply seed for sale. As of 2015, the largest seed sales were to the government, NGOs and development partners. In recent years, the amount purchased has increased to fulfil requirements. However, CSPs currently multiply seed at considerable cost under speculation of being able to sell their seed the following year. In order to avoid this kind of uncertainty and expecting CSPs to take all the business risk, a forward contract system could be introduced and institutionalised. This system would provide a guarantee regarding price, quantity, quality and time for delivery to the seed buyer and at the same time reduce risk for seed producers.

During the years that the Timor-Leste government purchases seed locally, MAF will need to set a national target for SRR for all major crops for which MAF-released varieties are available. MAF personnel at the national, regional and municipal level should also meet early in the second quarter of each year to forecast seed requirements for the following year and formulate a supply plan for discussion, finalisation and endorsement by the seed planning and production coordination committee of the National Seed Council.

In Timor-Leste, most improved food crop varieties are public goods released by MAF over the past decade. The private sector, NGOs and agencies all rely on accessing these varieties. As they are public goods, potential seed buyers from the private sector have limited incentive in promoting and marketing varieties over which they have no commercial control. Keeping the public informed about the benefits of their varieties and stimulating future demand for commercial seed will remain the responsibility of the government and CSPs for a number of years. One method of achieving this is to support CSPs with seed-related services such as advertising material and market information. Additional support could also be provided in the form of fertilisers, herbicides and pesticides if government funding allows.

There has been a wealth of information on nutrition and agriculture in Timor-Leste, however seed security actions are not pragmatically tied to better nutritional outcomes (Franzo 2013). Introduction of targeted seed security interventions linked to nutrition security would be the smart way forward in the future (USAID/OFDA 2013).

Each CSP has an individual label which identifies its particular product. It is therefore important for the CSPs to maintain high standards to build their brand image and reputation. As demand for good quality seed grew during the years leading up to 2015, CSPs commenced interacting with each other to establish a system for marketing bulk quantities of seed and ensuring the quality of seed from different sources was consistent. At the beginning of 2015, representatives of each of the 69 CSPs met to discuss quality issues, storage and marketing of their seed. During a meeting in March 2015, these CSP representatives formed a national association of commercial seed producers locally known as ANAPROFIKO (*Assosiasaun Nasional Produtor Fini Komersial*). In preparation for the 2015–16 harvest, ANAPROFIKO became a vehicle for input supply (e.g. providing plastic bags and labels to each CSP for packaging their seed to uniform NSSRV standards) and for defending the rights of CSPs on seed-related issues. However, ANAPROFIKO is in its infancy and follow-on support will be required in the near term for it to negotiate on behalf of all CSPs for large seed sales to government, NGOs and other organisations and to provide effective services to members.

The long-term future of the national seed system in Timor-Leste relies on increased involvement of the private sector. Currently, agro-input retailers sell mainly high-value low-volume hybrid vegetable seeds. A few sell seed of OPVs released by MAF but most do not because they see the government distributing large quantities of maize and rice free to farmers. Hence, there is no incentive or demand for seed of these crops to be marketed through private sector outlets. However, as subsidised seed multiplication and distribution is gradually phased out, the private sector should become increasingly involved. As in other countries, government agencies will continue to support varietal development and release and the distribution of seed to vulnerable households. These agencies will also need to create an enabling policy and regulatory framework to encourage the private seed sector to flourish.

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Collection and on-farm conservation of plant germplasm in Timor-Leste: prospects and challenges

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Abstract

On-farm or in situ plant germplasm conservation has been critical to successful food production since the beginning of agriculture. It has also been key to the adaptation of food crop species to seasonal variations and stresses and in meeting the food production criteria of smallholder farmers. These farmers are not only interested in higher yields but also in the crop's adaptability to different conditions, marketability of the products, their capacity to be stored, nutrition, taste, cultural characteristics and milling quality. In Timor-Leste where a majority of farmers are involved in subsistence agriculture, these crop characteristics are particularly important to meet national food and nutrition demands. This paper describes the close collaboration between farming communities, government departments and non-governmental organisations in Timor-Leste dedicated to enhancing seed security and diversifying seed systems at the household and community level. Challenges faced during in situ plant germplasm conservation are discussed and the progress made by RAEBIA in the collection, conservation and distribution of plant genetic material in Timor-Leste is presented. Discussion includes potential ways forward for improving community seed banks in Timor-Leste.

Introduction

Plant and animal genetic diversity has been generated since agriculture started approximately 12,000 years ago (National Geographic 2016). Supporting the use and adaptation of this diversity is one of the best ways to safeguard food supply. This can be done through in situ conservation where living collections of diverse seed varieties are maintained on-farm. Such germplasm can continuously adapt to changing and increasingly challenging growing conditions, and is a vital resource for food production and food security in a time of annual climate variability and growing food shortages (Martins and Walsh 2013). This diversity can be supported by ex situ seed banks, such as the Svalbard 'Doomsday Vault' (Crop Trust 2016) and other national and international gene banks around the world.

The most important considerations for germplasm collection and conservation with farmers as the leaders were summarised by Brush (1991): "Five principles should guide planning of *in situ* conservation: complementarity with off-site conservation, minimal institutional development, continuity with existing programs, meeting the development goals of increasing income and food, and accepting germplasm as an international public good."

In addition to addressing these principles for germplasm collection and conservation, four special considerations need to be taken into account in Timor-Leste. These are the country's climate, past losses of biodiversity, land tenure issues and the lack of local farmers' organisations.

Scientists and farmers alike have noted that inter-species and intra-species diversity are crucial for crops to adapt and survive in unfavourable environmental conditions. Studies clearly demonstrate the importance of crop diversity in counteracting the

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effects of drought and other environmental hazards, and ensuring family food security. For example, farmers cultivate early- and late-maturing varieties of the same crops to increase the period of food availability and to spread the workload at harvest time. Field observations also show that the range of crops planted in specific agro-ecological sites is determined by a careful selection process. By planting different varieties of cereals and legumes, farmers benefit both from more productive but less hardy varieties, while at the same time hedging this risk with varieties that are less productive yet more tolerant to drought and other adverse climatic conditions. For example, sweetpotato is often cultivated between rows of corn in Timor-Leste and appropriate varieties should be conserved (Figure 1). Crop diversity enables people to mitigate climate- and market-related risks, cope with varying availability of labour, and secure a harvest even if they cannot sow at the normal time (Martins and Walsh 2013; Witcombe et al. 2001).

The existence of a reasonably stable climate cycle assists farming communities in improving their seed security and diversity. However, this balance is fragile. For example, in the 2015–16 growing season in Timor-Leste, crops were affected by a severe El Niño event and by the end of January 2016 only 50% of expected rainfalls were experienced in many areas (MAF 2016). By this stage, up to 50% of farmers had insufficient rainfall to germinate their maize crops. Farmers lack knowledge of and access to crop varieties that can cope with such climatic conditions. It is therefore very important that we have a strong program for the collection, assessment, conservation and use of a wide diversity of plant germplasm, and both local and introduced varieties and landraces should be included.

Figure 1. On-farm conservation of the sweetpotato variety Hohorae and local varieties at Batara-Laclubar.

Challenges for the collection and conservation of plant germplasm in Timor-Leste

Loss of diversity

Human consumption of a range of plant resources was high in Timor-Leste prior to the arrival of colonialists 400 years ago. During the Portuguese era (1615 to 1975) this food crop diversity started to diminish when plantation-based farming, particularly for coffee, vanilla and rubber, was introduced. The introduction of rice and maize further eroded the consumption of key native food crops, particularly yams and beans (Erskine et al. 2016). Similarly, during the Indonesian occupation (1975–99), a monoculture system was promoted particularly with an expansion of the area of rice under irrigation (Shepherd 2013). The government of the day also encouraged the use of Green Revolution packages of seeds, fertilisers and pesticides, further limiting the area cultivated to farmers' varieties. To help stem this flow, in 1999 the non-governmental organisation (NGO) USC Canada commenced a program on sustainable agriculture concentrating on livelihoods and biodiversity-based agriculture. This program was called the Seeds of Survival (SoS) program (USC Canada 2015). In 2013, the local NGO RAEBIA took over the reins of the program and turned to identifying and conserving local food crop varieties. Included were field crop seeds and planting material of taro, yam, cassava, sweetpotato and some vegetables and fruits.

Lack of secure land ownership

For the preservation of plant genetic resources at the household and community level it is essential that farmers have secure ownership of the land they cultivate. It is therefore important to support government policies and programs that provide farmers with clear land titles.

Weak farmers' organisations and networking

Another challenge preventing efficient transfer of local seed from one family to the next in Timor-Leste is the lack of connections farmers have across the country. There are no coordinated bodies or farmers' associations that link key seed-saving farmers to others. This limits germplasm exchange, testing across agro-ecologies and the mapping of available diversity within the country.

Process of germplasm collection and conservation

Technical support from USC Canada and numerous exchange visits of workers in community seed banks in Timor-Leste to Nepal, Ethiopia, Canada and Bangladesh helped develop the national farmer-based germplasm collection currently being coordinated by RAEBIA. The five steps recommended by Sthapit et al. (2012) and followed by RAEBIA for effective germplasm collection and conservation are: (a) collection; (b) multiplication (Figure 2); (c) documentation; d) conservation; and (e) distribution. These are described in more detail below.

Figure 2. Arquelino Da Cunha conserving kankun (water spinach) on-farm.

Collection

Seed saver or custodian farmers are identified and encouraged to take on this role for their community. Most of the current seed saver farmers were also active in the previous SoS program. All farmers involved in the program promote biodiversity-based agriculture in Timor-Leste. This program is closely linked to the participatory land use planning/community natural resource management programs of RAEBIA, the Japanese International Cooperation Agency (JICA) and the Ministry of Agriculture and Fisheries (MAF), and with the conservation agriculture (CA) program of RAEBIA, MAF and the United Nations' Food and Agriculture Organization (FAO). Farmers share their field crop and vegetable seeds and grow a variety of other planting material. The history of each variety is initially collected and documented at RAEBIA headquarters. As staff travel through the country, they also look for varieties that could be introduced into other communities. It is important that any new material is adaptable to local agro-climatic conditions.

One of the key challenges during collection is the fact that farmers often use different names for the same variety. They also use different descriptors of key characteristics resulting in duplication. It is also difficult to collect comprehensively during the short period when the crops are still in the field, and to find sufficient seed of unique varieties for seed multiplication.

Multiplication

Material is multiplied in the field and then cross-checked with information provided by the farmers. Ideally, these samples continue to be grown by the donor farmer and if possible, in other communities. All the multiplication (grow-out) farmers are trained on how to observe and record necessary information on varietal characteristics of the particular crop. One set of these varieties is also grown out at the established agrobiodiversity resource centres in the villages of Umakaduak and Manelima in the municipality of Manatutu.

Documentation

It is important that varietal information details be properly documented without the task becoming too burdensome for farmers. Finding a balance for the amount of information collected is important for accuracy and recognition of farmer knowledge. RAEBIA field staff play a lead role in this step, which is also an opportunity for more in-depth conversations with farmers.

Conservation

Germplasm of field crops, vegetables and fruit trees is conserved both in situ and ex situ. Both are important in the overarching goal of conserving agrobiodiversity. In situ conservation takes place in typical farming conditions, and is the most desired method of conservation as it allows continuous adaptation to the changing agro-climatic conditions and socio-economic preferences.

Ex situ conservation of plant genetic resources is done in controlled conditions within a particular institutional setting away from the environment that the farmer normally works in. The agrobiodiversity resource centres at Umakaduak and Menelima are the primary ex situ conservation sites of RAEBIA (Figure 3). The number of centres will soon expand to three when the site at Cristo Rei, Dili is fully established. Seeds which can grow normally (called calcitrant or orthodox seeds) are kept in seed containers in conditions which prolong the seed life. Plants with recalcitrant (unorthodox) seeds are conserved by establishing field gene banks by planting and maintaining them in the field, often as an intercrop as they are normally cultivated in Timor-Leste (Figure 4).

A selection of the germplasm collected and maintained at the RAEBIA community agrobiodiversity resource and learning centres is presented in Table 1. There are a total of 84 species/varieties at the centres.

Figure 3. Ex situ germplasm collection and conservation.

Figure 4. Intercropping of Sele maize and Utamua peanut at the RAEBIA resource centre.

Table 1. Species, source and collection date of select in situ germplasm in storage at the RAEBIA community agrobiodiversity resource and learning centres.

Local name	English name	Scientific name	Source of seed	Year
Batar Noi mutin	Maize	*Zea mays*	MAF/SoL	2011
Batar Sele	Maize	*Zea mays*	MAF/SoL	2013
Fore Rai Utamua	Peanut	*Arachis hypogaea*	MAF/SoL	2013
Ai-Farina Ai-Luka 2	Cassava	*Manihot esculenta*	MAF/SoL	2013
Fehuk Hohorai	Sweetpotato	*Ipomea batatas*	MAF/SoL	2013
Fehuk local mean	Pulpier sweetpotato	*Ipomea batatas*	Manelima	2010
Aifarina mantega	Yellow cassava	*Manihot esculenta*	Natarbora	2010
Talas	Taro	*Colocasia esculenta*	Manelima	2010
Uhi	Purple yam	*Dioscorea bulbifera*	Natarbora	2012
Kumbili	Yam	*Dioscorea* sp.	Fadabloko	2010
Kanko	Water spinach	*Ipomoea aquatica*	RAEBIA office	2007
Ainanas	Pineapple	*Ananas comosus*	Batara	2009
Ai-Anin	Hog plums	*Spondias pinnata*	Be'eHedan	2005
Au'u	Bamboo	*Dendrocalamus asper*	Dare	2008
Ai-turi mean	Sesbania	*Sesbania grandiflora*	RAEBIA office	2013
Ai-bubur	Eucalyptus	*Eucalyptus alba*	KIKA	Native[1]
Sokaer	Tamarind	*Tamarindus indica*	KIKA	Native[1]
Menkudu	Indian mulberry	*Morinda citrifolia*	Dili	2005
Kinor	Turmeric	*Curcuma domestica*	Faturasa	2013

[1] i.e. not collected from another source.

Distribution

RAEBIA and its predecessor, USC Canada, has been distributing germplasm of a number of crop species and varieties since 2004. This has been primarily through farmer groups in the municipality of Manatutu. For example, the farmer group Ilimanuk oan kiak (KIKA) in Manatutu has a well-conserved collection of a range of crops which is exchanged among farmer members and others in neighbouring communities. Crops being distributed from this group are presented in Table 2.

Table 2. Crops distributed by Ilimanuk oan kiak farmer group, Manatutu, 2004–15.

English name	Scientific name
Aloe vera	*Aloe vera*
Bamboo	*Dendrocalamus asper*
Banana	*Musa* spp.
Beans	*Phaseolus* spp.
Black mustard	*Brassica nigra*
Blue ginger	*Dichorisandra thyrsiflora*
Calliandra	*Calliandra* spp.
Cassava	*Manihot esculenta*
Chili	*Capsicum* spp.
Citrus	*Citrus* spp.
Coconut	*Cocos nucifera*
Eggplant	*Solanum melongena*
Elephant grass	*Pennisetum purpureum*
Ginger	*Zingiber officinale*
Gliricidia	*Gliricidia sepium*
Jackfruit	*Artocarpus eterophyllus*
Lemongrass	*Cymbopogon schoenanthus*
Maize	*Zea mays* L.
Mango	*Mangifera* spp.
Mucuna	*Mucuna pruriens*
Mustard	*Brassica* spp.
Papaya	*Carica papaya*
Peanut	*Arachis hypogaea*
Sesbania	*Sesbania grandiflora*
Sweetpotato	*Ipomoea batatas*
Taro	*Colocasia esculenta*
Tomato	*Solanum lycopersicum*
Water spinach	*Ipomoea aquatica*
Yam	*Dioscorea* spp.

Ways forward

There are positive ways forward for the collection and multiplication of planting material before distribution to the farming community in Timor-Leste. As mentioned earlier, one of the major challenges has been differentiating between different crop varieties with the same name and different names for the same crop variety. Another challenge has been determining the diversity status of a particular crop and the potential for the loss of that germplasm from the farming environment. RAEBIA's experience is that it is important to carry out conservation and planting material multiplication in the right growing environment before distributing the material to the farming community for their own on-farm conservation. The best way of doing this is through community seed banks and field gene banks established within the farming communities and managed by farmers themselves. Community seed banks are locally managed providing easy farmer access to planting material.

It is possible for a strong system of germplasm collection and conservation be operating in Timor-Leste within 5 years with farmers at the centre of the process. Some suggestions to achieve this are as follows.

- MAF takes a lead role in supporting organisations like RAEBIA to help farming communities in the collection, assessment and documentation of the nation's plant germplasm.
- Government and development partners facilitate access to Timor-Leste's diverse plant germplasm by farming communities using innovative and participatory approaches such as participatory variety selection and diversity kits.
- Government and development partners facilitate access to seed in the international gene banks for deployment in farmers' fields for evaluation under farmers' conditions.
- Organisations use RAEBIA's and USC Canada's experience in establishing and strengthening community seed bank systems in Timor-Leste. This also complies with the policy provisions outlined in the draft National Seed Policy 2014.
- MAF facilitates the establishment of a national gene bank for Timor-Leste as outlined in the draft National Seed Policy 2014. This gene bank will both support the conservation and sustainable use of plant germplasm, and develop linkages with international gene banks to further diversify its collection, as depicted in Figure 5.

- NGOs and other organisations including the German agency for international cooperation GIZ (GIZ 2015), FAO and other bilateral and multilateral projects in Timor-Leste help develop a strong network of farmers or farmers' associations dedicated to conservation of germplasm in a sustainable manner. This would allow for more coverage of the many diverse landscapes and agro-climatic zones in Timor-Leste.

Conclusions

Recognising farmers' local knowledge and working closely with them for the collection and conservation of food crops, vegetables and fruit is a long-term commitment and key to food security (Engels et al. 1991). NGOs in Timor-Leste are still learning this process, having had the freedom to work closely with farmers for only the past 10 years. The work of Seeds of Life/MAF since 2005 has ensured this aspect of seed security and diversity in the country, and this needs to continue after the end of the SoL program. At the same time, community collection and conservation of germplasm also needs to continue. RAEBIA, with its experienced team of staff, have the strong skills, knowledge and experience necessary to engage in and contribute to the national collection and germplasm conservation program. With a concerted collaborative effort by all organisations working in agriculture, the nation's plant genetic resources can be maintained.

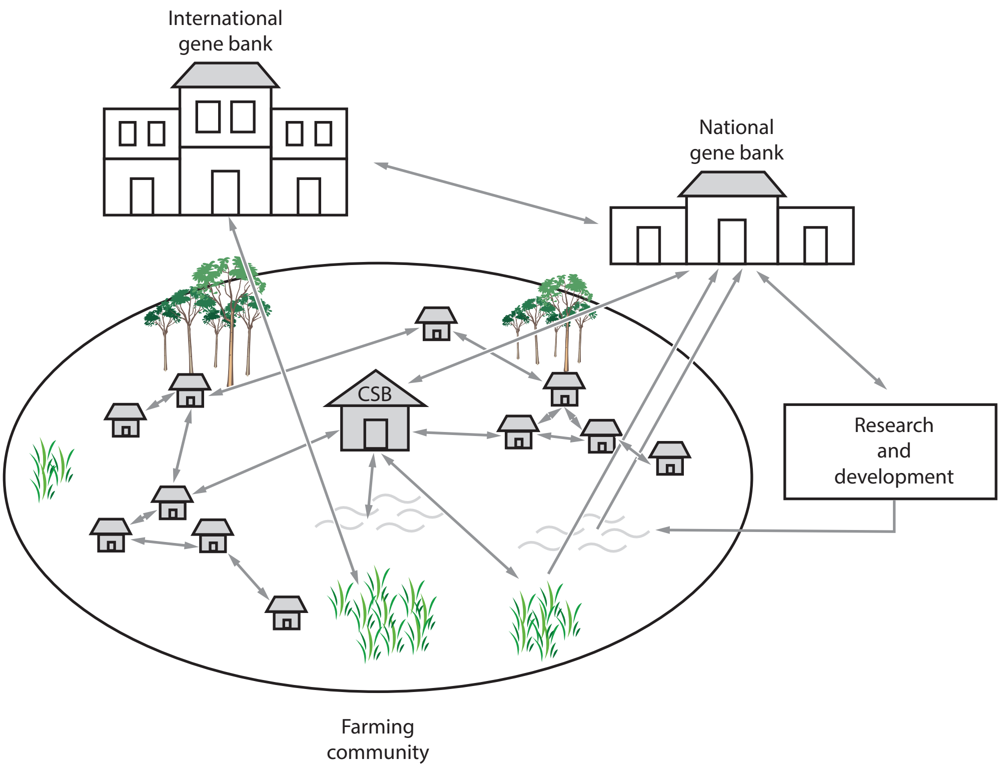

Figure 5. Schematic diagram showing linkage of the community seed bank with individual farming households, and with the national and international gene banks (Shrestha and Kumar 2014).

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Characterisation of farmer groups successfully multiplying and disseminating seed in Timor-Leste

Modesto Lopes[1]

Abstract

Past studies have shown that a promising method of scaling up new technologies in developing countries is through a community-based approach. This paper explores the characteristics of successful community and commercial seed production groups in multiplying and disseminating seed in Timor-Leste. Farmer groups successfully multiplying seed for commercial purposes (commercial seed producers) and at the local level (community seed production groups) showed similar characteristics. Both groups possessed a capacity to manage their operation well with good involvement of their members. Leadership was important, a gender balance within the groups preferable, and good attendance of meetings highly desirable. In the case of the commercial groups selling their seed, trustworthy financial management was also an important characteristic along with them possessing good networking skills so that they linked well with government, other authorities and potential markets. The success of the community and commercial seed producers in meeting their goals was measured in the quality and quantity of seed produced and marketed. In the case of the commercial seed producers, sufficient seed was produced in 2014–15 to replace 75% of the nation's seed importation requirements.

Introduction

An effective distribution system is an essential element of all successful national seed systems. It is especially important in developing countries, where improving the availability (time, place, quality and quantity) of high yielding crop varieties reduces the nations' dependency on external sources. Establishing such systems requires concerted action by many actors, particularly in isolated areas where poor infrastructure restricts transport and communication. In such regions, there is potential for collective farmer action to promote timely access to seed at affordable prices (Tiwari et al. 2009). The involvement of farmers and farmer groups will often strengthen the link between technology development and transfer (David 2004).

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The Ministry of Agriculture and Fisheries (MAF) in Timor-Leste has, over recent years, developed a national seed system for released varieties which is greatly dependent on community action. This has involved: (i) establishment of a seed department to strengthen the public functions of seed quality control and varietal registration; (ii) supporting commercial seed producers to produce and trade seed; and (iii) strengthening community seed production groups to produce good quality seed for group members and the surrounding community.

Seed sources and seed multiplication

Improving seed security is a high priority for the MAF in Timor-Leste. Over the past 15 years, MAF's research program has identified improved varieties of the major food crops which are high yielding and preferred by the farming community. The new maize varieties, for example, have a 50% yield advantage over locally grown landraces and are popular with farmers for their good eating qualities.

Pure seed of maize, rice, peanuts and other food crops is generated in small quantities by the National Directorate of Research, Statistics and Geographic Information, but multiplying and distributing sufficient seed at the farmer level is a challenge. The amount of seed produced under the formal system is limited and expensive.

Farmers in Timor-Leste traditionally obtain their seed through informal seed channels. If short of seed, they generally approach their social networks, including relatives, neighbours, friends and members of farmer groups, for supplies. Seed exchange, bartering, borrowing, lending and gifting are common within this system (SoL 2007). However, there is little access to quality seed of high yielding varieties. To address this, a new approach in Timor-Leste is to support these traditional channels through community seed production groups, and assist them in multiplying high yielding seed and other technology dissemination within the farming community. Understanding what constitutes a successful group will help in the formation of such groups, and will ultimately help to effectively plan and develop a better seed system in Timor-Leste.

Community-based systems for seed multiplication and dissemination

The pace at which quality seed is disseminated via traditional, formal seed multiplication and distribution systems in developing countries is limited (Jones et al. 2001), but community participation has been shown to enhance the process (Lacoste et al. 2012). Community-based seed production enterprises also contribute to market stability and rural development sustainability (Borges et al. 2009), and help develop the socio-cultural diversity of farming communities, promoting cooperation between farmers (Pautasso et al. 2013).

With this background knowledge, the MAF in Timor-Leste developed their national seed system by strengthening community seed multiplication and extension. The concept was that pure seed of MAF-released varieties would be multiplied under the highly regulated government system for distribution to commercial seed producers (CSPs), who would in turn multiply the seed in sufficient quantities for further multiplication by community seed production groups (CSPGs) for use by farmers. The establishment of this informal system commenced in 2011, and by the 2014–15 cropping season 54 CSPs and 1,135 CSPGs were successfully harvesting and distributing seed. The formation of these groups was particularly important for the multiplication of maize, which is an open pollinated variety requiring multiplication in isolation from other maize varieties to maintain purity. Varieties of five crops released by the MAF were multiplied by CSPGs during this period: maize (varieties of Sele and Noi Mutin), rice (Nakroma), peanut (Utamua), cassava (Ailuka 1, Ailuka 2 and Ailuka 4) and sweetpotato (Hohrae 1, Hohrae 2 and Hohrae 3).

The main objective of the CSPGs is to multiply commercial seed into sufficient quantities for use by group members and their families. Any surplus is usually gifted or bartered with other village members but in some cases is sold to members of the surrounding community. The more successful the CSPGs are at producing good quality seed, the more opportunity they have of meeting their own requirements and having sufficient to barter.

Community seed production groups for seed multiplication and dissemination

A group or collective action approach has proven to be an effective way to empower farmers in accessing new technologies, particularly seed (Anandajayasekeram et al. 2008). Groups more successfully utilise resources such as labour, knowledge and extension services than individuals (Lopes et al. 2015). It is also the experience of extension services that working with seed production groups ensures greater inclusiveness of the rural poor in innovation development. Community-based seed production is also cost-effective compared with the formal seed multiplication system (Kunwar et al. 2016).

For seed dissemination to be successful, farmers need access to sufficient seed of a desired variety at the right time. A study in Timor-Leste just after seed distribution in 2014 found that 58% of surveyed farmers had access to seed from CSPGs in a timely manner, while 42% received seed in time from other channels (SoL 2015). Forty-four per cent of the farmers preferred the seed from the CSPGs, while 18% of the participants stated that agricultural shops were the most efficient channels for seed distribution. Seventeen per cent of farmers accessed seed from both CSPGs and CSPs, while 15% of participants preferred buying seed from CSPs. These results indicate that both CSPs and CSPGs play a crucial role in the technology transfer process in Timor-Leste. The main reason farmers liked their supply channel was because it was located near their farm (61%), they trusted the seed supply (49%), and access to their seed supply also provided opportunities for training (5%). Only 5% of farmers considered price to be a factor.

Characteristics of successful community seed production groups

Only CSPGs providing farmers with sufficient quantities of good quality seed were considered to be successful, and these successful groups possessed a certain set of characters which made them that way.

In a study by Lopes et al. (2015), CSPGs which successfully multiplied and disseminated seed had quality leadership, had a high degree of trust within the group, and the group had good management structure and a respected decision-making process. Successful groups also had a good gender balance and held regular meetings. Other demographic characteristics such as group size and education of members, especially the leader, were also important.

These characteristics were correlated against amount of seed disseminated to group members and the surrounding community. Meeting frequency ($r = 0.69$), leadership quality ($r = 0.57$), the level of group trust ($r = 0.51$) and the group management structure ($r = 0.41$) were particularly correlated with the amount of seed disseminated (Figure 1).

With increased meeting frequency, group members are able to discuss their ideas more regularly and problems can be addressed (Lopes et al. 2015).

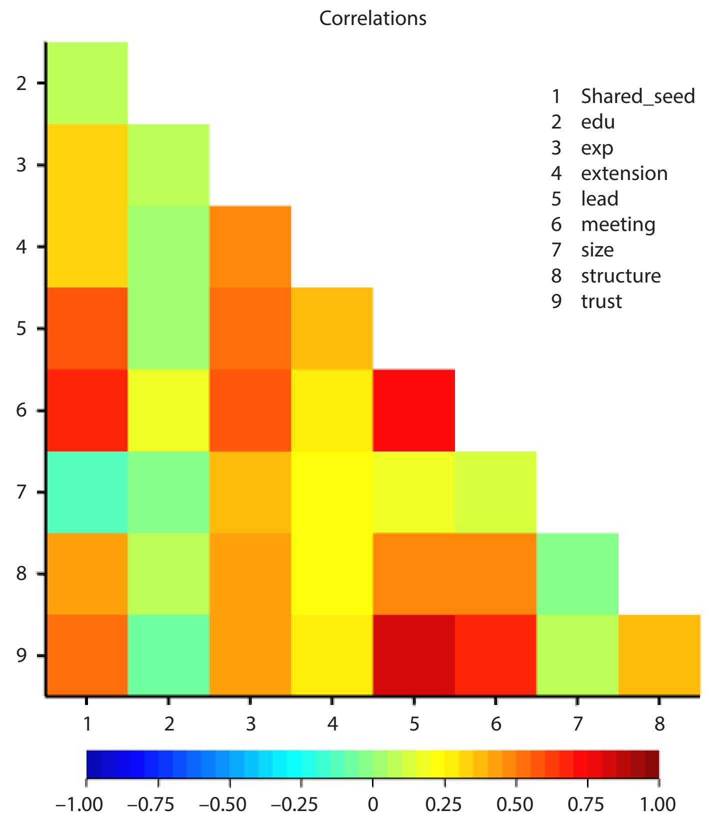

Figure 1. Heat diagram of correlation coefficients between all pairs of group characteristics and the quantity of shared seed. The correlation coefficient at $P < 0.01$ is $r = 0.46$ ($df = 28$). (Source: Lopes et al. 2015.)

According to Anandajayasekeram et al. (2008), the holding of regular meetings also promotes transparency and accountability and encourages group members to participate in the decision-making process thereby promoting group cohesiveness.

Good leadership is also clearly important, with the leader willing to defend the groups' decisions. This concept is supported by Das (2012) who considers that one of the objectives is to create a positive expectation that may motivate the group to achieve their goals. Promoting collective confidence is important. Each member's needs should be taken into account, but in some cases it may be necessary for the group leader to insist that members comply with the group decision.

Trust plays an essential role within the seed groups, as well as within the local community, because seed quality often has to be taken on trust (Lewis and Mulvany 1997). It is believed that a high level of trust has a positive impact within an organisation in general and within a cooperative organisation in particular (Hansen et al. 2002). When a democratic environment is established, the group objective is more likely to be achieved. Place et al. (2004) described the level of trust as being a measure of the group's ability to design and implement new ideas. This statement supports the idea that bonding social capital, in the form of trust, is critical and more valued than the formation of groups with different skill mixes (Place et al. 2004).

Achieving a good gender balance within the group helps the development of sustainable agricultural practices. Sanginga et al. (2001) maintain that it is a particularly important component in the establishment of effective mechanisms for resource-poor farmers. Women account for 43% of the global agriculture labour force (SOFA Team and Doss 2011). It is well documented that women farmers have a greater ability for seed selection and maintenance than men (Lewis and Mulvany 1997). Seed production and seed exchange programs are often led by women (Maharjan et al. 2011). Participation of women has a positive effect on group dynamics and often leads to achieving group goals. In some situations it is perceived that, if men do not achieve the group expectations quickly they are likely to leave the group, whereas women have more patience and greater staying power (Abaru et al. 2006).

Cohesiveness is an essential characteristic for sustainability of the group, and plays an important role in the group achieving its objectives. A cohesive group is one in which members respect one another and all have the desire and commitment to remain a part of the group (Dyaram and Kamalanabhan 2005; Hansen et al. 2002; Klein and Mulvey 1995). Group cohesion aligns with a high degree of motivation, morale and management skills (Das 2012; Hansen et al. 2002).

Understanding group dynamics is important for understanding group cohesiveness (Oerlemans and Assouline 2004). Differences in overall expectations, expected benefits and expected commitment often lead to declining group cohesion. Das (2012) noted that homogeneity is one of the factors which contribute to groups cohesiveness, because it enables group activity selection common to many members. Cohesiveness can depend on initial group formation, for example groups form under their own initiative can be highly cohesive compared to groups formed through external intervention.

The level of education of members often contributes to group performance. Bartham and Chitemi (2009) found, in a study on marketing, that groups achieving no improvement were those with a low level of literacy (primary education only), while groups achieving improvement had members with 7 years or more of schooling. It was inferred that groups with higher education levels are able to absorb more knowledge and apply it to succeed in reaching the groups' goals. It was presumed that education is the basis of knowledge accumulation in all sectors. However, education is not the only demographic characteristic to predict a successful group. Farmers who are illiterate or have little education but have past experience with group activities can also make significant contributions to successfully achieving group objectives. This is the case in Timor-Leste where the level of education in the rural areas is poor. Leadership experience was found to be more valuable than academic achievement (Lopes et al. 2015).

Characteristics of successful commercial seed producers

Commercial seed producers are groups of MAF-registered farmers who multiply high quality seed for commercial purposes. They multiply government-certified seed in coordination with the MAF Seed Department to ensure that the product is of sufficient high quality for trade. Being farmer groups, successful CSPs should possess similar characteristics to successful CSPGs. They should hold regular meetings, have good leadership, have a high degree of trust within the group and with their customers, have a well-structured management style and be gender inclusive. CSPs also have the added responsibilities of handling money and storing larger volumes of grain or planting material for sale to distant markets.

In a recent study (SoL 2016), many of the characteristics of successful CSPs were indeed similar to those of successful CSPGs plus the extra financial and networking responsibilities. It was determined that the most successful CSPs have the following characteristics:

- Institutional capacity including solidarity amongst members, a good gender balance and a collective decision-making process;
- A robust management style including a strong and democratic leader and active members who manage group assets well;
- High technical capacity with members following good agriculture practices and not overly dependent on the *suco* extension officer (SEO) for support;
- The financial capacity to collect funds for investment, record expenses and properly administer income;
- Networking capacity including linkages with the SEO, local authorities and other agencies.

CSPs and CSPGs in Timor-Leste

In 2014, the CSPs produced a total of 83 tonnes of maize, rice and peanut seed (Table 1). This high quality seed was distributed to CSPGs for further multiplication or sold on to NGOs and other agencies requiring high quality seed. Seed from the CSPGs was distributed amongst their own members. The number of CSPs more than doubled between 2013–14 and 2014–15 and their total production in 2014–15 was sufficient to sell to the MAF and replace 75% of the seed importation requirement and still provide quality seed to the CSPGs.

CSPGs were initially established in 2011–12. During that year, of the 240 CSPGs, 213 CSPGs were able to grow maize, rice and peanuts and 185 of the 213 CSPGs successfully harvested seed (a failure rate of 13%). After three years of experience, 1,207 CSPGs existed in 2014–15 and 1,135 harvested seed (failure rate reduced to 9%).

A small number of CSPs (31) was established to multiply certified seed in the 2013–14 season, of which 26 harvested seed (a 16% failure rate). These CSPs received considerable training during the year and new CSPs were also established. Emphasis was placed on groups possessing the characteristics mentioned above. The numbers of CSPs increased dramatically over one year to 58 and success rate was high, with 54 harvesting and selling high quality seed (the others either did not plant or faced harvest failure), and also producing higher amounts of seed. The CSPs in 2014–15 increased seed production to an average of 4.87 tonnes of maize seed compared with 2.45 tonnes in 2013–14. The MAF will register in the future only those CSPs which have the characters of success, and training will be provided to CSPGs to improve their performance and that of the CSPs even further.

Table 1. Seed multiplied by CSPGs and CSPs in 2013–14 and 2014–15.

Year	Crop	CSPGs		CSPs	
		Number	Seed multiplied (t)	Number	Seed multiplied (t)
2014–15	Maize	670	104	38	185
	Rice	185	75	15	110
	Peanuts	280	13	13	10
Total		1135	192	55*	305
2013–14	Maize	520	96	20	49
	Rice	178	71	4	33
	Peanuts	257	18	2	1
Total		955	185	19*	83

* Some CSPs produced seed of more than one type of crop, hence the numbers of CSPs growing each crop do not add up to the totals.

Overall, the community-based approach has proven to be an effective channel for technology transfer in Timor-Leste. Seed multiplication and distribution is managed by the community-led system, with quality control regulated by the government.

Conclusions

The community-based seed multiplication system in Timor-Leste has proven to be low cost compared with the formal regulated system. The quality of seed multiplied by the CSPs is trusted by farmers who are prepared to pay for quality seed of improved varieties for multiplication by CSPGs. In turn, seed from this source is easily disseminated though sale, gifting, lending or bartering. The most successful groups in terms of multiplying sufficient quantities of seed had good leadership which stimulated a high degree of trust within the group and with the group's product. These groups also had a good management structure with a gender balance and a respected decision-making process. Such groups held meetings more regularly than groups disseminating less seed. Despite some groups being less successful than others at multiplying and distributing seed, the CSPGs in Timor-Leste produced sufficient seed for their own needs and their neighbours in 2015. CSPs also produced 185 tonnes of high yielding maize seed (Sele and Noi mutin), 110 tonnes of rice and 10 tonnes of peanut for sale in 2015. CSPs have a similar structure to CSPGs and their success is highly dependent on maintaining trust in their seed which is sold at a high premium to grain.

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Section 3: Crops and their environments

Conservation agriculture in Timor-Leste: experiences and opportunities

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Abstract

In Timor-Leste, 'slash and burn' and the free grazing of livestock are leading to low soil fertility and reduced crop productivity. Weather variability and climate change also affect crop productivity, especially with more frequent dry spells and less rainfall. This paper focuses on how conservation agriculture (CA) technologies can increase farmers' efficiency in crop production as well as their capacity to adapt to variable climatic conditions. Evidence for this has been observed and measured through a project that supports farmer groups to test and adopt CA in demonstration plots and in their fields in five municipalities in Timor-Leste. This paper provides a brief review of CA principles, a summary of the project's participatory adaptive research using the farmer field school approach, and an overview of the results obtained, constraints presented and opportunities for the future. The described project is the first to test and promote the adoption of CA in Timor-Leste, and initial results demonstrate that subsistence Timorese farmers can produce maize and legumes more efficiently (with up to a 50% reduction in labour) with crops which are better adapted to weather variability, particularly dry spells and reduced rainfall.

Introduction

'Slash and burn' is still the predominant farming practice in Timor-Leste, especially in hilly areas. As the population increases and the farmed area expands, there is increased pressure on natural resources and land degradation is becoming a real concern. Deforestation, over-grazing, lack of fallowing, continuous ploughing, harrowing and rotovating, together with the widespread practice of burning organic matter on the soil's surface before planting are contributing to land degradation. Due to these farming practices, most of the cultivable soils of Timor-Leste tend to lack structure, are low in organic matter, lack water-holding capacity and are prone to erosion. The Food and Agriculture Organization of the United Nations (FAO) and other agriculture-related organisations no longer consider tillage as essential for crop production, especially for those cropping patterns found in Timor-Leste (Sorrenson 1997). They now promote 'conservation agriculture' (CA) as the most cost-effective and environmentally stable approach to producing most crops.

FAO and the Ministry of Agriculture and Fisheries (MAF), in partnership with two non-governmental organisations (NGOs), Mercy Corps and RAEBIA Timor-Leste, have been promoting CA in rainfed areas of Timor-Leste since August 2013. The 4-year project, funded by the Office of United States Foreign Disaster Assistance of the United States Agency for International Development (USAID) is, at present, focusing on maize growing on sloping upland and flat lowland areas in the municipalities of Baucau, Ermera, Manatuto, Aileu and Manufahi.

The first 2 years of the project focused on participatory and adaptive research and replication of CA technologies and practices through group demonstration plots implemented by 34 farmer field schools (FFS), with some 835 participating men and women farmers. In addition, the project implemented three experimental sites in MAF research stations at Betano, municipality of Manufahi; Darasula, municipality of Baucau; and at the Natarbora agricultural technical school, municipality of Manatutu. During

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the third and fourth years the focus will be on the up-scaling of validated CA technologies and practices to benefit approximately 3,200 resource-poor smallholder farmers.

Principles of conservation agriculture

CA is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and increased food security while preserving and enhancing the resource base and the environment. CA is characterised by three linked principles (FAO 2015):

1. Continuous minimum mechanical soil disturbance;
2. Permanent organic soil cover;
3. Diversification of crop species grown in sequences and/or associations.

CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical soil disturbance are reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes. Complemented by other known good practices including the use of quality seeds and integrated pest, nutrient, weed and water management, CA is a base for sustainable agricultural production intensification (FAO 2011).

The idea of minimising soil disturbance was introduced in the 1930s as a soil conservation system to counter the 'dust bowl' effect in the United States, but the term 'conservation agriculture' was not coined until the 1990s (FAO 2014). Only recently has CA been promoted on the basis of its climate adaptation and mitigation benefits. Worldwide, CA was practised on 125 million ha in 2010 and this is steadily increasing (Friedrich et al. 2012; Kassam et al. 2014). Its use is widespread in parts of the Americas and Australia (FAO 2014). In the tropics, Brazil has the longest experience with CA where the principles have been practised since the 1970s and it now covers over 30 million hectares (Junior et al. 2012). CA history in South-East Asia is recent (less than a decade), which largely explains why its development is mainly limited to the research sector with little being extended to farming communities (Legoupil et al. 2013).

Participatory adaptive research through farmer field schools in Timor-Leste

Participatory adaptive research was conducted during three cropping seasons in Timor-Leste to evaluate aspects of CA. Eighteen farmer groups participated in the first season (2013–14). In the second and subsequent seasons (2014–15 and 2015–16), the number of groups increased to 34. MAF, FAO and NGO partners supported farmer groups to establish and manage demonstration plots comprising a control, where maize was grown using traditional methods (i.e. burning the organic matter and ploughing the soil), and three to five CA practices (i.e. no burning and no/minimum tillage) with variables appropriate to the respective agro-ecological zone. Variables included mulching, the use of local maize varieties or improved (open-pollinated) maize varieties such as 'Sele' and 'Noi mutin', and different intercropped legumes (i.e. cowpeas, lima beans, lablab, pigeonpeas, velvet bean and winged bean). On the northern rainfed flat or slightly sloping land, a single maize crop was grown. In the south, sites with similar topography were double cropped with maize.

Farmers followed the participatory farmer field school (FFS) approach of 'learning by doing'. Each group of 20–30 smallholder men and women farmers met every two or three weeks to test the CA practices and techniques. Guidance was provided by trained FFS facilitators belonging to the project and to MAF's network of extension workers. The facilitators supported the farmers to carry out the CA tasks and techniques, including cutting organic matter for mulch, planting the maize and legumes, weeding, pest control, harvesting and measuring yields. Guidance was also provided by FAO and partner technical staff about new and improved practices, and they facilitated discussion among farmers regarding visible differences between plots and the pros and cons of CA compared with traditional techniques. FAO and its partners also guided FFSs with complementary techniques such as planting in contour lines and recommended distances between maize plants. Training on soil-related testing techniques was provided, which included the calculation of water-holding capacity, soil erosion simulation, water and nutrient uptake simulation, and evaporation of water from the soil surface. In addition, FFS groups tested CA machinery including a rolling crimper drawn by a two-wheel tractor (2WT). The crimper kills legume cover crops leaving a layer of organic matter ready for direct planting. A 2WT-drawn direct seeder designed to drill maize and legume directly into the soil seed through a layer of organic matter was also demonstrated.

As part of the program, farmers participated in exchange/cross visits to other successful FFSs. They also visited intercropping research trials at Betano research station and at the agriculture technical school of Natarbora. These visits encouraged less successful FFSs during the first year of implementation.

Given that intercropping legumes with maize was the key variable introduced in the research, a summary of findings on this aspect is provided below (Baker et al. 2014/2015).

Velvet bean (*Mucuna pruriens*) performed very well in terms of biomass production in lowland areas (Figure 1). It grows vigorously, and therefore needs to be planted around four weeks after the maize is planted to avoid competition with the maize. In southern areas the bean can survive the whole year until the main planting season in November/December while in central and northern parts of the island it dies in June or July. The main constraint to adopting the use of this bean as a cover crop is that, if its seeds are not collected at maturity, they can germinate prematurely the following season and become a weed that damages the crop by competing for nutrients and sunlight. Maize–velvet bean trials are described in Correia et al. (2013).

Winged bean (*Psophocarpus tetragonolobus*) performed well at low altitudes and produced a good amount of biomass when planted every 50 cm (Figure 1). At middle altitudes it grew less vigorously. This bean can be planted at the same time as maize as it grows slowly and produces much of its biomass after the maize is harvested. In both southern and northern areas the bean dies in June/July, which means that in southern areas where there is an additional cropping season it can supress weeds until the start of the second cropping season, making it a good cover crop for the main cropping season (November–March). In addition, this very nutritious bean that had previously been practically unknown to Timorese farmers proved to be quite palatable for those who tried them.

Lablab (*Lablab purpureus*) also performed well, although it should be noted that lablab was tested only in a few plots due to limited availability of seeds. The first results showed that it performed very well in lowlands, creating as much biomass as velvet bean (Figure 1). It showed potential to survive and cover the soil until the following cropping season, which would make it a good option for northern (drier) areas as it can stand the dry season better than velvet bean. The bean grows slowly and can therefore be planted at the same time as maize (at a minimum distance of 50 cm) and does not carry the risk of becoming a weed for the following crop.

Of all the legumes tested, the two local varieties of cowpea (*Vigna unguiculata*) tested ('fore masin' and 'fore metan') proved to have the best adaptability in all agro-ecological zones (Figure 1). The bean performed well at low, medium and high altitudes producing a large amount of biomass, especially in lowlands. It can be planted at the same time as maize, although at low altitudes the spacing should be at a minimum of 50 cm. As it usually dies in April/May, cowpea can be a good option for intercropping with maize in the southern lowlands in the main season as it can maintain biomass until the second planting season in April/May.

Lima or butter bean (*Phaseolus lunatus*) performed irregularly, totally covering the soil in some plots but not growing well in others. Overall, it performed better at medium to high altitudes, although not in all plots. Lima bean could tolerate the dry season, supressing most of the weeds until October. As the plant grows relatively slowly it can be planted at the same time as maize at a distance of 50–100 cm.

Pigeonpea (*Cajanus cajan*) was evaluated mainly at medium and high altitudes planted on contour lines. While it does not produce much biomass to supress weeds, one of its benefits is the capacity of mobilising phosphorous in the soil making it available for other cultivated crops (Arihara et al. 1990). As it grows slowly, it can be planted at the same time as maize, at a distance of 50 cm.

Results

Two main advantages of using CA were observed during the project. Efficiency in the cultivation of maize was increased through a reduction in the amount of both labour needed and fuel used (Figures 2 and 3). Additionally, maize yield increased when CA practices were applied properly.

Data from sub-plots belonging to the 34 farmer groups confirmed that CA plots needed between 40% and 50% less time to produce the same or higher maize yield compared with the control plots (Figure 2). The main saving in time was due to CA

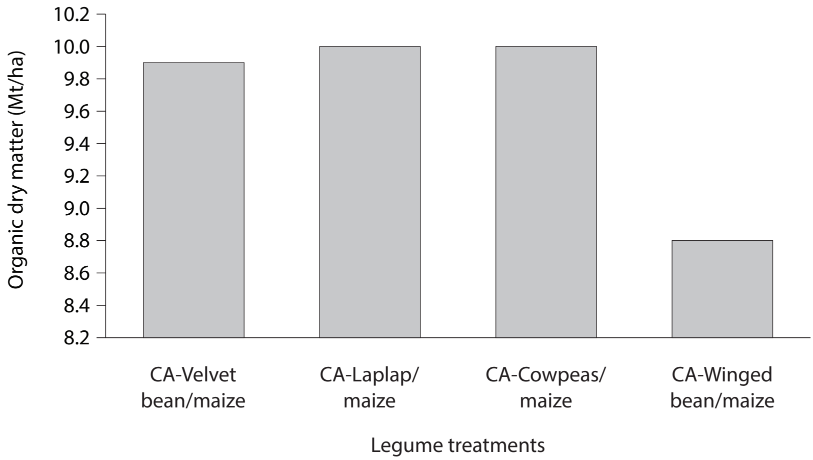

Figure 1. Organic dry matter in Natarbora technical school research plot, November 2014–March 2015 cropping season.

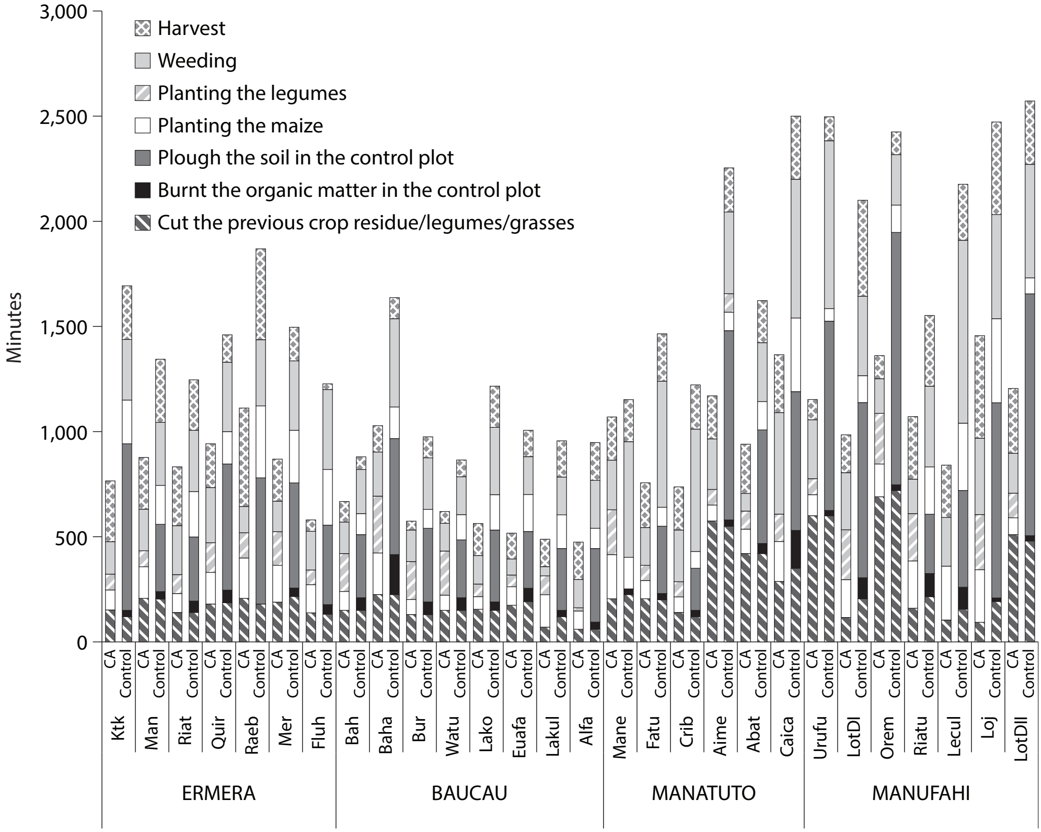

Figure 2. Time comparison for CA plots versus control plots (person-minutes).

not requiring the soil to be ploughed and reduction in weeding times due to crop residue shading the germinating weed seeds. On flatter areas in the south of the island (Same and Natarbora), farmer adopters reduced the amount of fuel used for ploughing and rotovating by up to 80%. Consumption was reduced from 50–60 litres of fuel per hectare to 10 litres per hectare when CA equipment was used (Figure 3).

Most CA adopters experienced some increase in maize yield. In dry conditions, the yield differences were exceptional. For example, during the drier than usual May–September 2015 cropping season in the south of the island, most FFS CA plots had 100% and in some cases 200% higher yields than the controls (Figure 4), and this was visible in the field (Figure 5). It is postulated that the main reason for the higher yields was the higher capacity of the soil in the CA sub-plots to retain moisture. These plots were covered by crop residue and legume cover crops which improved rainwater infiltration and reduced evaporation. In contrast, control plots were bare, increasing evaporation, and possessed a hard surface reducing water infiltration when it did rain. The benefit of moisture retention as a result of CA technologies was also observed after the planting of maize and legumes in the November 2015–March 2016 cropping season in most FFS plots. Just after planting the maize, a 2–3 week dry spell affected germination and plant survival in several plots. The germination/survival of maize was higher in the CA plots compared with the controls (Figure 6).

Soil sample analysis from FFS demonstration plots that had applied CA for 2 years demonstrated that CA was improving soil physical properties (bulk density) as well as biological properties (Niemeyer 2015; Figure 7). This soil improvement, together with dry conditions in the last cropping seasons, allowed farmers to observe the benefits of CA in their own farms. In addition to observing the increased efficiency of the cropping system by reducing labour and inputs, many farmers realised that implementing CA technologies can also improve crop resilience to variable weather events.

Constraints

Despite many farmers experiencing good results from using CA technologies, they face some constraints in adopting this practice on their farms. The three main constraints are: (1) their strong mindset regarding farming practices inherited from their ancestors; (2) the free grazing of livestock practised in most parts of the country; and (3) the government policy of subsidising ploughing of cropping land.

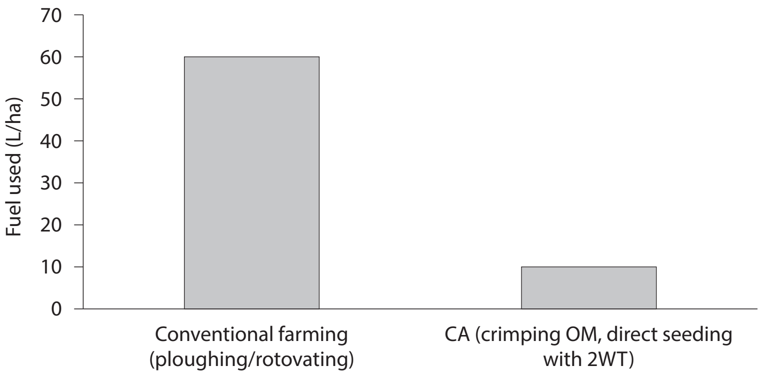

Figure. 3. Comparison of fuel used per hectare on flat lands in conventional farming versus CA.

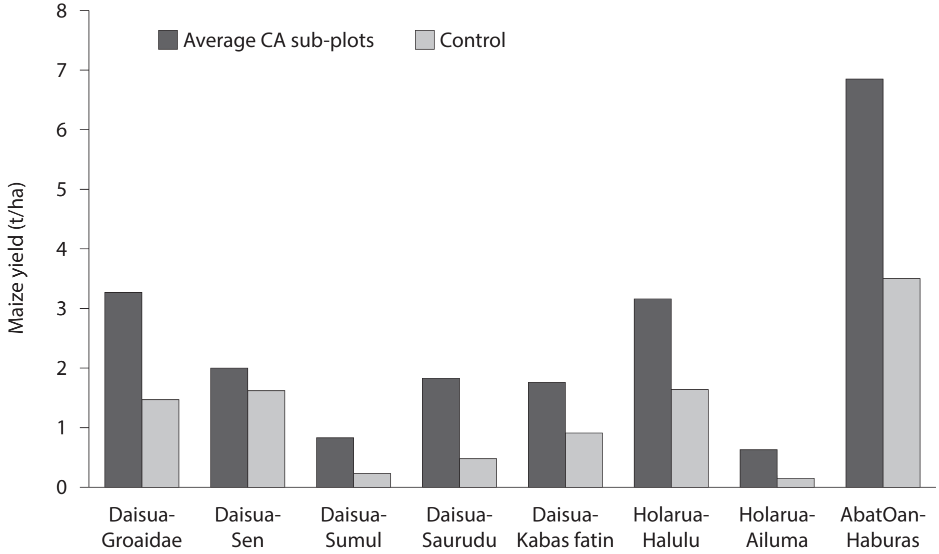

Figure 4. Maize yield (t/ha of wet cobs) in FFS plots in southern Timor-Leste, May–September 2015 cropping season.

Figure 5. FFS demonstration plots in Natarbora, Manatutu. Left plot: CA with cowpeas; centre: control; right: CA with velvet beans.

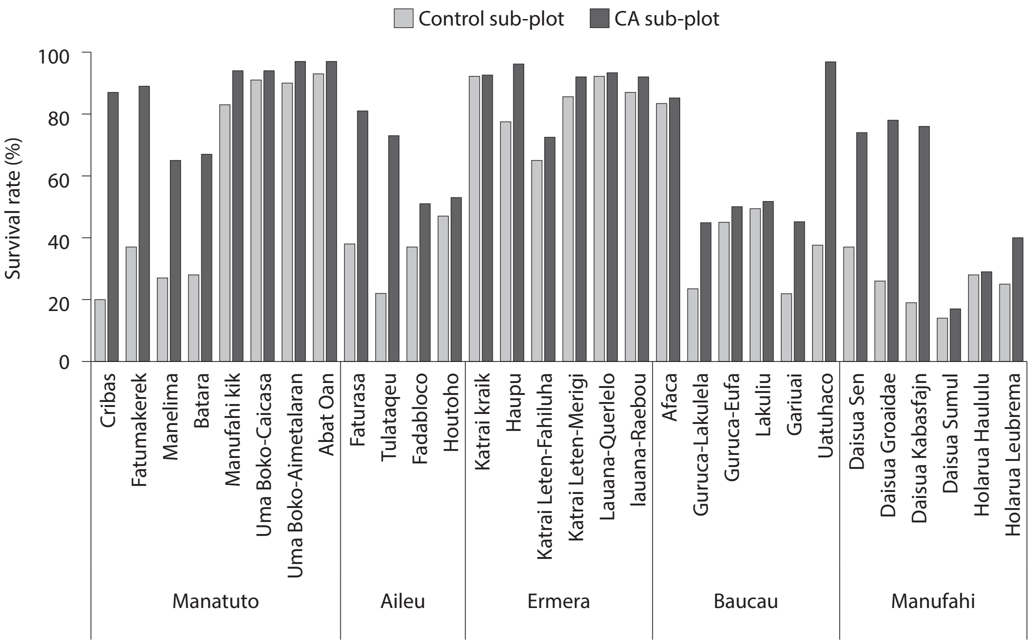

Figure 6. Survival rate of maize in FFS plots, October 2015–March 2016 cropping season.

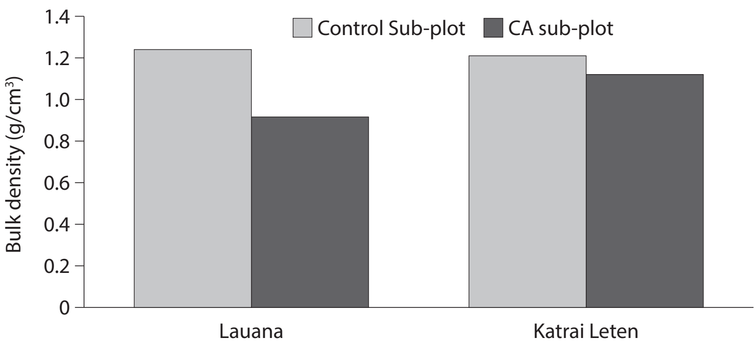

Figure 7. Bulk density of soils in two FFS plots in Ermera municipality.

At the beginning of the program, farmers were reluctant to test CA because burning and ploughing were considered essential tasks for good crop production. These practices are deeply rooted in their farming traditions, making it essential to demonstrate the benefits of CA practices in farmers' fields. Farming traditions may also lead farmers to be pressured by their neighbours and relatives to return to traditional practices even if good results are visible.

Free grazing of livestock is a problem because freely roaming animals eat crop residues and legume cover crops remaining in the field during the dry season. To overcome this constraint in some *sucos*, FAO and RAEBIA help facilitate participatory land use management plans through *tara bandu* (local ritual directives) requested and driven by the communities. Initial results are promising and this can be an effective tool to increase mulch-based crop production. Free grazing is also an issue with out-of-season cropping in irrigated areas and in agroforestry and forestry programs within Timor-Leste. There is scope for researchers to assist the development of a wider ranging policy on the management of animals through an extended system of *tara bandu* at the local level, through municipal directives or by a national law.

Opportunities

CA efficiencies have been demonstrated on 34 sites across five municipalities over 2 years with 835 participating farmers. At the end of 2015 one more year of data was yet to be collected from these sites. However, initial results indicate that the adoption of CA in Timor-Leste will make farming more efficient than traditional practices which, in turn, will encourage young people to remain on their farms rather than migrate to cities in search of paid labour positions.

Farmers experienced the impact of El Niño in several parts of the country during the second part of 2015 and into 2016. Because of this event, farmers were able to observe that keeping a layer of crop residue on the soil surface can help their maize perform better. This clear advantage of CA in such a critical weather event is serving as an entry point for farmers, who realise the disadvantages of burning organic matter in their fields.

More farmers may be attracted to CA when government ploughing subsidies are reduced. Between 2006 and 2009, MAF invested US$16 million in two- and four-wheel tractors (da Cruz 2016), and continued providing fuel and maintenance to support cultivation practices up to 2016. Many of these tractors are reaching the end of their lives and the government does not intend to purchase replacements. In the years leading up to 2016, some of the operational costs of the equipment were born by the farmers themselves. When these costs are taken into account, CA practices are more appealing to the farmers and adoption rates may improve further in the program's final year.

The FFS approach has proven to be an effective way for farmers to learn and will continue for as long as the program has external funding. The 'learning by doing' approach provides an opportunity for farmers to experience improved practices over a period of time, also helping them to overcome the stigma of not following traditional farming practices.

There are opportunities for CA to expand into more *sucos* in the participating municipalities, and beyond. Although MAF involvement has been extensive, the FFS approach is expensive in terms of time and manpower and MAF resources are limited. There is, however, an opportunity to adapt the approach to a less time-intensive training/extension system to reach farmers outside the program. Over the last year of the program, farmers will be encouraged to extend the lessons they have learned to neighbours and friends. MAF *suco* extension officers will also gain experience at the FFS sites for extension of CA practices to other villages.

The traditional practice of allowing livestock to roam freely during the off-season is recognised as a constraint to agricultural production in a number of farming systems and in urban areas. Free grazing has been outlawed in the municipality of Dili, for example, due to the danger of animals causing traffic problems and acting as vectors for disease. The use of *tara bundu* is an effective way of controlling some animals at the rural village level but, apart from Dili, had not been tried on a wider scale by the end of 2015. There is potential for extending the practice into large areas of cultivable land with the support of both the farming community and government administration. Management of a national policy on animal control would be difficult to implement as the farming area is extremely fragmented. However, individual municipalities, with support of the traditional village elders, could implement a local law to restrict the damage done to off-season food and mulching crops.

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Wild plant food in Timor-Leste

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Abstract

In Timor-Leste food insecurity is seasonal with the hungry season prior to grain harvests. Foraging for wild foods is often cited among coping strategies for household food insecurity. Historically from 42,000 to 4,500 BP all food (100%) came from wild sources in Timor-Leste. From 4,500 BP up to the arrival of the Europeans in the 16th century, despite the presence of domestic animals and plants, the predominant food sources were hunting, gathering and fishing. Thereafter there was a slow decline in the importance of wild food until the early 20th century when the pace of decline steepened as swidden agriculture, particularly with maize, increased. Today, wild food consumption fluctuates widely over the year being much reduced in the wet season (December–April) compared to the dry season (May–November). Comparing wild food use in a normal year (2007) and a food-deficit year (2011) (with a severe hungry season), wild food foraging, particularly by poor households, was dramatically higher in the food-insecure season. The most widely eaten wild foods in Timor-Leste are lesser yam (*Dioscorea esculenta*) which is consumed by 30% of households, followed by elephant's foot yam (*Amorphophallus paeoniifolius*) and bitter bean (*Phaseolus lunatus*). Looking ahead in Timor-Leste, the wild food resource in woodland ecosystems will continue to provide an important food buffer in food-deficit years, especially to poor at-risk households, increasing their resilience and reducing their vulnerability to shocks.

Introduction

Many rural households in the developing world are subject to chronic seasonal food insecurity. Timor-Leste—a small, young country that is among the poorest in Asia—is no exception and experiences widespread seasonal household food insecurity with a hungry season prior to maize and rice harvests (da Costa et al. 2013). The population of Timor-Leste is 1.17 million (GDS 2015) and the country had the seventh highest rate of population growth in the world during the period 2005–2010, although this had come down to 1.81% by mid-2015 (UN 2009; GDS 2015). After independence Timor-Leste had the third highest stunting rate (indicating chronically malnourished children) in the world (UNICEF 2011), but the malnutrition rate decreased from 44.7% in 2010 to 38.1% in 2013 (Seameo 2013).

Farm households cope with food insecurity through crop diversification, with tubers playing a lead role as grain stocks dwindle. Foraging for wild food, selling animals and other assets, and social networks are other key strategies for coping with food insecurity (da Costa et al. 2013).

This paper examines evidence for the foraging for wild plant food resources in Timor-Leste. We first take a pre-historic/historical perspective of plant collection in Timor-Leste. Historical evidence for plant collection is mostly indirect, coming primarily from the known use of domesticated food sources with the rest of the plant diet presumed to come from the wild larder. We then briefly mention the management of

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the forest resource; compare wild plant foods with domesticated ones in a general sense; then examine evidence of differences in plant foraging by district and by season, and their incorporation into the diet; and finally we discuss evidence of wild food foraging in response to food insecurity from recent surveys.

Pre-historic/historical perspective

42,000–4,500 BP: Archaeological excavation of Lene Hara Cave has revealed evidence of the earliest human settlement in Timor-Leste which dates back some 42,000 years (O'Connor et al. 2010). From this period until approximately 4,500 BP the Timorese subsisted as hunters, gatherers and fishing folk in their diverse environment (Shepherd and Palmer 2015). Sago (*Corypha utan* Lam.), palm juice and various fruits were some of the main foods (Fox 1977). The early settlers of the excavated caves inhabited an island that had no native mammals other than several genera of rodents, all of which became extinct by at least 1,500 BP (Glover 1986).

4,500 BP: Major changes then occurred from 4,500 BP. They begin with the appearance of pottery and pig bones at about 4,500 BP followed at less certain dates by the appearance of dogs, goats, cattle (probably in that order) and the Polynesian rat (*Rattus exulans*) (Glover 1986). Such changes probably reflect the arrival on the island of agricultural people. Several other wild animal species appeared concurrently with the pigs—civet cats and macaque monkeys from the west and phalangers (cuscuses) from New Guinea or the Moluccas to the north. It is presumed that all these species were introduced to the island deliberately (except the rat which could have stowed away on a canoe) as domesticated animals, as pets or simply to hunt on an island which had no meaty wild animals of its own (Glover 1986).

No doubt a large range of indigenous plant foods were harvested, for example *Celtis* (for fruit and/or barkcloth), Polynesian chestnut (*Inocarpus*) (Glover 1986) and Job's tears (*Coix lacryma-jobi* L.)—apparently for necklaces. *C. lacryma-jobi* was also later the first grain to be grown (Glover 1986; Fox 2003). Migrations and interactions with the west (Melanesia) and east (Indonesia) saw both rice (*Oryza sativa* L.) and millet (*Setaria italica* L.), the main cereal crops of the Austronesians, introduced at an early period, followed by sugarcane (*Saccharum officinarum* L.), yams (*Discorea* sp.) and taro (*Colocasia esculenta* (L.) Schott) (Oliveira 2012), sesame (*Sesame orientale* L.), a variety of beans including a kind of mung bean (*Phaseolus aureus* Roxb.), and garlic/onions (*Allium* spp.) (Fox 1977). Root crops predominated—taro and yam (Fox 1977). There was evidence of early use of fire in the planting of these crops in gardens or swiddens (Glover 1971; Fox 1988). Sorghum (*Sorghum bicolor* [L.] Moench) came at a later date, probably in the wake of extended trade between eastern Indonesia and India (Fox 1988).

Fourteenth century: In the 14th century, sago remained the main staple, underlining the continued importance of the collection economy (Fox 1988). Despite the presence of a wide range of domesticated animals and plants, up to the arrival of the Europeans the predominant food sources in Timor-Leste were from hunting, gathering, and fishing.

Sixteenth century: From the 16th century, Europeans, drawn by the commercial prospects of sandalwood (*Santalum album* L.) and to a lesser extent beeswax, came with watermelon (*Citrullus lanatus* (Thunb.) var. *lanatus*), papaya (*Carica papaya* L.), chilli (*Capsicum* sp.), potato (*Solanum tuberosum* L.), tomato (*Solanum lycopersicum* L.), eggplant (*Solanum melongena* L.) and cabbage (*Brassica oleracea* L.). They also brought maize (*Zea mays* L.), cassava (*Manihot utililissima* Pohl), pumpkin/squash (*Cucurbita* spp.), sweetpotato (*Ipomoea batatas* L. (Lam.)) and peanut (*Arachis hypogea* L.) (Fox 2003). The latter crops were destined to become major staples.

From c. 1860 the development of the coffee crop was a Portuguese priority. Governor Castro (1859–63) said "In our opinion, the future of the colony depends on coffee" (Shepherd and Palmer 2015). This gave rise to the dual economy—'rich crops', i.e. introduced and profitable crops such as coffee, vs 'poor crops', i.e. pre-existing subsistence crops (Fox 1977; Shepherd and Palmer 2015).

Shepherd and Palmer (2015) recently showed that from the 16th to the early 20th century maize was not as widely cultivated as formerly thought (Fox 1977), although, alongside rice, it was clearly important and stood out in the indigenous and colonial systems of tribute, exchange and power relations as a key component of the subsistence base. The rugged interior terrain made Timor-Leste more resilient to diminishment of the diverse subsistence economic base which included foraging (Shepherd and Palmer 2015). Through most of the 19th and early 20th centuries, rice was grown in limited areas as a rainfed or partially irrigated crop (Fox 2003).

In Timor-Leste, colonial drivers—peace, plantations, tax, land regulation, forced labour, and a limited maize and rice market—propelled a particular style of swiddening into being, which we recognise now as traditional slash and burn (Shepherd and Palmer 2015).

From the 16th century until the early 20th century hunting, gathering, and fishing were still very important food sources in Timor-Leste.

In the 1910s and 1920s, maize and rice cultivation were consolidated and accelerated by Portuguese colonial interventions, and other forms of survival (such as hunting and foraging) experienced a decline (Shepherd and Palmer 2015).

While far-reaching modification to rice cultivation is generally associated with the Green Revolution of the 1960s and 1970s, it has been shown that the early 20th century was also a major developmental period for this grain (Shepherd and Palmer 2015). Experimentation with fertiliser and the varietal evaluation of lines from the International Rice Research Institute (IRRI), IR5 and IR8, were in full swing as the Portuguese left and Indonesia took over in 1975. Indonesia strongly encouraged irrigated rice production (Fox 2003).

During the Japanese occupation of the mid-20th century (1942–45), cassava rose to prominence when the Japanese forced the local population to intensify the crop (Shepherd and Palmer 2015).

Swidden-style practices in Timor-Leste were and are part of a diverse pattern of landscape use and exploitation, as well as dynamic livelihood systems which are quick to embrace change, innovation and transformation. In Timor-Leste, if less so in the neighbouring west, the continued reliance on wild foods in rural diets and the persistence of pre-colonial root crops and tubers attest to this dynamism (Shepherd and Palmer 2015). The overall picture in terms of plants with the potential for food production in Timor-Leste is one where the major changes occurred within the last ca. 500 years, after the first European contact (Oliveira 2012).

Managing the forest resource

The main tools to manage the landscape in which wild foods grow are fire and grazing. Tree cover was reduced from 59% to 48% from 1997 to 2012 (FAOSTAT 2015). Population pressure and increasing temperatures and rainfall make traditional shifting slash-and-burn agriculture in Timor-Leste unsustainable in the long term (Molyneux et al. 2012). Constant cultivation and over-grazing increase the risk of land degradation especially on slopes. Landscape use and exploitation is clearly dynamic in Timor-Leste.

Wild foods compared with domesticated

Many crops have as their botanical species name *esculenta*, meaning fit for eating or edible (e.g. *Colocasia esculenta* Linn. (CE) and *Dioscorea esculenta* L), reflecting their relative ease of growing and preparing as food. Wild plant food, by contrast, is usually highly time and energy consuming, firstly to forage and secondly to prepare (Erskine et al. 2015). Tubers and beans are the most commonly consumed wild foods, and require labour-intensive processing prior to cooking, in addition to carrying firewood and water for boiling. Repeated boiling to remove bitterness or toxins is a common practice in the preparation of wild foods, mainly beans, and a specific term in the Tetun language (*tisi*) describes this practice. Toxic components include the glucoside phaseolutanin which denatures to hydrocyanic acid in lima beans (Purseglove 1968), L-dopa in Mucuna bean (Correia et al. 2014) and calcium oxalate in elephant's foot yam (Purseglove 1972).

Wild food consumption

In two surveys, there were clear differences between districts in the extent of wild food foraging (Erskine et al. 2015). Overall, a relationship was observed between vegetation type and wild food carrying capacity which was reflected in foraging/reliance on wild food in the different districts. A mixed forest (open woodland or savannah), which is moist but does not have a dense canopy, supports a wide variety of wild foods, while a denser forest combined with low population density supports a habitat for larger game. Such a relationship could be tested across other districts in the future.

The consumption of wild food fluctuates widely across the year, with consumption much reduced in the wet season (December–April) compared to the dry season (May–November) (Figure 1). The periodicity of consumption of the most widely eaten wild plant foods in Timor-Leste—lesser yam

(*Dioscorea esculenta* (Lour.) Burkill, considered wild in Timor-Leste), followed by elephant's foot yam (*Amorphophallus paeoniifolius* L.) and bitter bean (*Phaseolus lunatus* L.)—is also shown in Figure 1.

Palm trees represent a major (and rather under-documented) source of food and fibre in previous and current Timorese society. This includes fruit from the Arecaceae family, which includes betel nut (*Areca catechu* L.), tapping sugar from the black fibre palm (*Arenga pinnata* Merr.), and sugar palm (*Borassus flabellifer* L.), coconut (*Cocos nucifera* L.) and sago (*Corypha utan* Lam.) (Oliveria 2008). Sago palm is widespread along the north and south coast and is regularly eaten as a famine food. Although many of the groves of sugar palm and sago palm appear to be wild, they were probably planted and tended by earlier generations. The Papuan sago palm (*Metroxylon sagu* L.) was recorded by Metzner (1977) as occurring in a swamp on the south coast, but seems to be quite rare. More recently (post-colonisation), large areas of coconut trees were planted in plantation style, mainly in the east and south coast of the country.

A description of the parts of wild foods used, their preparation and consumption is given in Erskine et al. (2015). That wild food is perceived as complementary to cultivated within the diet is shown by the diverse wild and cultivated components of meals (Erskine et al. 2015).

Evidence of wild food foraging in response to food insecurity

Foraging for wild food is often observed as a response to household need and as an indicator of food insecurity (Bharucha and Pretty 2012). In 2006 the national maize production in Timor-Leste was 118,984 t, which is close to the annual average production during 2006–12 of 108,708 t (FAO 2013). By contrast, in the season 2010–11, maize production in Timor-Leste was particularly poor at 30,666 t (28% of the long-term average). As a direct result, the following hungry season (2011) was particularly severe. Wild food use in a normal year (2006–07) and in a food-deficit year (2010–11, resulting in a severe hungry season in 2011–12) were compared (Erskine et al. 2015). In the normal year the maize grain store was exhausted in 50% of households (expressed as cumulative percentage of 'at risk' households) during the month of August and the percentage of households consuming wild food was 9.2% (Figure 2). By

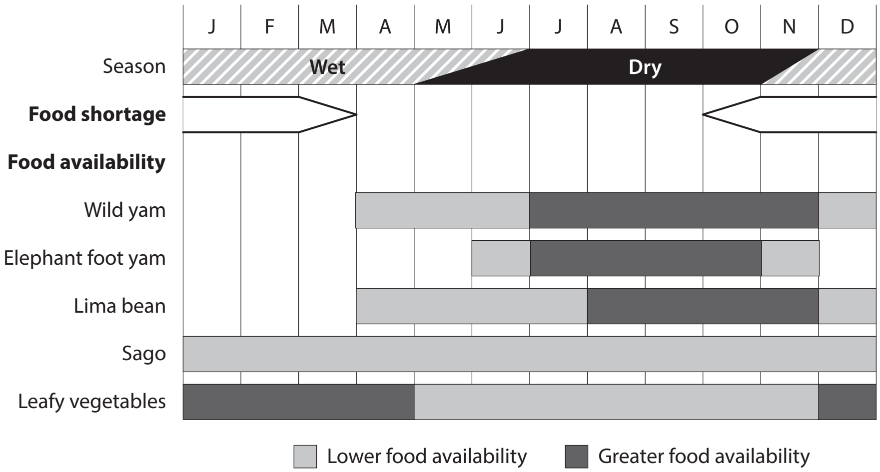

Figure 1. Seasonal calendar showing generalised dry, wet and hungry seasons and the availability of key wild foods across the study area in Timor-Leste (Erskine et al. 2015). The dry season varies from approximately 3 to 6 months according to elevation (upland or coastal lowland) and north or south coastal location. Lighter shade shows lower food availability; darker shade shows greater food availability. Sources: Glazebrook et al. (2007); da Costa et al. (2013).

contrast, in the food-deficit year, maize grain stores were typically exhausted 2 months earlier (June) than in a normal year, and 50% of all interviewed households were foraging for wild food by May in four districts. Clearly in the food-deficit season wild food foraging was dramatically increased and wild food played a substantially larger role in the diet than in a normal year, particularly in poor at-risk households. This confirmed the understanding that poor households depend most on wild foods (Bharucha and Pretty 2012).

In north-east Thailand, recent evidence of rice farmers' extensive transplanting of wild species in their gardens and fields indicated that they are ensuring availability and stability of the wild food plant supply for domestic consumption (Cruz-Garcia and Price 2014). The authors concluded that conventional dichotomies of wild versus domesticated underlying conventional thinking and research on human food systems overlook the reality of how 'wilderness' and 'farming' come together in creative ways, forming foodways and securing the food supply. Clearly the management and contribution of wild plant resources to food security is inadequately understood in Timor-Leste. The nutritional significance of wild foods in the Timorese diet also needs clarification. This is particularly important in light of the recent national nutritional strategy which emphasises dietary diversity by increasing the availability of food from animal sources at household level and reducing micronutrient deficiencies (MoH 2014). In this context there is little information available on animals caught from the wild and their role in the diet, and on the medicinal use of the Timorese flora.

Notwithstanding gaps in knowledge, looking ahead, the wild food resource and the close integration of non-agricultural systems with agricultural systems in the rural landscape will continue to provide an important food buffer in food-deficit years for poor at-risk households in Timor-Leste, increasing their resilience and reducing their vulnerability to climatic and political shocks.

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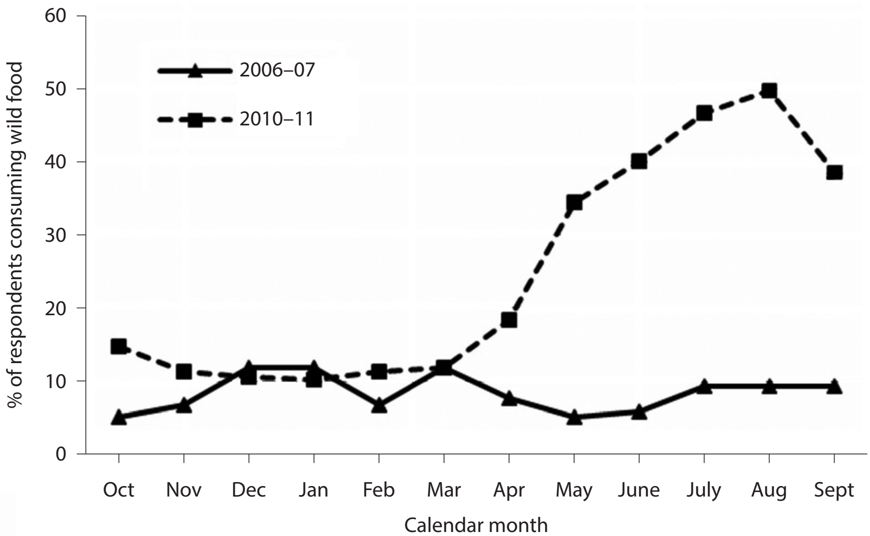

Figure 2. Percentage of household respondents consuming wild food in a month in an average season for maize production (2006–07; n = 119) and a very low maize production season (2010–11; n = 473) in four districts (Aileu, Baucau, Liquiça and Manufahi). Data extracted from SoL (2007, 2012). Source: Erskine et al. (2015).

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Is there a place for temperate crops in Timor-Leste?

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Abstract

Timor-Leste has areas of high-altitude land which have been cultivated with temperate crops for hundreds of years. The area capable of growing these crops and the types and quantities of these crops cultivated in Timor-Leste have not been documented in recent years. This paper describes a study that estimated the area suited to the cultivation of temperate crops, and surveyed the types of crops grown and their marketability. The study, which was conducted on farmland over 1,200 metres above sea level, showed that the range of temperate crops cultivated includes cereals, grain legumes and fruit. Most of the production is consumed on-farm but some of the fruit and grain legume product is sold locally. Little of this produce is reaching Dili, where a large market exists for temperate crop produce. There is sufficient suitable area in the highlands to increase temperate crop production for national consumption and export, but quality and production constraints need to first be addressed.

Introduction

Timor-Leste is a tropical country situated at a latitude of approximately 9° south at the eastern edge of the Indonesian archipelago. It has a land area of 15,000 km^2 and a population estimated to be over 1,167,000 (2015 census, GoTL 2015). The majority of the population resides in subsistence farming households which primarily grow a range of tropical cereals such as rice, maize, tropical fruits such as banana and mango, and tuber crops such as sweet-potato, cassava and taro.

Climatic zones are not determined strictly by latitude, but also by geography. Altitude, for example, can influence factors such as temperature and rainfall. Timor-Leste is dominated by a mountainous central spine which divides the country into a northern coastal area with a single growing season (November to April), and a southern coastal plain with a shorter dry season allowing the cultivation of two crops per year. The mountain range has a significant area of land at high altitudes with a cooler climate and significant rainfall (Figure 1). There is potential for the cultivation of a range of temperate crops in these higher altitudes.

As an example, wheat, a cool climate crop, usually requires 750–1,600 mm annual rainfall and has an optimum temperature of 20–25°C at germination, then cool temperatures in the early growth period which help to increase tillering (Procrop 2007). Preferably, this should be followed by a frost-free reproductive stage and then a dry period to maturity with maximum temperatures in the 25–30°C range for maximum yield potential.

Although there are limited historical climate data available in Timor-Leste, records from one long-term site near Maubisse (elevation of 1,600 m above sea level, masl) indicate an average annual rainfall of 1,500 mm, with 1,000+ mm falling between April and July. This period has minimum–maximum temperature range of 6–22°C followed by a dry (less than 10 mm) August–September period with an average maximum temp of 25°C.

Many temperate crops were introduced during the Portuguese colonial period (1515–1975) including wheat, legumes and fruit, and these are still grown in

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Timor-Leste. This paper reviews the past and current cultivation of these crops and assesses their potential for further expanded cultivation. It reports the findings of a survey conducted in 2015 to determine what temperate crops were being grown in Timor-Leste. A map of survey sites and locations where low average annual temperatures occur is presented in Figure 1.

Historical background

European presence in the eastern part of the island of Timor began in the 1500s with the arrival of the Portuguese who later colonised part of the island. Crops cultivated in Europe were gradually introduced to the more temperate areas of the country over the following 400 years. The presence of these crops in eastern Timor was noted by various authors and the estimated arrival of each crop was given by De Oliveira in his PhD thesis (De Oliveira 2008). A summary of the first records of various temperate crops in eastern Timor is presented in Table 1, and indicates that farmers at higher altitudes have been growing some temperate crops for hundreds of years.

The first agricultural stations were established by the Portuguese authorities in the 1900s. If not already introduced, a range of temperate crops such as barley, peaches, almonds, apples and olives, not previously mentioned in the records but with which the Portuguese were very familiar, would have been brought in for testing in higher altitude areas. A film made in 1954 mentioned the existence of an

Table 1. Original record of various temperate crops cultivated in Timor-Leste.

Crop	Year of first mention in literature
Cowpeas	1525
Pearl millet	1624
Grape	1634
Pomegranate	1699
Wheat	1800
Peas, mustard, figs	1818
Wheat and potatoes	1869*
Phaseolus	1885
Granadilla	1900

* Wallace (1869) reported both crops grown in abundance from 900 masl, and by 1858 26 tonnes of wheat was exported from Dili.

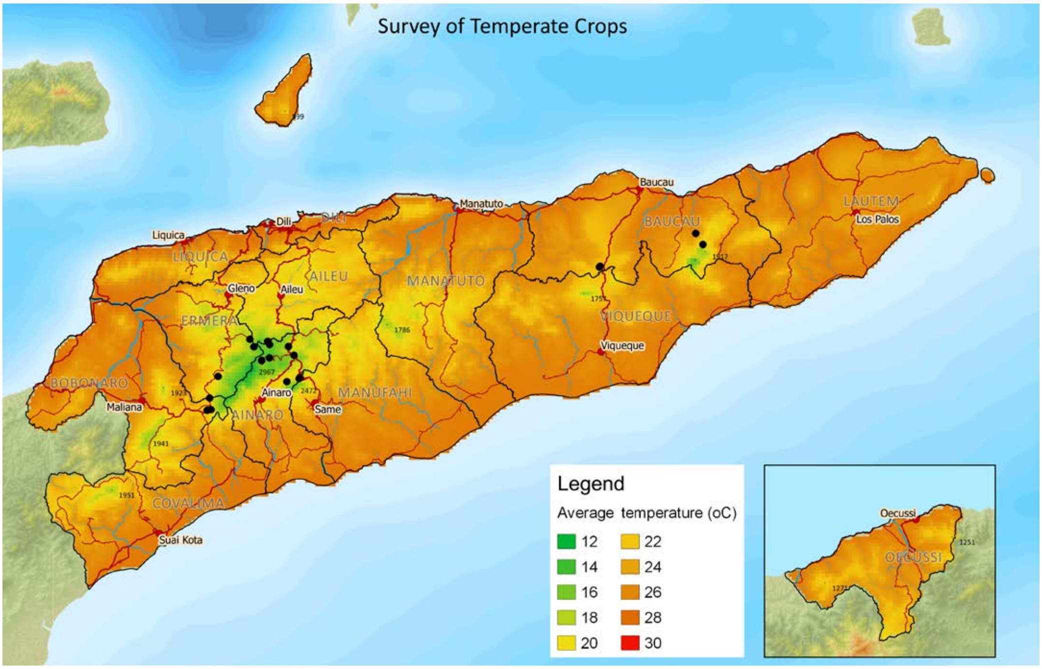

Figure 1. Map showing annual mean temperature in Timor-Leste, with survey sites marked.

agricultural shop in Portugal which supplied seeds and trees for people who were visiting or working in Timor and other Portuguese colonies, supporting this hypothesis.

Unfortunately, there are very few records of the subsequent extent of cultivation of temperate crops. The abrupt nature of the Portuguese departure, the ensuing brief civil war and the Indonesian invasion resulted in most records being misplaced or destroyed. Surviving records from the national archives indicate that there was a total of 20 tonnes of wheat produced in a 4-year period from 1967 to 1970. Records also state that the village of Aitutu in the municipality of Ainaro produced 10 tonnes of wheat in 1973 and in 1975 and that three other villages (Edi, Horai-Quic and Liurai) in this same municipality produced a combined total of 6 tonnes. There are also reports that a mill operating in Aileu processed approximately 1 tonne/month of wheat sourced from the Maubisse area of Ainaro between 1963 and 1968. It is not known whether this wheat was voluntarily grown by farmers and freely traded to the mill, or the result of a forced-labour system similar to that which occurred in some coffee plantations at the time. The existence of another mill in Dili producing 2 tonnes/month of wheat flour during 1973–75 but relying on imported wheat from Australia would seem to indicate that the supply of wheat was both limited and unreliable.

The tumult and dislocation during the period after the Indonesian invasion resulted in the abandonment and neglect of many farmers' fields with consequent loss of temperate crops and seeds. It is also likely that development emphasis for the following 25 years was on those tropical crops and farming systems which form the backbone of Indonesian agriculture. Even if there was recognition by some individuals and/or organisations of the potential for temperate crops in Timor-Leste (given that very little of the rest of the Indonesian archipelago has a similar cool upland climate), the policy of moving people from the more remote higher altitudes to settle along established roads at lower altitudes (in order to better control the Timorese and also provide more economic access to services) is likely to have resulted in relatively little effort by the Indonesian authorities to develop the potential of temperate crops.

As after the Portuguese administration, few agricultural records from the Indonesian period remain in Timor-Leste. Similarly, the violence marking the end of the Indonesian occupation significantly curtailed both agricultural production and the availability of replanting material.

The current situation

Temperate vegetables such as cabbages, carrots, beans and potatoes provide significant sources of income for farmers at higher altitudes. When in season, plums are sold from roadsides (for example in the *suco* Aitula in the Maubisse region), and peaches are also found though to a lesser extent. However all fruit are small in size and not very sweet in comparison with fruit available in other countries. Although wheat and barley are not now found for sale in the markets, some farmers still cultivate these cereals for home consumption.

A qualitative survey was carried out in order to gain more insight into the earlier and ongoing cultivation of a selected number of temperate crops. Those temperate vegetable crops known to be relatively widely grown (mentioned above) were not included in this survey. The methodology and results are detailed in the following sections.

Survey methods

The survey was conducted during March/April 2015. Respondents were shown photos of selected temperate crops and asked whether they recognised the crop. If so, they were asked if they grow it, and if so how much they harvest, how much they consumed and how much if any was sold, and the price. Questions were then asked about the origin of the crop, for example, did or do their parents, relatives or neighbours grow the crop?

Members of a total of 20 farming households from 15 different villages were interviewed. These villages were selected on the basis of being situated at sufficiently high altitude (+1,200 masl) to be considered suitable for the cultivation of temperate crops and/or having some recorded history of growing such crops. Above 1,200 masl, the temperatures are considered to be at least 6°C cooler than at sea level. Thirteen of the villages were in the central highland regions of Ainaro, Aileu, Ermera and Manufahi with altitudes ranging from 1,310 m to 2,110 m, while three were from lower altitudes (901 m to 1,110 m) in the western municipality of Bobonaro and four were from lower altitudes (470 m to 1,230 m) in the eastern municipality of Baucau, where there were reports of historical cultivation of temperate crops.

Respondents from the selected villages were shown photos of mature plants and seeds and/or fruits of the 17 temperate crops listed in Table 2.

To gauge current demand as well as production, a market survey was conducted in Dili to determine fresh and processed produce costs and marketability.

Potential areas of cultivation

An assumption was made that the most suitable altitudes for temperate crops, including wheat and barley, are 1,200+ masl. Altitudes and slopes were obtained from Google maps satellite imagery. The slope classes within each *suco* (village) were derived from a 30 m resolution digital elevation model (DEM) using the Spatial Analyst tool ArcGIS. The per cent land distribution for each slope class was derived using the same tool based on official administrative size/area of the *sucos*. Slopes were determined as %; for example, a rise of 1 m over a run of 2 m = 50% slope. Numbers of households in the villages were obtained from 2010 census data. Soils in the areas of Ainaro/Ermera/Aileu are mostly mollisols or vertisols, loam or clay-loam with neutral pH.

The results of this study were compared with those of Pinheiro da Luz (2003) who evaluated the potential for various agricultural crops, including wheat and barley, in Timor-Leste using GIS and meteorological data. He estimated periods of crop growth across Timor-Leste and suitability of crop type according to slope. In addition he applied available temperature data and altitude and FAO soil maps to an ArcView program and through quadricular models predicted the suitability of each crop to soil type and subsequently potential distribution in Timor-Leste.

Table 2. The temperate crops investigated in the survey.

Crop type	Common name	Scientific name
Cereals	Wheat	*Triticum aestivum*
	Barley	*Hordeum vulgare*
Grain legumes	Broad bean	*Vicia faba*
	Green pea	*Pisum sativum*
	Lupin	*Lupinus albus*
Fruit	Peach	*Prunus persica*
	Apple	*Malus domestica*
	Pear	*Pyrus communis*
	Plum	*Prunus domestica*
	Strawberry	*Fragaria vescas*
	Almond	*Prunus dulsus*
	Lemon	*Citrus limon*
	Grape	*Vitus* sp.
	Mulberry	*Morus alba*
	Olive	*Olea europaea*
	Loquat	*Eriobotrya japonica*
	Quince	*Cydonia oblonga*

Survey results

Cereals

Wheat was recognised by all respondents, with 95% either still growing, had grown themselves, or remembered their parents and/or grandparents having grown it (Table 3). Barley was less well known and only 15% of the respondents were still growing this crop. No one indicated that they had sold any of the wheat or barley they had produced and all production was for household consumption. Both wheat and barley were eaten boiled whole, either alone or more often mixed with beans. Wheat may also have been fried but never barley. Wheat was preferred to barley because of the difficulty in removing the husk from barley. Although people knew that wheat flour can be used to make bread or biscuits, no one had tried to grind wheat for this purpose. Also, no one knew that barley is used in the production of beer. Both two-row and six-row barley were observed being grown.

Among the 45% who still cultivated either wheat or wheat and barley (none cultivated only barley), production levels ranged from two to five bags (60–200 kg) per year. Those who had grown previously but had ceased to grow either crop said they no longer had seed and did not look for new seed sources because their family had become accustomed to eating rice, or 'the children don't like to eat wheat'. Similar comments were made by farmers still growing wheat. It appeared that only the older generation liked to grow and eat wheat. Given the small amounts of wheat produced (60–200 kg/year/household) and the difficulty of storing wheat seed, there is a limited chance of farmers finding seed to return to its cultivation. A number of respondents did however comment that if there was a market for wheat they would be happy to grow it again. Without this incentive, they preferred to use their land to grow cash crops such as potatoes and beans and to use the proceeds to purchase rice as their staple.

Table 3. Cultivation of temperate crops in surveyed areas.

Crop	% who recognise	% who now grow	% who sell	% who used to grow	% whose ancestors grew	% who have never grown
Wheat	100	45	0	50	95	5
Barley	75	15	0	30	35	25
Faba bean	80	60	30	10	10	30
Green pea	85	70	50	70	75	15
Lupin	55	45*	0	50	45	50
Peach	45	30	5	35	40	60
Apple	50	35	0	35	40	55
Pear	10	52	0	0	5	95
Plum	45	25	5	25	25	75
Strawberry	50	25	10	35	30	65
Almond	20	0	0	5	5	95
Lemon	95	90	40	90	90	10
Grape	20	51	0	10*	5*	75
Mulberry	70	70	0	20	65	25
Olive	30	0	0	10	10	90
Loquat	75	60	5	60	55	30
Quince	5	5	0	5	5	95

* Not actually grown but harvested wild.

Legumes

As with the cereals, there was a significant amount of recognition of all three legumes shown to the respondents (faba bean, green pea and lupin), but in particular green peas, which 70% continued to cultivate (Table 3). In contrast to wheat and barley, there was a ready market for green peas with 50% of respondents selling some of their produce. The cultivation and sale of a number of different types of beans continues to be widespread in the higher altitude areas and green peas have been part of the farming system in the mountain areas of Ainaro, Ermera, Aileu and Manufahi since Portuguese times. None of the respondents from the lower altitude sites in Baucau cultivated peas or other legumes.

Faba beans were widely recognised, grown and sold in Maubisse, Ermera, Aileu and Manufahi, but not in Bobonaro or Baucau. Some respondents indicated that although their parents/grandparents had grown faba beans, the current level of production is a recent development. A number said they had only started growing in recent years as seed availability improved. Production estimates were relatively small, i.e. one–two 'buckets' (10–20 kg) per harvest, and prices ranged from $1 to $1.50/kg. The response indicated a positive opinion of faba beans for both home consumption and as a source of cash.

Lupins were also easily recognised, however in contrast to both peas and faba beans, no respondents said they sold it. The lupins grow wild in the mountain areas of Ainaro, Ermera, Aileu and Manufahi and are harvested when needed. Because they are not cultivated and no plants were either flowering or seeding at the time of the interviews, it cannot be confirmed whether the lupins being referred to by the respondents were a domesticated variety self-seeding or a wild relative of lupin. All respondents consistently referred to the photos of domesticated lupin plants and seed by its local name 'tremosu'. One farmer indicated that they harvest one large bucket per year but many said they ate it only if their cultivated crops failed.

Fruit

All but one respondent recognised lemons and, with the exception of Baucau, all sites surveyed had at least a few lemon trees (Table 3). Forty per cent of respondents sold some of the harvest. One respondent estimated production at two buckets per tree and sold at 50 c for four lemons.

Loquats and mulberries were also widely recognised and 'grown', however as with lupins, these were considered to be wild and used just for home consumption when in season.

Apples, peaches, plums or strawberries were grown by most of the respondents from the higher altitude areas of Ainaro, Ermera, Manufahi and Aileu (Table 3). These sites were all 1,800+ masl. One enterprising farmer at 1,400 masl at Brigada in Maubisse successfully grew all four of these fruit species and had recently planted grapes and quince. This farm had 40 peach trees producing 80 buckets of fruit per year which were sold at 25 c for six fruits. They also produced a bucket of strawberries per month which were sold at $10/plate. This household was on the main road to Dili and marketed their own fruit.

There was some recognition of both grapes and olives, due partly to their biblical connections, but a couple of respondents did remember trees from their childhood. In many interviews, it was the children of the family who quickly recognised pictures of fruit trees and also knew where they were growing.

Almonds were also recognised and one respondent mentioned that their grandparents had almond trees, but there was some confusion between temperate almond and the tropical version *Terminalia catappa* which can be found around Dili and down on the south coast at Suai.

Estimated crop areas suitable for temperate crops

The number of households, total area and slope characteristics for municipalities having land above 1,200 masl are presented in Table 4.

An assumption was made that slopes over 50% should not be used for agriculture, that areas with slopes of 30–50% are suitable for fruit trees but not cultivated crops, and that land with less than 30% slope is suitable for cultivated crops. Table 5 presents estimated potential areas suitable for the cultivation of temperate crops in the three main municipalities covering the mountain areas of Timor-Leste.

The modelling of Pinheiro da Luz (2003) produced specific estimates of the land area suitable for the cultivation of temperate crops. As an example, the results for wheat and barley are presented in Table 6. He concluded that there was approximately 33,000 ha suitable or marginally suitable for temperate crops, the largest areas being for wheat and barley. The areas of adequate and moderately adequate suitability are more extensive for barley, which may be related to its improved drought tolerance and perhaps greater tillering ability leading to different classification regarding suitability to steeper slopes and shallower soils.

Table 4. Number of households and slope characteristics of land above 1,200 masl in the different municipalities.

Municipality	Number of households above 1,200 masl	Area above 1,200 masl (ha)	Area with slope >50% (ha)	Area with slope 30–50% (ha)	Area with slope 10–30% (ha)	Area with slope 5–10% (ha)	Area with slope 0–5% (ha)
Ermera	4,800	25,273	2,129	7,523	13,931	1,255	436
Ainaro	4,925	27,597	6,431	9,220	10,724	891	361
Aileu	1,751	13,669	310	3,767	8,475	673	188
Manututu	1,501	8,394	1,604	3,768	2,709	223	89
Bobonaro	313	7,053	1,686	2,589	2,560	180	42
Manufahi	374	5,856	1,957	2,115	1,557	133	36
Cova Lima	155	2,627	802	884	856	66	19
Viqueque	34	2,250	601	770	784	64	31
Baucau	349	3361	1,575	934	701	99	53
Liquica	573	321	21	79	92	15	2
Totals	14,775	96,400	17,116	31,648	42,388	3,600	1,256

Table 5. Number of households and major areas estimated to be suitable for temperate fruit trees and crops in Timor-Leste.

Municipality	Number of households	Area (ha) suitable for fruit trees only	Area (ha) suitable for crops
Ermera	4,800	7,523	15,622
Ainaro	4,925	9,220	11,976
Aileu	1,751	3,767	9,336
Total	11,476	20,510	36,934

Table 6. Summary of data from Pinheiro da Luz (2003) of areas suitable for wheat and barley cultivation.

Suitability class	Area for wheat (ha)	Municipalities where areas occur	Area for barley (ha)	Municipalities where areas occur
Very adequate	521	Ainaro, Aileu, Ermera	521	Ainaro, Aileu, Ermera
Adequate	3,732	As above plus Manufahi, Manututo, Baucau	5,732	As above plus Manufahi, Manututo, Baucau, Cova Lima, Bobonaro
Moderately adequate	6,855	As above plus Cova Lima, Bobonaro	5,920	As above plus Lautem, Viqueque
Marginal	22,630	As above	21,589	As above
Totals	33,738		33,762	

Market survey results

The temperate-climate product imported in highest quantities was wheat flour, used for bread and cake preparation (Table 7). A large amount of fruit, particularly apples, was also imported during 2015, as fresh, canned or dried fruit.

Discussion

The results of this study indicate that temperate crops are being cultivated, consumed and sold in Timor-Leste. However, the areas under cultivation are small. The decision of which crops to grow is driven by household needs, both food and non-food, i.e. either to be directly consumed or sold to generate cash. Legumes are cultivated for both home consumption and some sales, while wheat is grown for home consumption only and is being replaced by rice and other cheap imported grains purchased with cash from off-farm income. Off-farm income has, in recent years, been augmented with government welfare payments.

As Table 7 indicates, there is widespread use of imported wheat flour throughout Timor-Leste to make bread, cakes etc. Approximately 18,000 tonnes of flour are imported annually from Australia, India, USA and Canada. In addition, wheat-based processed foods such as instant noodles are imported. As shown in this study, there is potential for the cultivation of wheat to be scaled up to meet at least some of this demand. This requires the establishment of a mill and the cultivation of disease-resistant varieties which have the right quality for bread-, biscuit- and cake-making. The establishment of a mill is dependent on the availability of sufficient quantities of quality wheat. The retail price of imported wheat flour is approximately \$18 for a 25 kg bag which equates to approximately 0.70 c/kg. The profitability and sustainability of a local flour mill will depend on the mill operator being able to source suitable wheat either from overseas (e.g. Australia) or locally at a price which allows them to process and then sell at a wholesale price which can compete with imported flour. An economic feasibility study needs to be conducted to determine whether this is possible.

Interviewed farmers currently consuming both wheat and barley prefer to eat wheat because of the difficulty in removing the husk from barley. There is, however, a potential commercial market for malting barley. The Heineken company plans to establish a

Table 7. Summary of results of the market survey: imported temperate-climate products on sale in Dili.

Product	Sold as	Source	Quantity (t/year)	Average retail price (US$/kg)	Total value (US$)
Wheat flour	25 kg bags	Indonesia	17,900	0.7	12,500,000
Apple	Fresh	China, USA, Singapore	0.6	2.4	1,430,000
Pear	Canned and fresh	China, Singapore	62	3.8	235,600
Peach	Fresh	South Africa, China, Portugal	0.4	6.0	2,268
Plum	Fresh	Australia, Chile, Singapore	7.3	6.2	45,260
Pea	Canned and fresh	Portugal, Australia, China, Malaysia	27.8	3.3	91,740
Lemon	Fresh	Australia, South Africa, Egypt	20.7	4.4	91,080
Almond	Fresh and canned	Portugal, USA, Australia	0.5	18.4	8,924
Grape	Fresh	Singapore, South Africa, USA	31.9	6.5	205,755
Strawberry	Fresh	USA, Singapore	0.15	16.3	2,364
Olive	Canned	Portugal, Greece, Spain	1.7	7.8	13,260
Quince	Canned	Portugal	0.3	17.6	4,570
Lupin	Packet	Portugal	0.8	7.5	6,243
Total					>14,660,000

brewery and produce 30 million litres of beer per annum. This will require approximately 10,000 tonnes of barley to produce 7,500 tonnes of malt for the brewing process. A small-scale malting barley industry can be developed to supply this market.

Although there is no immediate market for processed legumes, this study suggests there is potential for increased cultivation of both green peas and faba beans for home consumption and for supplying local markets. These two legumes as well as other beans traditionally grown in mountain areas (including soybeans grown in the warmer season) could play an important role as rotation crops with cereals such as wheat and maize. There is a need to test and release varieties with improved disease resistance and higher yield potential.

The market survey indicated that there are significant amounts of apples imported into Timor-Leste, and although oranges and mandarins were not included in the survey, it is likely that the import volumes of these fruits may be in a similar range. Lemons imports are smaller, and as with plums and peaches, lemons are commonly sold on road-side stalls. All these fruits are currently being cultivated, but in reality they are basically harvested as wild fruits with no inputs. The trees are also old and consequently yields are very low with poor fruit quality. However there is a market for apples and citrus if production and quality can be improved. In addition to the planting of new stock, it may be possible to graft improved varieties onto existing trees. A similar approach could also be tried with stone fruits such as peaches and plums.

Once the quality and production constraints are resolved and farmers can meet local demand, there is potential for exporting some temperate fruit in the future. Cool temperate environments are not common in the region adjacent to Timor-Leste, and there is potential to supply some of this market. This will require good harvest and postharvest management, efficient transport and the use of varieties with suitable shelf-life (particularly for soft stone fruit and strawberries). Although they are easily perishable, strawberries are small and of high value, making air transport more economic. Daily flights from Dili to Singapore, Bali and Darwin provide a link to these lucrative markets. The possibility of exporting fresh-cut flowers should also be investigated.

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Section 4: Reaching a food surplus

Strengthening agricultural markets to enhance food security in Timor-Leste

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Abstract

Constraints to improving food security in Timor-Leste are numerous and severe but interventions designed to develop the country's agricultural market system can make a difference. The most effective of these focus on encouraging private sector actors to help eliminate bottlenecks to trade, including regulatory reform, establishing more reliable and less costly access to end markets, providing more frequent and efficient transportation, making available more market information and improving storage facilities. A good example of this approach is the partnership between the development program Market Development Facility (MDF) and Acelda II Unipessoal Lda (Acelda). MDF has helped to expand Acelda's core business into the realm of local products, initially focusing on processing and packaging of locally sourced rice. Early results are promising and after only two years of activity there are clear signs of progress. Acelda is sourcing increasing amounts of rice from an expanding geographic area and its sales have grown in pace. Farmers selling to Acelda are realising substantially increased incomes and profits and growing in numbers. In addition to a steady source of income, farming households are benefitting from better nutrition, health and access to education. Evidence suggests these trends are likely to continue and the initiative will expand in the coming years.

Introduction

Food security in Timor-Leste is precarious. On average, 64% of the population suffer from chronic food insecurity and experience cyclical food shortages because of low agricultural productivity and lack of income to purchase food when stocks are depleted (Webb and Dazé 2011). There are few markets in rural areas and although roads in some municipalities are improving, many rural people have to walk for hours to reach a market. The distance from markets limits the opportunity that farmers have to earn income from the sale of their products, giving them little or no incentive to reinvest in their farms (Anderson et al. 2013). These factors contribute to a situation characterised by low crop yields, lack of income-generating activities, limited purchasing power, lack of infrastructure, and underdeveloped markets (WFP 2016).

The government and international donors are involved in a range of activities and programs designed to improve the state of food security in Timor-Leste. While much of their efforts are directed at increasing food production, there is recognition that strengthening the country's agricultural market systems can also play a major role.

Below we describe the relationship between markets and food security, provide an assessment of the state of agricultural markets in Timor-Leste, and advance a number of key constraints and potential interventions. We conclude with a review of the impact of an intervention designed to trigger market change through enabling sourcing of local rice paddy, adding value through high-quality processing, and promoting the resulting product through an effective marketing campaign.

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Market systems and food security

The Rome Declaration on World Food Security asserts the commitment from governments around the world to the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger (FAO 1996). Based on this declaration, a definition of food security has been agreed upon which emphasises four components, all of which must be present for complete food security (Rocha 2006):

- *Availability*—food in sufficient amounts to meet people's needs;
- *Accessibility*—assured physical and economic access to food;
- *Adequacy*—food that is nutritious and safe, needed to maintain healthy lifestyles, and produced in environmentally sustainable ways;
- *Acceptability*—food that is culturally acceptable, produced and obtained in ways that do not compromise people's dignity, self-respect and human rights.

Much of the work of governments and development agencies focuses on the availability component, i.e. on increasing food production, and this is obviously a key factor. Increased investment in research and development and improvements to production capacity are absolutely vital to increase the availability of food (Hebebrand and Wedding 2010). But, as stated by the International Fund for Agricultural Development (IFAD undated), the critical discrepancy between sufficient food being available and the existence of malnutrition is a sombre reminder that the challenge of food security for all involves more than simply raising per capita food production.

Many contend that improving access to markets is a key factor and is at least as important as increasing production. The livelihoods and livelihood opportunities of most poor people are directly (but not solely) dependent on their involvement in a range of markets as private agents or as employees, and are indirectly dependent on the wider economy for the demand and supply of goods and services (Poulton and Dorward 2003).

A fundamental strength of marketing and increasing access to markets is that it can simultaneously address all four factors of food security. Improved access to agricultural input markets—such as seed and fertiliser—is crucial for productivity growth. Addressing the accessibility factor through marketing is achieved in two ways. One is ensuring that markets are functioning where people can find the food items they need. At the simplest level, trade allows food to flow from areas of surplus to areas of deficit—in local, regional and global markets (Hebebrand and Wedding 2010). Marketing can also influence accessibility by promoting economic growth and development. Economic growth is considered to be a key factor in the achievement of social as well as economic goals (Ifezue 2005). This is because economic development leads to increased incomes and increased effective demand for food. Economic accessibility to food is intimately related to income security. Lack of participation in markets as consumers of food due to poverty is the most prevalent cause of food insecurity. It is also one of the most important factors in health insecurity, as it leads to malnutrition and related illnesses (Rocha 2006). In order to achieve the goals of economic development it is necessary to be concerned with the basic institutions of industrial society in general and with the management of business enterprise in particular. Definitely, one cannot successfully accomplish such activities without direct concern with marketing (Ifezue 2005).

Marketing also ensures that food is adequate and acceptable to consumers. Marketing by itself might go far toward changing the entire economic tone of the existing system without any change in methods of production, distribution of population, or of income. For example, it would make the producers capable of producing marketable products by providing them with standards, quality demands and specifications for their product. It would make the product capable of being brought to markets instead of perishing on the way. Also, it would make the consumer capable of discrimination, that is, of obtaining the greatest value for his or her very limited purchasing power (Ifezue 2005).

But developing a robust agricultural market economy is no small task, particularly when the objective is broad-based development that includes the poor. Smallholder farming activities, and particularly those carried out by poor people in poor areas, experience to a greater extent than most other sectors problems that lead to a low-level equilibrium trap. Poor physical transport and communications, remoteness, dependence on an uncertain and seasonal environment and production processes, small production units, and poverty all lead to thin markets with associated high costs and coordination and opportunistic risks, not just for farmers but also for providers of agricultural services to farmers. These problems are particularly important when purchased inputs are required to raise agricultural productivity, since this increases farmers' investment risks in agricultural production, while at the same time demanding greater coordination along the supply chain (involving input suppliers and input finance, as well as output traders; Poulton and Dorward 2003).

Status of Timor-Leste's agricultural market system

The situation described above is certainly recognisable in Timor-Leste and well documented by a number of studies conducted by the Market Development Facility (MDF). Chief among these are two studies titled 'Inclusive analysis of growth, poverty and gender at sector level and sector growth strategy for poverty reduction and women's economic empowerment– agribusiness, processing and rural distribution' (MDF 2013) and 'Household level analysis of poverty and gender dynamics in Timor-Leste' (MDF 2014). The bulk of the information presented in this section is drawn directly from these two reports.

MDF's various analyses of Timor-Leste's agricultural marketing sector paint a stark picture of an agricultural economy that is not working well. Their studies note that, for the majority, farming is characterised by little investment, limited access to markets, inadequate production inputs and knowhow, low yields, relatively high production costs (low returns on investment), relatively high wastage (no opportunity to sell, limited capacity to store), low productivity and, ultimately, low earnings.

Much of the blame for this situation can be traced to decades of colonisation and conflict that resulted in the near collapse of local trade structures, extension services, infrastructure and other vital aspects of the market system that makes rural trade and investment feasible. Timor-Leste has become a largely subsistence-oriented rural economy, with few extension workers, crumbling roads, and very little inter-municipality (let alone international) trade.

Problems in Timor-Leste's agricultural sector are numerous, diverse, complex and interrelated. Farm yields are low, cultivation techniques are basic at best, and the use of inputs is minimal. Farmers' trade is often restricted to small volumes in nearby *suco* markets, sometimes in the form of barter. Since most farmers in a given area grow more or less the same crops, demand only increases in the hungry season, when households start running out of stock, or when a trader shows up to buy produce for the Dili or export market. Travelling to the Dili market is an option for farmers in nearby municipalities, but transportation costs are high, roads are often badly maintained, and it is not always possible to hire a truck, especially when the weather is bad. Travelling to the market is not only costly but is also time consuming, and women often find this particularly difficult as it reduces time they have available to spend at home on other productive activities and family obligations. Some truck owners may refuse to travel to certain areas, and storage facilities to prevent produce from spoiling are often inadequate, if available at all.

Overall, the market system is one of shallow value chains with few actors and fewer specialists engaged in any individual crop. End markets—in particular Dili which represents about 16% of the country's population and a much larger percentage of its total purchasing power—are undersupplied. When traders show up to buy at the farm gate, farmers' attempts to make the most of the immediate opportunity (by demanding high prices or concealing quality issues) often discourage traders from returning. Traders also may not have information about where to source products in the first place. All these factors make imports attractive and exports difficult.

Agricultural inputs, which could make cultivation more productive and more efficient, are often not available in local markets; and when they are, retailers often have little knowledge of the product and it may not be prominently displayed or easy to find. Although access to information and inputs is generally challenging, women have greater difficulties in access and often have to rely on informal sources. The government's provision of inputs and machinery for free or at subsidised rates encourages input businesses to wait for government orders rather than developing their own retail networks. Some farmers' bad experiences with chemical inputs (often due to incorrect application) and the disconnect between municipality- and Dili-based retailers add to the issues around availability and use of inputs. The situation is further exacerbated through free distribution of selective agro-inputs by public agencies which makes private enterprises reluctant to enter the market for fear of being uncompetitive.

Priority marketing constraints in Timor-Leste

Constraints to agricultural marketing in Timor-Leste are clearly highlighted in the section above. MDF has summarised these and proposed potential interventions for each (Table 1).

The key, as MDF sees it, is to fill gaps in the trade system between Dili and the districts. Their research suggests that a specific bottleneck in this process is the difficulties traders face when buying, processing and packaging crops produced by local farmers, such as maize and rice, for retail in the local market. While there is demand for these local grains, farmers do not grow much beyond what they can eat, and do not sell much because they have few and irregular buyers. MDF's research and experience suggest that the best way to address these constraints is to invest in businesses that contribute to increasing trade/distribution and value addition to local raw materials. This includes sourcing from farmers, turning their produce into in-demand products, and supplying them with inputs, information and financing to increase production. This will help connect farmers to markets and make farming a more rewarding undertaking and farming households more resilient. It is expected that, if they are made aware of successful business models, additional actors will engage in similar enterprises that promote local trade and value addition to local raw materials.

Theory into practice: Acelda

Farmers in Timor-Leste are disconnected from markets giving them little incentive to invest in their farms and improve productivity. Similarly, insufficient information on producers/suppliers make businesses reluctant to invest in diversified products (away from safe government contracts). Therefore, it was key for MDF to support a business model that would create access to markets for producers and showcase the success of investing in local trading and processing of local raw materials to other dormant investors.

MDF found a partner, Acelda II Unipessoal Lda (Acelda), a private agribusiness company based in Baucau. Acelda was interested in expanding beyond its core business of sourcing and exporting candlenuts, and tapping into the growing domestic agriculture product markets. Acelda's owner expressed interest in connecting local farmers to sub-national and national consumers by adding value to their produce (in this case, rice). The idea was that Acelda would buy rice from local farmers, process it and market it

Table 1. Market constraints and associated potential intervention strategies (MDF undated).

Constraint to growth in agribusiness, processing and rural distribution	MDF's strategy to unlock growth in the agribusiness, processing and rural distribution sector
Famers lack resources to invest in agriculture resulting in low and fluctuating yields threatening household food security	Stimulate investment in more reliable and less costly access to end markets (e.g. more traders buying at farm gate, more frequent and more efficient transportation) resulting in more transactions
Farmers lack the knowledge to make better use of available resources to maximise productivity and/or reduce risk (crop failure, food insecurity)	Improve access to information on cultivation techniques and input use
Farmers lack access to agricultural inputs, machinery and services	Improve access to affordable, cost-saving and yield-increasing inputs and equipment
Traders struggle to, and lack information and skills to, create robust supply chains	Support investments in establishing or improving 'upstream' linkages to production centres
Poor infrastructure and communication confines trade to the village and district levels	Support investment in establishing or improving infrastructure around local sourcing such as quality testing, specialised transport and storage
Prevailing rules and regulations around agribusiness (inputs and trading) create an unfriendly environment for the private sector, leading to limited investment in local agribusinesses	Improve public–private dialogue in the agribusiness sector around agribusiness policies and regulations

as locally branded rice to supply a growing demand (currently fed by imports). The farmers that Acelda buys from would have access to a consistent buyer who would regularly visit their farms to purchase their surplus (which is otherwise sold irregularly to the local market or kept aside for consumption or even goes to waste), providing them with a stable income. Over time, with consistency in sale of rice to Acelda, farmers would see the arrangement as a lucrative venture and be motivated to invest in improving production—either by increasing the use of existing fallow land or increasing production on the existing land.

The partnership between MDF and Acelda aimed to trigger market change through the development of an efficient sourcing plan, establishment of a modern rice milling facility to add value to local rice, and the design and implementation of an effective marketing campaign to promote the country's first locally branded rice under the label 'Fos Timor'. The intervention's aim is to connect farmers in rural production centres to markets, giving them an incentive to invest back into their farms and see commercial production as a beneficial livelihood option. It also contributes to increasing the competitiveness of local products in Timor-Leste.

Although the partnership has only been active since November 2013 there are already some encouraging indications that it is working. Acelda has been supplying local rice to the domestic market in the face of stiff competition from imported rice, and farmers are seeing increased income and other benefits by supplying to Acelda.

Benefits to Acelda

Introducing the first commercial rice milling facility and marketing the country's first local rice brand has not been an easy journey for Acelda. The company had to invest heavily in infrastructure, staff and also building relationships with farming communities from the sourcing locations. Traditionally, farmers would either sell their rice to inconsistent and inflated government purchasers or sell (if they could) in the local neighbouring markets. Acelda had to conduct numerous socialisation campaigns to build relationships with farmers, convince them to sell their rice for around $0.40/kg (less than the irregular government buy-back price), and convince them that Acelda was a reliable buyer who would consistently pick up produce from the farm gate if supplied on a regular basis.

Table 2. Rice sourcing by Acelda by municipality and year.

Municipality	Quantity (tonnes)	
	2014	2015
Baucau	13	66
Manatuto	22	33
Viqueque		33
Lautem		14
Total	35	146

After a number of procurement cycles from different areas, Acelda has now secured the trust of suppliers and is able to source rice from farmers on a regular basis. In order to fulfil the needs of its rice milling facility it has expanded its sourcing activities to more municipalities; initially only sourcing from the municipalities of Baucau and Manatuto, it has now expanded to include Viqueque and Lautem. Table 2 shows details of this growth.

Of course, in order for the whole effort to be sustainable and offer growth potential, Acelda must sell the rice it sources. Acelda began selling rice from their own outlets in Baucau and Dili and then gradually started selling through a number of wholesalers and retailers in those areas. In the first year of sales, the company was able to sell only 9.8 tonnes of rice (20% of the volume sourced); this increased in the subsequent year to 40 tonnes as of December 2015. Despite growth in sales the company still holds stock in hand, and is focusing efforts on improving sales through multiple channels such as improving visibility of the product, conducting consumer surveys to understand any issues with product quality, and diversifying through the introduction of red and black rice into the range. MDF has helped the company design effective campaigns to promote the local rice brand (e.g. TV/radio advertisements); and MDF continues to guide Acelda in exploring other effective promotion methods.

Acelda is continuing to engage with the government to deter government buy-back programs that will hurt the competitive price at which Acelda can purchase from farmers. The company is also advocating with the government to support commercial local rice production.

Acelda believes in its product and wants to capitalise on the general preference Timorese consumers have for local rice. Acelda believes that over time and with greater promotion and endorsement from the government, sales of 'Fos Timor' will increase.

Benefits to farmers

MDF research indicates that the increase in sourcing offers substantial benefits to cooperating farmers. As shown in Table 3, the number of farmers with increased income has risen. Table 3 also indicates that farmers have increased their sales (without compromising their consumption needs), as they have a more regular avenue to sell. Measurements of farmer sales revenue, net profits and net increase in income per farmer all show substantial positive trends.

There is strong evidence to suggest that Acelda's rice sourcing business will grow and Acelda and participating farmers will continue to benefit from increased sales. Projections show numbers of farmers selling to Acelda will rise and fuel rising incomes. Farmer interviews reveal that farmers are happy with the arrangement for several reasons, including:

- Earning regular income for the family;
- Time and cost saved from travelling to the market to make a sale;
- The ability to use the money from sale to Acelda to cover the cost of their children's education (e.g. fees, buying books, school uniform, etc.);
- Have more money for household items (including clothing).

In addition to these benefits, many farming households have reported that they use the proceeds from sales to buy food and household necessities for the family. Assessments of farming households that sold rice to Acelda reported that one of the main reasons for their strong desire to sell to Acelda in the following year was for additional and timely income to buy food for themselves and their children and for household necessities including health needs.

Focus group discussions have revealed that women play a very significant part in rice cultivation, particularly in watering, weeding, harvesting and post-harvest handling (drying), and in many cases they are involved in selling rice. Purchase of rice by Acelda from the farm gate reduces the time and strenuous physical effort that women would otherwise undertake in carrying the rice to the nearby market (without any guarantee of sales). The proceeds of sales to Acelda are pooled in the household, and the women feel proud that they are able to contribute to this household income through their work.

Acelda is obviously optimistic about the future and has substantially increased its investment in the enterprise over the past year. The company has added additional milling capacity and purchased new equipment and vehicles including a packaging machine, a large tractor, two hand tractors and two trucks.

Farmers are also seeing the arrangement with a long-term perspective. One good example is provided by six farmer groups in Baucau municipality. In 2015, these farmers negotiated an agreement to exchange their rice for farming equipment in the form of hand tractors, which will allow them to increase production and lower costs in the future.

Overall, the trading relationship between farmers and Acelda is not only helping farming households secure a regular source of additional income, but more importantly it is enabing families to attain better food and nutrition in the household.

Table 3. Farmer benefits resulting from association with Acelda.

Indicator	Base year (without Acelda)	After initiating sales to Acelda	
	2013	2014	2015
Total number of farmers selling rice to Acelda	0	93	374
Volume of harvest sold per farmer (kg)	99	380	395
Total harvest sold per farmer (%)	4.10%	13%	14%
Sales revenue from paddy sale (US$)	43	150	156
Net profit from sale of produce/farmer (US$) (cost of production was consistent over all three periods)	37	120	125
Net additional increase in income/farmer (US$) as a result of purchase by Acelda		83	88

[1] In year 2014 and 2015 all of the harvest sold was to Acelda.

Summary and conclusions

Marketing and food security are integrally connected. While much development effort is focused on increasing food availability through improved production mechanisms, equally crucial for boosting production is the existence of markets (Hebebrand and Wedding 2010). Marketing not only contributes to increasing food availability, but also to improving food accessibility, adequacy and acceptability—all four of the factors that define food security.

Decades of conflict have reduced Timor-Leste to a mostly subsistence-oriented rural economy with very little trade of any nature. Local trade structures have largely collapsed along with extension services, infrastructure and other vital aspects of the market system that make rural trade and investment feasible. However there are a number of potential interventions that can help restore and build Timor-Leste's agricultural market systems. MDF is committed to market development in Timor-Leste, and is actively working to promote diversification of industries, jobs and income sources, connecting markets and people and adding value to local products. The program undertakes initiatives in partnership with the private sector to eliminate bottlenecks to trade and establish more reliable and less costly access to end markets through more traders buying at the farm gate, more frequent and efficient transportation, more market information and improved storage facilities. It develops tailor-made solutions built around the realities of the market system in order to stimulate investment, business innovation and regulatory reform to create an environment for sustainable pro-poor growth. The partnership with Acelda, where MDF is helping to expand Acelda's core business into the realm of local products, exemplifies one such business model that is demonstrating how private sector enterprises can invest in sourcing and processing local raw materials for a growing local market.

Early results are promising. After only 2 years of activity there are clear signs of progress. Acelda is sourcing increasing amounts of rice from an expanding geographic area and its sales have grown in pace. Farmers selling to Acelda are realising substantially increased income and profits and growing in numbers. In addition to a steady source of income, farming households are benefitting from better nutrition, health and education.

These trends seem likely to continue. Farmers are now aware that a reliable market exists for them to sell to. It is expected that as time goes by and trust increases, farmers will be motivated to invest in improving productivity of their farms. Early signs of a move in this direction have already been seen: some farmers have requested not to receive cash payment from Acelda and instead negotiated a deal to exchange their produce for farming equipment. If projections are borne out, Acelda plans to expand its operations by sourcing multiple products that occupy different parts of existing cropping patterns. Farmers will be able to sell their surplus of multiple products at different times in the year, realising a consistent income which they will be able to use for healthier and more food-secure households.

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Savings and loans schemes: a way forward for agricultural development in rural Timor-Leste?

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Abstract

Savings and loans schemes were established in Timor-Leste during the late 1990s and early 2000s to help develop financial independence from high cost usury practices in the country's rural areas. Between 2013 and 2015, farmer associations involved in seed production were encouraged to establish savings and loans as an avenue to invest income from seed sales and provide capital for investment in agriculture and other enterprises. A study of the uses of their funds indicated that most individual farmers borrowed money for micro-enterprises or for personal needs including education, health or housing. Only a small part of the funds was utilised for agricultural purposes, however the overall fund allocations to different sectors compare with rural areas in other parts of Timor-Leste, Indonesia and in Africa. Although savings and loans activities did not contribute directly to agricultural development, they significantly assisted rural development in general. Their formation also helped to improve the sustainability and effectiveness of the farmers' groups themselves.

Introduction

Farmers in developing countries need to overcome a range of problems before they can improve agricultural productivity, and this is particularly the case for nations emerging from conflict (Erskine and Nesbitt 2009). The majority of rural economies in poorer countries are based on rainfed agriculture, and production cycles remain seasonal; in addition, access to improved seed and other technologies is often limited, agricultural support extension systems are undeveloped, and access to markets is poor (Roux 2008). In all subsistence systems monetary income from agriculture is limited and agricultural prices are notoriously volatile even if surpluses are produced. Few farmers in this environment can offer guarantees that are legally or financially acceptable for accessing funds to address their daily needs or for investment purposes. In Timor-Leste, 70% of the population is involved in the agriculture sector and more than half of these are subsistence/smallholder farmers.

As a relatively new nation, the banking sector is undeveloped in Timor-Leste. All four banks operating in the nation during 2015 were located in the capital, Dili, and only one of the four had commenced operations in the municipalities. Three of the banks are foreign owned, originating from Australia (Australia and New Zealand Bank (ANZ) Banking Group), Portugal (Caixa Geral de Depositos, SA (CGD/BNU)), and Indonesia (PT. Bank Mandiri (Persero) Tbk. Dii). The fourth, the Banco Nacional de Comercio de Timor-Leste (BNCTL), converted in July 2011 from a government-sponsored microfinance organisation to become the first Timorese bank exclusively owned by the Government of Timor-Leste. Originally this bank was established to provide loans with a ceiling of US$5,000 for each borrower and could provide loans only to those possessing sufficient capital.

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3 Aldeia Samagia, Suco Tequinomata, Administrative Post Laga, Baucau Municipality, Timor-Leste

Timorese farmers, like farmers in many other developing countries, have difficulty accessing credit from formal credit institutions. Consequently, many people borrow from individual money lenders at interest rates as high as 20% per month, 50% for 6 months or up to 100% annually. To do this, they often have to mortgage their assets. This situation has caused some farmers to become entangled in prolonged debt, and to have to sell assets to pay off debts.

A small number of development organisations addressed these issues by forming self-help groups (SHGs) in villages. For example, the Oecussi Community Activation Program (OCAP) funded by the United Nations Development Programme (UNDP) from 2002 to 2009 developed SHGs in villages in the Oecussi region of Timor-Leste. One of the activities of the SHGs was the establishment of savings and loans (S&L) schemes. This effort was continued by the non-governmental organisation (NGO) World Neighbors in 2007 (Utami 2011). The NGOs Oxfam International and Caritas Australia were also involved in encouraging the development of S&L groups in rural upland communities. Although the pattern and approach were slightly different, the main goal of all S&L groups is to strengthen the financial situation of the rural community and improve access to credit.

About savings and loans groups

S&L associations are informal financial institutions established to accept savings deposits from, and lend back to, members. Similar institutions have existed in the western world for over 200 years and are known in some countries (e.g. UK) as building societies and others (e.g. USA) as thrifts. S&Ls have similarities to revolving loan funds and micro-financial institutions, but the source of capital is the members rather than one particular party or outside sources (Ritchie 2007). Members of S&L groups generally have equal voting rights and can have considerable input into the management of the organisation. Such groups are generally formed in developing countries to reduce the negative impact of usury practices in rural communities (Utami 2011). However, they may be formed for more than one purpose. For example, Catholic Relief Services (CRS) helped rural communities in Ghana to participate in savings and internal lending communities (SILCs) to not only encourage participants to generate financial resources that can be invested in agricultural productivity, but also to provide a link between groups and the Ministry of Food and Agriculture's agricultural extension services (Asombobillah 2011).

According to Mathews (2014), various models of S&L groups have been established in Timor-Leste. These models can be classified into four groups: those established for a limited time, such as SILCs developed by CRS and another NGO, Mercy Corps; more permanent organisations as developed by OCAP in the form of SHGs; the S&L groups promoted by World Neighbors, Caritas Australia and Oxfam International; and in addition there are thousands of 'arisan' groups where the money collected is not recorded. ('Arisan' is a savings group that meets regularly. Members bring with them an agreed amount of money which is collected and handed directly to the person who wins a draw.)

All S&L groups established in Timorese society are similar in their process and purpose. Members contribute an agreed amount to the society on a regular basis with the main objective of generating financial resources so that all members can access loans as needed. In contrast to banks or microfinance institutions, S&L associations are microfinance institutions developed in the community by the community themselves.

All capital of S&L groups established in Timor-Leste is derived from group members. This is different from banks or other financial institutions, where capital is raised by the bank owners and the profit belongs to the stockholders.

The rules in S&L groups are developed by mutual agreement of all members. The principal rules are usually related to the amount of principal and mandatory savings, the maximum amount of a loan, the terms of repayment, and the interest rate. Revenue earned from the S&L management process is accumulated in the form of profit. At the end of each fiscal year, after deducting operating expenses and services of the governing council, the profit is shared among all members through the mechanism of the annual assembly meeting. In other words, the management pattern for S&Ls is based on basic cooperatives principles.

Savings and loans groups in Timor-Leste

Based on a study undertaken by Mathews (2014) from August to October 2014, there were 329 S&L

groups in Timor-Leste involving 6,645 members. Of these groups, 170 (52%) were from the Oecussi region, comprising 3,900 or 59% of all members. The establishment of groups in the Oecussi region was promoted by the United Nations and NGOs between 2004 and 2008, while in other districts they were not formed until after 2010. Figure 1 compares the numbers of S&L groups and total member numbers in the different municipalities.

The groups charged between 2% and 3% interest per month for loans, which is 10–15% of that charged by money lenders. Repayment rates of the loans were very high due to peer pressure from the other members to repay loans reasonably quickly. All members shared in the profits. The groups were maintained at a manageable size of approximately 20 persons. Some had larger amounts of capital while others were still expanding.

One study conducted by World Neighbors in 2013 showed that 899 people (595 men and 304 women) were involved in 24 S&L groups possessing total capital of US$212,649, and the amount of loans provided over the five year period between 2008 and 2013 was US$1,183,244. This represents a significant contribution to the development of the Oecussi region.

In addition to the S&L groups in Timor-Leste mentioned above, farmers' associations (FAs) established within the National Seed System for Released Varieties (NSSRV) integrated savings and loans into their commercial seed production activities. As of the end of September 2015, there were 40 FAs that had integrated S&L into their activities, with 781 FA members (482 men, 299 women) involved in S&L activities. Most members were from the FAs, but Ministry of Agriculture and Fisheries (MAF) *suco* (local administrative area) extension officers (SEOs) who helped establish the FAs and S&L groups, and a number of professional members, also joined.

The involvement of the SEOs in the S&L activities allows them to access benefits from the scheme while providing assistance to the farmers. The SEOs, like other members, are expected to attend monthly meetings and make appropriate contributions before taking loans. They often provide assistance in the administration and bookkeeping, and at meetings they also have the opportunity to provide motivation, training, and other extension services. It is considered that involvement of the SEOs in the S&Ls is beneficial for the sustainability of both the S&Ls and the FAs.

Non-FA members and non-SEOs were also attracted to the S&Ls. These members were primarily professionals, including teachers, health workers and police, but even included some students. These individuals requested involvement because they could see that there was transparency in financial management, it was easy to access loans at low interest rates, there were no administrative costs, and profit sharing at the end of the fiscal year was attractive. Membership of professionals tended to bolster the administration of the schemes.

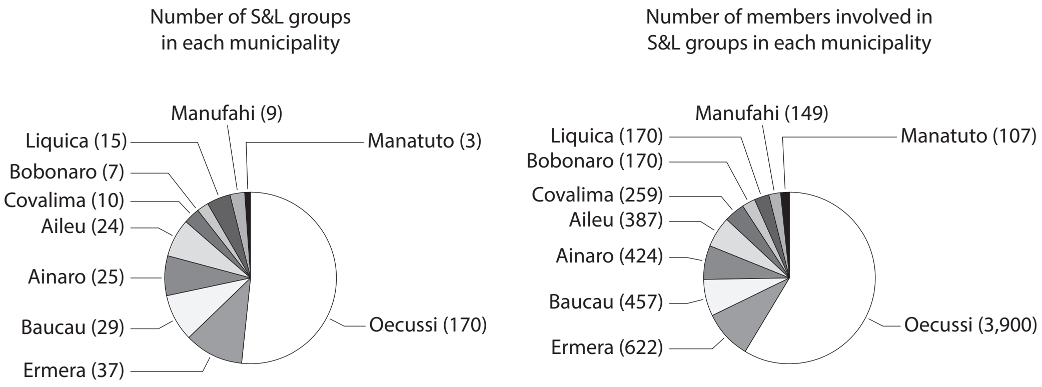

Figure 1. Savings and loans groups and member numbers in the different municipalities.

Contribution of S&L schemes to agricultural development

Thirty-eight per cent of the loans in the Oecussi region were invested in establishing or expanding small-scale enterprises such as cake production, kiosks, stores for the sale and purchase of agricultural products, and the purchase of motorcycles for motor taxi businesses (Table 1). A further 31% of the loans helped cover school fees of members' children, who were studying in either Dili or West Timor. In addition, about 17% of the loans were used by members to fix or build new houses. Only about 12% of the total loans were used for investment in the agricultural sector, mostly in the form of vegetable seeds and livestock (mainly chickens, pigs and cattle). There was no significant difference in the ownership of agricultural tools among group members. Only a small percentage of loans (2%) in Oecussi was used for healthcare costs.

The use of loans for different purposes in Oecussi was similar to the nearby Indonesian districts of Ngada and Nagekeo on the island of Flores and North Central Timor district in West Timor. These S&L schemes were part of the program of Yayasan Mitra Tani Mandiri (YMTM), an NGO based in West Timor that focuses on agroforestry and rural livelihoods. In these areas, approximately 18% of loans were invested in the agricultural sector. These loans were used to buy seeds, fertilisers, pesticides and livestock (Table 1). As in Oecussi, the highest percentage of loan usage was for small business development (32%), followed by education (30%), housing (11%) and healthcare (7%). The remaining 2% were used for indigenous affairs.

From 2013 to 2015, newly developed FAs formed to help multiply and trade in crop seed were encouraged by the MAF to establish S&L schemes. It was envisaged that S&Ls would both provide an avenue for investing profits from seed trading and enhance the groups' capacity to purchase inputs for further seed production. By the end of September 2015, 20 of the 40 FAs were issuing loans with $23,335 (28%) being utilised for micro-enterprises, including buying and selling agricultural products. Only a small amount (2%) was spent on cultivating crops (Table 1).

In Africa, the percentage of loans from S&L schemes used for agricultural purposes tends to be similar to that in Timor-Leste and nearby parts of Indonesia. For example, Thuysbaert et al. (2012), after interviewing 15,000 households across 950 villages in Ghana, Malawi and Uganda, found that approximately 9% of farmers invested in small agriculture ventures. The highest percentage of investment was in micro-enterprises with greater cash flows. Asombobillah (2011) on the other hand found that 41% of a randomly selected 210 S&L members invested their loans in agricultural activities. Some of these funds were used to brew beer and trade in grain for resale.

Devi (2012) reported from East Godavari district of Andhra Pradesh, India, that short-term loans enabled farmers to meet the cost of labour, seed, fertiliser, pesticides, etc. Farmers tended to spend their borrowed funds to purchase high-yield variety (HYV)

Table 1. Comparison of uses of S&L loans in different countries.

District/country and project/reference	Micro-enterprises (agricultural) (%)	Micro-enterprises (non-agricultural) (%)	Housing (%)	Healthcare (%)	Education (%)	Other (%)
Oecussi region of Timor-Leste (World Neighbors 2011)	12	38	17	2	31	0
Farmers associations (20) in 12 Timor-Leste municipalities	28	22	20	7	21	2
Ngada, Nagekeo, North Central Timor, Indonesia (YMTM 1997)	18	32	11	7	30	2
Ghana, Malawi, Uganda (Thuysbaert et al. 2012)	9	29		12	13	31
Ghana (Asombobillah 2011)	41	30	17	3	9	0

seeds, increasing the adoption of these varieties and also increasing annual income from US$246.49 to US$407.18.

Interestingly, groups in India located closer to the markets had a higher tendency to use their loans for agriculture-related activities. Their location allowed the farmers to sell their agricultural products during market days thereby generating income to repay their loans reasonably quickly. Farmers with access to markets used their loans to purchase vegetable seeds, fruit seedlings and livestock.

Farmers taking out loans for agriculture purposes in the YMTM program in Indonesia also tended to be closely located to markets. For these farmers, it was easier to find quality seeds (mostly vegetable seeds), fertiliser and pesticides, and to sell the agricultural products. Another influencing factor was the availability of forages (e.g. gliricidia, leucaena, gmelina, king grass, etc.), which motivates farmers to fatten cattle. Some of these products were traded though farmer collectives providing farmers more bargaining power to negotiate prices. Farmers were able to trade onion, garlic, cashew, cocoa, candlenut and cattle through these collective marketing schemes.

Investment in agricultural activities is generally more effective if the activities are commercially orientated (Meyer 2012), as indicated by the relationship between the farming activity and markets found in Timor-Leste and Indonesia and also by the agricultural trading activities seen in African experiences (Asombobillah 2011; Thuysbaert et al. 2012).

In the case of the FAs in Timor-Leste, considerable financial capital was available but a comparatively small amount was spent on agricultural activities. The small investment in agriculture is thought to be caused by several factors including the following:

1. Agricultural production in Timor-Leste is still in a subsistence phase, where investment of money in agriculture does not necessarily generate a cash income to pay off loans. Only when there is production surplus to the family needs are agricultural products sold at the local market.
2. A lack of transport infrastructure. The agricultural production centres are often not connected with good roads thereby limiting transport of agricultural products. Transport costs are also high due to the poor roads and bulky nature of agricultural produce.
3. Competition with imported agricultural products. A lot of imported agricultural products are available at the market, for example, rice, onion, garlic, tomatoes, potatoes, and other various kinds of vegetables, at prices much cheaper than the production costs incurred by the local farmers.
4. There are few people or agencies encouraging agro-business development. Existing agencies tend to be small compared with other non-agriculture sectors. Those involved include World Vision, GIZ, and the Developing Agricultural Communities (DAC) program of the United States Agency for International Development (USAID. The latter project facilitates farmer groups to develop agro-business, including developing value chains in the systems they have developed.

Impact of savings and loans on farmer groups

Although S&L activities have not yet directly contributed significantly to agricultural development in Timor-Leste, they have contributed to rural development in general. Easier access to loans is contributing to non-agriculture-based rural livelihoods, affordability of higher education, and healthier households. Additionally, the existence of S&L groups has contributed to a reduction in the negative impacts of usury practices. Members of S&L groups are now less likely to borrow from money lenders or need to mortgage their assets.

The existence of S&L schemes in farmer groups keeps the groups active and encourages the groups to hold regular meetings. It can be said that well-managed S&L activities in farmer groups promote the sustainability of the group.

S&L schemes have also contributed significantly to micro-enterprise development. These efforts include local food processing, the purchase and selling of agricultural products, purchase and selling of livestock, establishment of kiosks, and investment in local transportation. Imron and Spyckerelle (2015) noted that women were significant beneficiaries of S&Ls. In the farmer association operating under the name of Naroman in Liquica municipality, women were significant recipients of funds allowing them to expand their scope of business. Loans were taken out to buy livestock and for the purchase and trading of agricultural products. Other significant social change in the community is due to the fact that poor families are able to borrow money during critical periods to send their children to pursue higher education.

Using loan money for children's education is seen as a longer term investment but is paying dividends. In the Rasik Hit'An group, nine people successfully completed their education at the university by the end of 2013 and in 2014, it was estimated that six more students would complete their degrees.

Discussion

The establishment of S&L schemes by farmers' associations in poor rural communities of Timor-Leste has been demonstrated to strengthen the groups' financial resources and improve access to credit. There are challenges, as farmers from subsistence agriculture backgrounds often lack the entrepreneurial spirit to develop micro-businesses to provide a significant financial return on their borrowings. However, the connectivity between S&L groups and agriculture tends to occur if members of the group have easy access to local markets. Governments may be able to support agricultural development by improving the network between production centres and potential markets. This connectivity is currently being improved in Timor-Leste through the installation of a national electricity grid, construction of a network of rural roads, and encouraging widespread telecommunications coverage. All three developments have the potential to decrease production costs, improve market access and improve market knowledge sufficiently for local products to compete with cheap imported food products. Farmers may need to identify products which have a competitive advantage allowing profits to be maximised on the open market.

S&L groups have the potential to drive social change in rural communities, both by reducing the negative impact of usury practices and by strengthening the assets in the community to improve their quality of life. There are also strong signals that well-managed S&L groups improve the sustainability and effectiveness of farmer groups. A united farming community increases individual farmers' bargaining power and, as demonstrated here, facilitates improved access to credit. More organisation is needed in Timor-Leste's rural areas to facilitate value chain development in agricultural production systems, including the provision of agricultural inputs, business plan development and utilisation of available capital.

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The place of ceremonial observances in sustainable livelihoods of crop producers in Timor-Leste

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Abstract

Ceremonial practices widely associated with ancient animist belief systems but also pertinent to more recently introduced Christian practices persist across Timor-Leste. Ceremonies based on family lineage groups—*lisan*—are conducted for numerous purposes, with many related to food production/consumption. While significant resources, including time, are expended to conduct such ceremonies, the act of participation can also lead to improved social cohesion. This in turn can lead to more effective collaboration in cultivation tasks where the household unit of labour is not efficient. Outside of more efficient crop production strategies, the social capital generated through participation in ceremonies can lead to greater levels of reciprocity when poor harvests produce a food or seed deficit, thereby enabling communities to negotiate risks. This may be at odds with some views in development that such practices act as a brake on progress. In this context, innovation in cropping was not found to be stifled by rituals. Farmers in Timor-Leste strive to attain a balance where they are capable of maintaining their cultural assets and the benefits attributed to these without this being at the expense of other priorities such as allocating sufficient resources to their 'productive' activities and their families' health and education. The sustainable livelihoods framework is used to investigate how the endeavour of crop production negotiated through ceremonial observances could fit within a sustainable livelihoods approach.

Introduction

In Timor-Leste the majority of the population derive their livelihood from agriculture (Jones 2014). Improvement of the livelihoods of farming families is the focus of support from the Ministry of Agriculture and Fisheries (MAF). A socio-economic component within the MAF has worked with rural communities in ways that are compatible with their social environment and livelihoods strategies. In this context, the role that ceremonies and rituals play in crop production was initially explored a decade ago. Such ceremonies derive from either pre-Christian or Christian belief systems and are often found to be an amalgamation of both (Browne et al. 2016).

Having such a high proportion of the population involved in agriculture is one reason that areas cultivated per household tend to be small. Another important reason is the lack of mechanisation which limits the cultivated area a household can maintain. A means of alleviating this latter constraint is through the improved effectiveness of manual labour.

Ritual practice in Timor-Leste often involves the assembly of groups to perform ceremonies directly related to events in the agricultural calendar. Such groupings often correspond with the requirement

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to have a number of families combine their labour resources to complete the most labour-demanding activities of the agricultural calendar, and will therefore often serve this dual purpose while involving the same social network. Potential conflicting outcomes of ceremonial obligations vis-à-vis increased efficiency in the crop production cycle are (1) the material and time resources required to conduct such ceremonies and (2) the possibility of stifling of crop innovation by rituals.

This paper examines the role that ceremonies play in crop production in Timor-Leste. The sustainable livelihoods approach (SLA) is utilised to evaluate benefits that can accrue from the interlinkage of both activities as well as the challenges posed. Ceremonies and rituals are explored in this context to determine if, in providing cultural resilience, they may also play a role in contributing to livelihood resilience.

Types of ceremonies conducted by farmers in Timor-Leste

Choudhury et al. (2014) found the most numerous informal groups in the community in Timor-Leste to be religious groups, whether traditional belief systems or church based. Ceremonies and rituals are greatest in rural areas where kinship ties are more concentrated. Urban dwellers will usually return to their rural place of origin to complete such observances augmenting the local populations' involvement. Many such rituals are directly related to events in the agricultural calendar, particularly crop production, and conducted in that setting. While focusing on the ceremonies directly linked to crop production and food security, links that other religious, social and cultural practices may have on crop production are also relevant.

Ceremonial practices were found to be integral elements in the cultivation cycles for maize and rice in surveys conducted by the Seeds of Life program within MAF in 2006–07 and 2015 (Browne et al. 2016). The former was a longitudinal survey in Aileu, Baucau, Liquiça and Manufahi municipalities conducted over one year and related only to ceremonies directly linked to crop production (Table 1). The latter—conducted in January/February 2015 in the municipalities of Aileu, Baucau and Bobonaro—considered all ceremonies and ritual activity conducted by participants along with the time, financial and other costs expended during their observance.

Most ceremonies recorded in Table 1 related to the most widely cultivated crop, maize. The ceremonies are seen as a form of exchange whereby through a sacrificial act the ritual elder (Tetum: *lia nian*) calls on the protection of the ancestor spirits (Tetum: *matebian*), custodian spirits of the land (Tetum: *rai nain*) and the Christian God (Tetum: *Maromak*) to protect and nurture the staple food crops. The most common ceremony for both maize and rice was that of *sau batar*/*sau hare* conducted around harvest. Other rituals were performed at the time of garden preparation (to invoke the ancestors' protection against accidents, e.g. while felling tall trees or slashing long grass), at the time of sowing (to invoke the ancestors' protection against weather events such as destructive winds, pests or animals destroying the seed) and at plant flowering (to invoke the ancestors' protection of the crop to bring a good harvest with large cobs). A chicken, goat or pig is usually sacrificed as part of these ceremonies to symbolise gratitude to the ancestors for the harvest.

Other non-agriculture-specific ceremonies recorded in 2015 included those related to life events (Tetum: *lia moris*) and those related to death (Tetum: *lia mate*). Both of these invoked elements of traditional customary practices (Tetum: *lisan*) as well as Christian practice. There were also church-specific ceremonies including weekly mass attendance.

Sustainable livelihoods approach

While the analytical framework of 'sustainable livelihoods' was explored in the 1980s and attained widespread use at the turn of the millennium (Daskon 2010), other frameworks have been conceived in the interim (Haidar 2009). These include those based on governance, human rights and making markets work for the poor. All of these find favour in development interventions being currently undertaken in Timor-Leste. However the sustainable livelihoods approach (SLA) incorporates elements of all these approaches through complementary perspectives which focus on poverty alleviation (Carney 1999; DFID 1999a), and has proved effective in rural contexts (Neely et al. 2004).

The most widely used sustainable livelihoods framework is that shown in Figure 1, introduced by the UK's Department for International Development (DFID 1999b). It has been adapted by a number of agencies in their program activities, as explored by Carney et al. (2000) during a forum on the issue.

Table 1. Ceremonial rituals associated with maize cultivation by village (district in parentheses) including leadership and participation (Browne personal communication).

Location	Ritual type	Person leading ritual	Household/s (HH) participating in ritual
Manucasa (Aileu)	Pre-consumption of new maize ritual	Head of HH	Single HH only, can invite members of extended family living elsewhere
Sarin (Aileu)	Postharvest/pre-consumption ritual	Ritual elder (Tetum: *Lia nain*)	All members of same ritual house
Seloi kraik (Alieu)	1. Pre-planting ritual 2. Pre-harvest ritual	1. Ritual elder 2. Ritual elder	1. 4–5 HHs whose gardens share boundaries 2. 4–5 HHs whose gardens share boundaries
Betano (Manufahi)	1. Pre-maize planting ritual 2. Maize flowering ritual 3. Pre-harvest ritual	1. Male head of HH 2. Male head of HH 3. Male head of HH	1. 1–3 HHs (those who planted the maize) 2. 1–3 HHs (those who planted the maize) 3. All member HHs of same ritual house
Dotik (Manufahi)	1. Pre-harvest ritual 2. Postharvest/pre-consumption ritual	1. Ritual elder 2. Ritual elder	1. 7–8 HHs whose gardens are proximate 2. All member HHs of same ritual house
Letefoho (Manufahi)	1. New garden ritual 2. Pre-consumption ritual	1. Ritual elder 2. Ritual elder	1. 4–5 HHs whose gardens are proximate 2. Member HHs of same ritual house
Daru Lete (Liquica)	1. Pre-planting ritual 2. Cob formation ritual 3. Harvest ritual	1. Male head of HH 2. Ritual elder 3. Ritual elder	1. 5–6 HHs, children can also attend 2. Generally, all members of same ritual house 3. Generally, all members of same ritual house
Gugleur (Liquica)	1. Opening new garden ritual (prior to burning) 2. Postharvest/pre-consumption ritual	1 and 2. Ritual specialist	1 and 2. Approximately 20 HHs—those whose gardens share boundaries
Vatuvao (Liquica)	1. Opening new garden ritual 2. Postharvest/pre-consumption ritual 3. Postharvest/pre-consumption ritual (prior to eating new maize)	1. Ritual elder 2. Ritual elder 3. Ritual elder	1. 20 HHs (depending on the number of farmers who assisted prepare the garden together i.e., mutual labour group members, can be as many as 50–70 HHs) 2. and 3. same as #1
Maubaralisa (Liquica)	1. 'Thorn removal' ritual 2. Pre-planting ritual 3. Postharvest/pre-consumption ritual	1 and 2. Ritual elder (mentioned as *rai nain* by respondent)—this person is said to 'hold the power for betel leaf and areca nut', i.e. knows how to speak to the ancestors	1 and 2. 20–30 HHs
Dato (Liquica)	1. Pre-planting ritual 2. Postharvest/pre-consumption ritual	1 and 2. Head of HH (Tetum: *xefe de familia*)	1 and 2. Single HH only (farmer only)
Garuwai (Baucau)	1. 'Feeding sacred rocks' ritual 2. Maize tying ritual 3. Pre-harvest ritual 4. Pre-consumption ritual	1, 2, 3 and 4. Ritual elder	1. Single HH only and ritual specialist 2. Single HH only and ritual specialist 3. Single HH only and ritual specialist 4. All HHs that are members of same ritual house
Loilubo (Baucau)	Pre-harvest ritual	Ritual elder	All HHs that are members of same ritual house

The International Fund for Agricultural Development (IFAD), a participant in this forum, subsequently proposed a more dramatic overhaul of the SLA framework after they conducted a number of workshops with their staff (Hamilton-Peach and Townsley no date). Two aspects of the latter process bear particular relevance to the subject of this paper. One was the encouragement from participants, particularly those from regional locations, that spiritual aspects of livelihoods become more explicit in the framework. It was thought that such aspects affect peoples' will and drive. Similarly, Daskon and McGregor (2012) explored the concept of cultural capital or assets within sustainable livelihoods. Although IFAD did not add spiritual aspects to their general framework, they did add personal assets to the five already in the DFID framework. This was intended to emphasise peoples' internal motivations of which their spiritual background could play a critical part.

For the purposes of the current study the DFID framework (Figure 1) is used, with the cultural component of the transforming structures and processes utilised to investigate how ceremonies and rituals could affect the vulnerability context which impacts in turn on certain livelihood assets and outcomes.

The influence of ceremonies on the sustainable livelihoods approach to crop production

Though possible to quantify the expenditure of time and other resources (animals, money, materials) needed to perform ceremonies, determining the return on this investment is much more elusive. What is clear is that ceremonies performed by farmers follow numerous complex pathways to influence their livelihood outcomes. The sustainable livelihoods framework can be utilised as a mechanism to depict how these influences occur. Although this framework does not present an exact representation of reality, it acts as an entry point by which it is possible to analyse the multitude of avenues through which livelihoods are influenced. Although the present study investigates just one factor, that of adherence to ceremonies performed during the livelihood strategy of crop production, the framework demonstrates the multiple pathways through which ceremonies are integral to the crop production cycle.

The DFID sustainable livelihoods framework is explained in detail through various guidance sheets

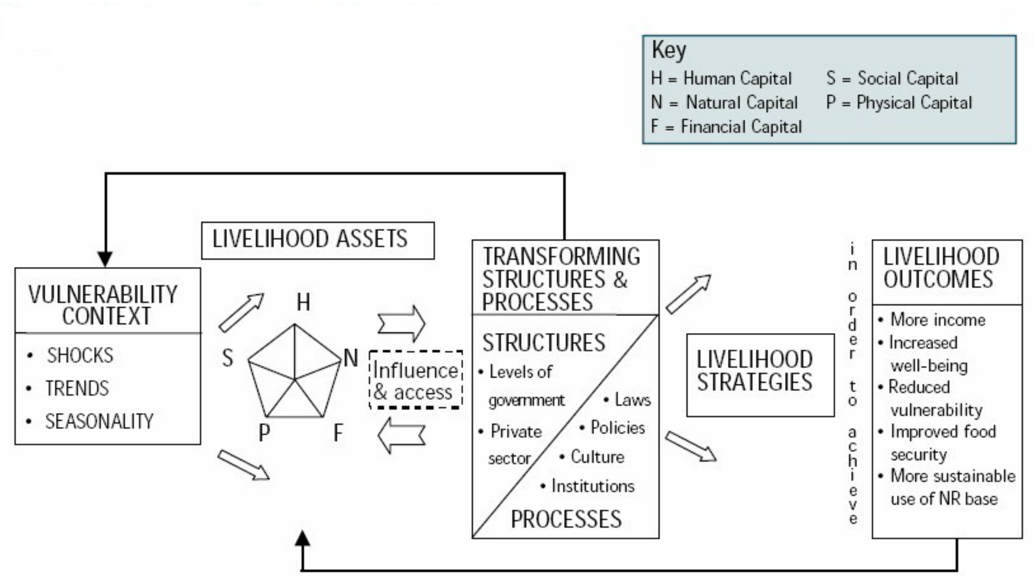

Figure 1. Sustainable livelihood framework (DFID 1999b).

(DFID 1999a, b). The levels of the various assets contained within the SLA pentagon in the framework are not static and the pentagon is not uniform. They constantly change and shift, influencing the shape of the pentagon. In this study the predominant pathway investigated through which ceremonies and rituals affect livelihood outcomes is the one whereby they can directly influence the access to and stocks of livelihood assets of crop producers and can thereby alter their livelihood outcomes.

Social capital—as referred to above—is the asset likely to be most impacted by ceremonies. Such networks of connectedness and reciprocity that increase farmers' trust and ability to work together are critical to the Timorese context of crop production. Households function as agricultural production units where all members participate in the work. However, some farming tasks in swidden agriculture, such as opening a new garden, maize weeding and some natural resource management activities, are most easily completed through working at a larger scale than an individual household (average household size = 5.7 including children; GoTL 2015) and are done through a mutual labour group. The social network involved with mutual labour groups often derives from *lisan* groups. These are family lineage groups which are the nucleus around which traditional ceremonies are conducted. When mutual labour groups rotate between members' fields the time-bound task can be completed much more quickly. Reciprocity is a common theme in both activities.

As well as enabling the efficient completion of cultivation tasks, the social capital nurtured through such groups can affect the vulnerability context within the SLA model by mitigating shocks and seasonality in agricultural production. After challenging harvests, increased sharing of food and seed stocks is enabled through membership of such networks. Lopes et al. (2015) found that group membership was a critical enabler in the sharing of seed stocks. While focused on seed production groups, there is a strong likelihood of overlap of these groups with *lisan* groups. A caveat regarding the social capital enabled through the *lisan* system is that it can be a rather closed social network dictated by family lineage. Where the ceremony is conducted in a ritual house (*uma lisan*), the exclusivity of this social network is further tightened. For those conducted in the field, broader representation is usually possible. In some systems, particularly irrigated rice production, where different families combine in mutual labour groups, the responsibility for conducting various agricultural ceremonies may be partitioned amongst the various families in the mutual labour group.

Physical capital in Timorese agriculture is often very low. However no new substantial construction is likely to be undertaken on-farm without first invoking the ancestors' protection through ceremonial sacrifice. Although expense is incurred through this endeavour, it could be viewed as a necessary preliminary process for securing the communities' assent, in a similar way to seeking planning permission in more formalised settings. Several pre-cultivation ceremonies for rice were recorded in Table 1 that translate from Tetum as 'washing the buffalo's legs'. Interestingly, the object of the buffalo had been replaced in some instances by a tractor, signifying that the requirement to conduct such ceremonies did not serve as a brake on mechanisation. The 2006–07 survey also found that ritual criteria are not tied to a particular variety or cultivation technique. Ceremonies are instead focused on stages of development that a plant passes through, such as germination, flowering or development of tubers, in the hope that the performance of such specific rituals will ultimately lead to a successful harvest.

Physical assets in the form of animals are often liquidated to perform various ceremonies. This acts as an opportunity cost where the asset cannot be used to bolster family finances. However an important source of animal protein is provided for family members during ceremonies. Importantly, AMSAT INT (2011) determined that in Timor-Leste 80% of total animal protein eaten was consumed during ceremonies.

Natural capital is mediated by customary laws and prohibitions that strive to maintain the natural resource base. With many agricultural practices in Timor-Leste still relying on slash and burn techniques, the natural resource base can sometimes become quickly degraded and prone to erosion and fertility loss. A mechanism to halt this decline is achievable through conducting a *tara bandu* ceremony. This includes the placing of a temporary or permanent prohibition on certain cultivation activities. McWilliam et al. (2014) argue that *tara bandu* is effectively a new concept introduced by development actors which hijacked various *lulik* (sacred) traditions to fashion into a more homogeneous regulatory practice. In the review conducted by McWilliam et al. (2014), the integral part that specific locations play during ceremonial observances has contrarily been interpreted by some as an obstruction for land resettlement.

Financial capital required to facilitate various ceremonies in the crop cultivation cycle is likely to leave this sector of the asset pentagon shrunk in comparison to the other livelihood assets. In the study, substantial financial costs were associated with the performance of ceremonies. Of ceremonies conducted, those related specifically to crop production tend to have the lowest cost. Some participants estimated the total financial costs of their participation in all ceremonies to exceed US$1,000 per year. The minimum wage in Timor-Leste is US$115 per month. Most of this expenditure related to ceremonies pertaining to life and death events. The costs involved in the holding of various ceremonies and rituals were a major cause of concern for many farmers. Many thought that, while it was essential that such traditions be continued, the ceremonies could become less elaborate. They were keen to reallocate some resources from this area to physical and human capital.

Human capital comprises knowledge, skills, ability to labour and health needed to pursue a livelihood. A concern for a number of farmers surveyed was that they needed to reallocate some of the resources expended in ceremonies to support their children's education. There is also a significant opportunity cost associated with participation in various ceremonies through the ability to labour that is forgone while involved in such ceremonies. Church-based ceremonies tended to consume the most time for attendance. As most of this activity tends to occur on Sundays, it could be argued that such activities were undertaken on the day of rest and did not therefore impact on a farmer's ability to labour. The network provided by the church may also provide opportunities to develop farmers' skill sets. Agricultural ceremonies required less time to participate in compared to other traditional ceremonies. As expected, agricultural ceremonies, particularly those relating to crops, commanded a much greater proportion of the total time dedicated to ceremonies by farmers compared to other community members.

While Daskon (2010) argues that cultural traditions can strengthen livelihood assets of rural communities, Hamilton-Peach and Townsley (no date) propose that an additional asset which includes ceremonial practices is added to the sustainable livelihoods framework. Calling this additional component 'personal assets', they argue that this emphasises peoples' internal motivations, a key part of which could constitute their spiritual side. While some aspects of personal assets could fit under human assets, they argue that the latter is predominantly focused on health and education.

Balancing economic and other objectives in crop production

Henriques et al. (2011) identify amongst land use patterns in Timor-Leste that of providing cultural goods and services. In doing so they partition economic purposes and those focused on well-being as objectives of development. The current study strives to examine the complementarity that both objectives could assume when considering the linkage between ceremonial observances undertaken during the crop production cycle.

Ceremonies can have more tangible outcomes through another form of exchange. Coping strategies for household food insecurity in Timor-Leste include the production of a diverse range of crops, the gathering of wild food plants (Erskine et al. 2015), and the receipt of loans and food gifts from a householder's social network (da Costa et al. 2013). Acting through the vulnerability context of shocks and seasonality in the sustainable livelihoods framework, the latter is a debit item to the social network to be repaid at some later date as a form of delayed reciprocity. By contrast, a ritual ceremony represents a form of credit for the householder into the same social safety network (or social exchange account) which acts as a hedge against future food insecurity. According to McWilliam et al. (2015):

Promoting agricultural innovation and change in a place like Timor-Leste is more than a straightforward matter of agronomy and yield improvement. Timorese farming practices are simultaneously deeply cultural practices that inform and guide the rhythm of agriculture and help reproduce fundamental exchange relationships and social safety nets. They also highlight the resilience of farming practices under conditions of marked climatic variability.

Although the sustainable livelihoods approach has in some ways been superseded by more recently introduced development frameworks, it has proved useful in depicting how ceremonial practices mediate all livelihood assets portrayed in the pentagon. These assets are not static and Timorese farmers are keenly aware of the need to maintain a balance between the various competing demands on their resources. It has been argued that cultural observances, including ceremonial practices, should be perceived themselves as a livelihood asset.

Ceremonies remain an integral part of the crop production cycle in Timor-Leste. Wide overlap exists between *lisan* groups that perform various ceremonies and mutual labour groups, critical to efficient crop production in the Timorese context. Farmers are keenly aware of the need to balance their livelihood assets and successfully utilise ceremonies to achieve this. They are also aware that an over-focus on ceremonial practices may be to the detriment of other livelihood assets.

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Developing meteorological data systems for agricultural applications in Timor-Leste

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Abstract

Meteorological data are vital for a wide range of applications such as agricultural production, risk management, infrastructure, insurance and health. Due to the rugged topography in Timor-Leste and highly variable climate, an agro-meteorological network was developed with a number of weather stations in each agro-ecological zone (AEZ) in order to understand climate variation across the country. Automatic weather stations consistently recorded large amounts of weather data which was transferred remotely and used in crop models for a variety of agricultural research applications to improve food security. Forty-three weather stations were installed by the Ministry across all AEZs, logging sub-daily data for a number of parameters including rain, temperature, relative humidity, solar radiation and wind speed. Weather data were then used to investigate limitations to maize production for various locations around the country across all AEZs with the use of Agricultural Production Systems sIMulator (APSIM). Systems were also tested to facilitate automatic data transfer from the stations to a secure government database and then released in an accessible format on the internet. Improved access to daily weather data presents opportunities to develop applications to assist farmers to improve productivity through strategic decision-making.

Introduction

The nation of Timor-Leste is approximately 275 km long and 75 km wide. It has rugged topography with steep slopes resulting from its location on the edge of the Australian tectonic plate which is colliding with the Indo-Pacific plate (Thompson 2011). There is a mountain range running east to west along the middle of the country and rising to nearly 3,000 m in the western region of the mainland. The country has been classified with seven agro-ecological zones (Molyneux et al. 2012). These provide an indication of the climate and associated agricultural systems in each zone. Three zones are on the northern side and three are on the southern side, with a temperate zone covering the high elevation area in the mountains. The zones are delineated by contour heights of 0–100 m, 100–500 m, 500–1,500 m and above 1,500 m. The temperate zone lower contour has been modified from 2,000 m to 1,500 m to reflect the temperate crops grown above this altitude (Figure 1).

A monsoonal weather pattern results in a wet season from November to May followed by a dry season for the rest of the year. As the monsoonal trough moves to the northern hemisphere it draws moisture from the south-east over the Timor Sea to deliver a second peak in rainfall to the southern slopes and the eastern end of the island during May–June (Australian Bureau of Meteorology and CSIRO 2014). At the higher altitudes the cooler weather leads to increased condensation of the rising humid air mass from the coast which generates increased rainfall.

Reliable and long-term weather data records allow a large range of applications with implications for health, agriculture, infrastructure, disaster monitoring, security and numerous other stakeholders. Long-term records are necessary for understanding climate

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Figure 1. Map of weather stations across the agro-ecological zones (AEZs). There are three AEZs on the northern side and three on the south with a temperate zone in the central mountains.

change and variability such as the El Niño southern oscillation (ENSO). They assist in risk management planning for extreme events such as flooding, high temperatures and destructive winds. Climate data are foundational for improving accuracy in weather forecasting. Rainfall data are required to plan water systems and understand underground water recharge rates. Climate information is also essential for agricultural research and development.

Within crop research, there are applications for developing simulations of crops such as maize, rice and other commodities to identify limitations and opportunities for increasing production. Crop models require daily weather data for rainfall, maximum temperature, minimum temperature and solar radiation over many years. The Agricultural Production Systems sIMulator (APSIM) maize model has been validated and developed over a wide range of datasets from around the world for factors such as sowing date, water supply, solar radiation, temperature, nitrogen (N) fertiliser rate and plant population (Sinclair and Muchow 1995). The model includes a large range of different maize varieties from early to late maturing with the capacity to modify parameters to suit newly calibrated varieties. Modules can be included that take into consideration intercropping, weeding, different management regimes, climate change and phosphorus-limited soils. Within the maize model, climate data are combined with soil and crop data to calibrate parameters and the simulated yields are compared with onsite data in Timor-Leste. With further research and development, automated systems for analysing data and making agricultural recommendations can be made accessible to farmers and other users for strategic planning.

Development of the agro-meteorological network

The Government of Timor-Leste has been working to build up meteorological services after the crisis in 1999, which had resulted in the complete destruction of all meteorological infrastructure. The Ministry of Agriculture and Fisheries required quality weather data at a number of research sites in order to investigate impacts on crop yields using crop modelling analysis.

With the formation of the Government of Timor-Leste (GoTL), the national meteorological service, *Direcçao Naçionál Meteorologia e Geofísika* (DNMG), was formed. This service installed two manual weather stations at the airport in Dili and Baucau and also an automatic weather station in Pante Macassar, Oecussi. Weather data were also being collected by the agro-meteorological department (Agriculture, Land-use and Geographic Information Systems (ALGIS)) in the Ministry of Agriculture and Fisheries (MAF). This department began operation of four automatic weather stations in 2004 and another eight in 2008, along with seven manual weather stations in a number of locations around the country. A third government department responsible for water quality and control, *Direcçao Naçionál Controla e Qualidade de Agua* (DNCQA), also operated 37 rain gauges across the country (Table 1). Other efforts to collect weather data included those by the United Nations Transitional Administration in East Timor (UNTAET) at operational airports and other offices, the Australian Bureau of Meteorology (BOM) at airports, the University of Hawaii for agriculture research, the Australian Centre for International Agricultural Research (ACIAR) livestock research program, the Japanese International Cooperation Agency (JICA) for irrigation systems, Seeds of Life (SoL) for crop research and companies such as Conoco-Philips involved in the petroleum industry. The stations that were known to be operational in 2015 are shown on the map (Figure 1).

Within MAF, the agro-meteorological network was designed with two broad divisions. The primary network denotes those weather stations that measure rain, temperature, relative humidity, solar radiation, wind speed, wind direction, soil temperature (at 5 cm depth) and soil moisture (at 10 cm depth). The secondary network measures only the five parameters of rain, temperature, relative humidity, solar radiation and wind speed. The network was designed to cover each of the AEZs within each of the 13 municipalities, as per the recommendations from the World Meteorological Organization (WMO) that "each large homogeneous phyto-geographical region should be represented by at least one principal meteorological station" (WMO 2010). Where practical, these stations were located at original weather station sites, at agriculture research stations and agricultural colleges.

From 2005, agricultural research staff in MAF collected daily rainfall data at agriculture research stations as well as at on-farm demonstration trials (OFDTs) using standard rain gauges. In 2012, a further 22 weather stations were installed in 12 municipalities across all seven agro-ecological zones. These were located at each of the five research centres as well as 12 field sites where OFDTs with maize (*Zea mays*) were being conducted, and five other significant sites. Onset Hobo Weather Data and Micro Data loggers were launched to log data at 10 minute intervals with sampling every 1 minute. The loggers receive data from five sensors: rainfall (0.2 mm tipping bucket), temperature (°C), relative humidity (%), wind speed (with gust speed, m/s) and total solar radiation (W/m^2). Two satellite data transfer units were tested in the enclave of Oecussi and the island of Atauro due to their remote locations. In 2014, JICA and SoL assisted MAF to install 10 systems that could transfer data through the Global System for Mobile (GSM) telecommunications network. During 2015 and 2016, 16 stations were upgraded with Hobo RX3000 units to transfer data using a local Subscriber Identity Module (SIM) card on the 3G network.

Through these systems data are delivered on a daily basis to secure websites and opened for public access (Figure 2). Automated processing of data was developed through the establishment of a cloud-based server which could receive data from the weather stations. These are then processed and imported into the database known as Climate Data for the Environment (CliDE). Potential evapotranspiration was calculated using the Penman–Monteith equations (Snyder and Eching 2009). Various applications were developed for agriculture including weather reporting, calculation of evapotranspiration and soil water balance with comparisons to the historical average.

A crop model to simulate maize growth was developed using the APSIM program. The daily weather data were combined with soil data accessed from the soil survey data in O Solos De Timor (Garcia and Cardoso 1978) and crop data collected by MAF research staff (SoL 2012). The model was calibrated and used to investigate the impact of the variation in solar radiation, nitrogen supply and climate change on maize yields (Bacon et al. 2016).

Climate data and crop modelling

The 22 Hobo weather stations that were established in 2012 were able to deliver data at 80–90% of potential data collection. These were in addition to the 12 Cimel automatic weather stations already

Table 1. Weather stations in Timor-Leste, and government departments and organisations supporting meteorological systems.

Org.	No of stations	Type of station	Parameters measured	Logging interval	Data storage
DNMG	3	2 manual 1 AWS Vaisala	Rain, temperature, relative humidity, evaporation, wind speed and direction, sunshine hours, atmospheric pressure	3 hours	Spreadsheets, CliDE on Govt LAN
DNCQA	37	Manual rain gauges	Rain	12 hours	Spreadsheets
ALGIS	23	3 Cimel 405 7 Cimel 420 5 Manual 6 Hobo GSM	Rain, temperature, relative humidity, wind speed, solar radiation, soil temperature, soil moisture	1 hour	Spreadsheets, with MAF CliDE in development
SoL	22	9 Hobo RX3000 3 Hobo GSM 2 Hobo Satellite 8 Hobo Micro	Rain, temperature, relative humidity, wind speed and direction, solar radiation, soil temperature, soil moisture	10 min	Spreadsheets, with MAF CliDE in development
ACIAR	5	5 Tiny Tag	Rain, temperature, solar radiation	10 min	Spreadsheets
GIZ/ Camoes	Joint operation to assist with planning and capacity building for ALGIS with purchase of some replacement parts				
FAO	Assistance for ALGIS with data analysis, station maintenance and replacement parts, and reporting				
BESIK	Assistance for DNCQA in data collation and management				

GIZ = Deutsche Gesellschaft für Internationale Zusammenarbeit; FAO = the Food and Agriculture Organization of the UN; BESIK = Bee, Saneamentu no Ijiene iha Komunidade; all other abbreviations are given in the text.

established. Data were processed and collated on spreadsheets and shared on the internet. The data were stored on a CliDE database set up within MAF, copied to the main GoTL CliDE and submitted to the Australian Bureau of Meteorology (BOM).

The weather data collected confirmed a high variation in temperature from a maximum of 38.4°C at Ritabou on the Maliana plain and a minimum of 3.8°C at the high altitude site of Urulefa, Maubisse, only 46 km away. Total annual rainfall in the 2013–2014 period ranged from 965 mm in Betano to 2,250 mm in Ritabou (Figure 3). The data indicated high inter-annual variability when compared with the long-term average. For example, Aileu historically receives 148 mm on average in December, but in 2013 Aileu received 428 mm in December. During 2014, the rainfall in the northern AEZs had rapidly declined by May, whereas in the southern AEZs the greatest rainfall was received in May and June. Another area for concern is the potential for extended dry periods during the cropping season such as indicated by the rainfall in Loes in March 2014 (Figure 3).

Current weather data were compared with historical data for eight sites to find that over the last 50 years total annual rainfall had decreased by 19%, maximum temperatures had increased by 1.8% and minimum temperatures had remained the same or increased by approximately 0.5% (Pereira et al. 2013).

Simulating maize growth using the collected weather data allowed improved analysis of radiation levels at critical times of maize development. It was found that changes in radiation across sites did not explain the lower yields found at higher elevations. Solar radiation levels have the greatest impact on yield during flowering and grain filling (Edmeades and Daynard 1979). Measurements of solar radiation

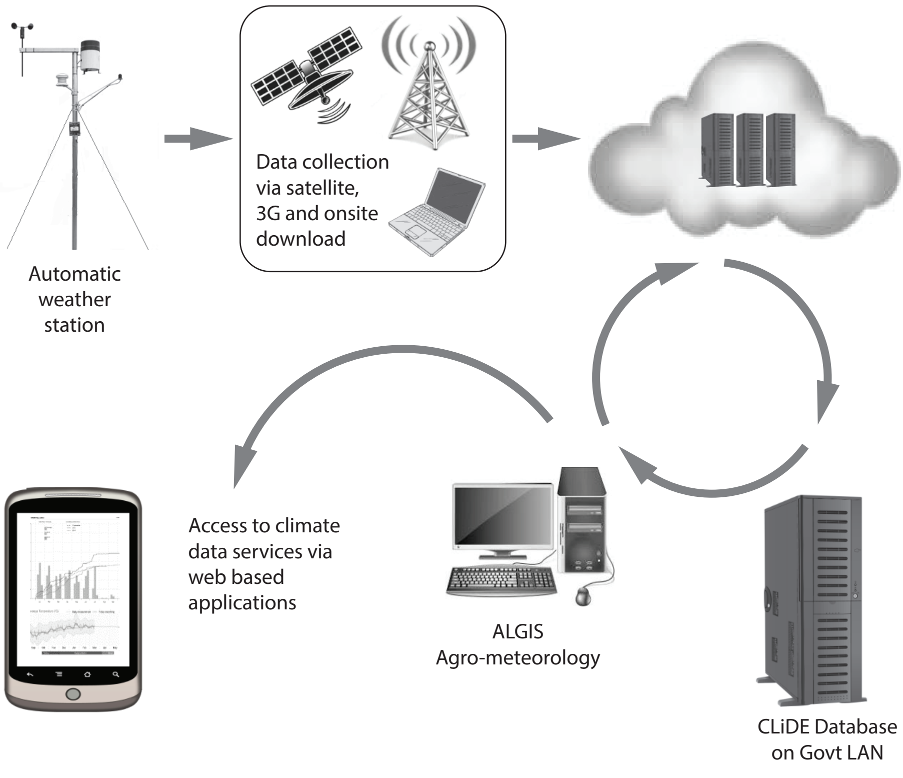

Figure 2. Weather data are collected with automatic weather stations and transferred to a cloud-based server for processing and storage. From here climate products and models can be developed and accessed via the internet and shared on the government's local area network (LAN).

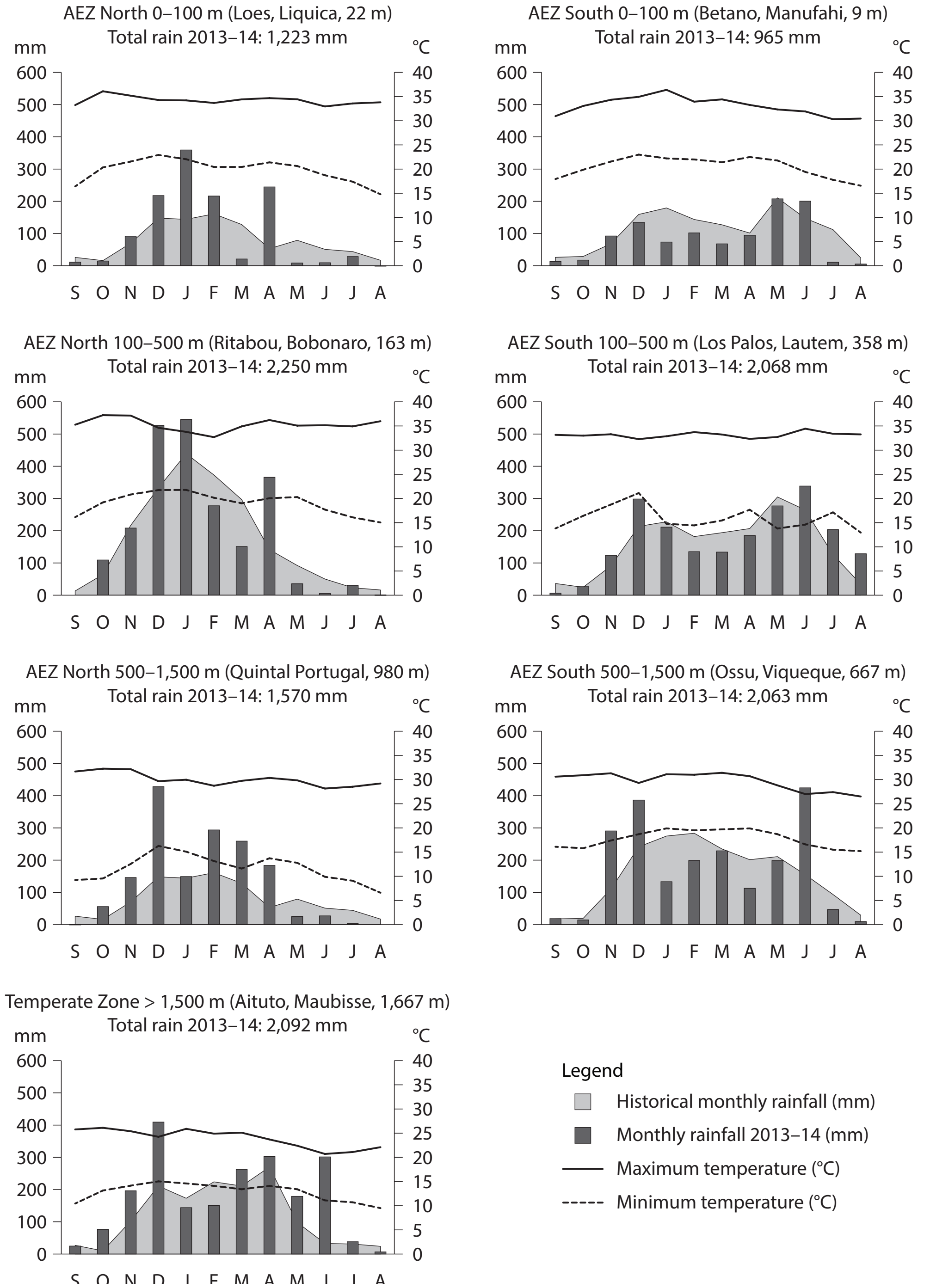

Figure 3. Representative weather station data from each AEZ showing monthly rainfall data (mm) compared with historical data and monthly maximum and minimum temperatures (°C).

showed that coastal areas of Timor-Leste had lower levels of radiation at critical development stages compared to higher altitude locations. For example, Ritabou at 163 m received 464 MJ of radiation during grainfilling whereas Aituto at 1,667 m received 711 MJ during grainfilling (Figure 4).

When the APSIM maize simulation was run at 1.5°C and then at 3.0°C it was found that maize production changed depending on the location. In cooler mountain areas, yields for subsistence farmers increased with increasing temperatures. For warmer coastal areas, yields decreased for subsistence farmers above maximum temperatures of 31°C (Bacon et al. 2016). Furthermore, simulations demonstrated that differences in total solar radiation during the cropping season were not likely to be a major contributing factor to overall differences in yield from coastal to mountain areas. Simulations demonstrated that a significant limiting factor was nitrogen supply, which was especially lacking at cool temperature locations due to low soil organic matter turnover.

Data transfer, storage and reporting

Extensive investigation was conducted to find an affordable, rugged and versatile automatic weather station that could be easily operated and met the standards required by the WMO (WMO 2012). The Onset Hobo system was considered suitable in that it was very affordable and easy to operate. A station could be deployed within 2 hours from arrival on site. It was also easily upgraded to remote data transfer. The Hobolink 3G data transfer system significantly reduced time and costs related to data collection and greatly improved access to the data. However, data storage into the CliDE system proved very difficult as it required very specific formatting and relatively high levels of computing skills to import the data into the system. Extensive testing and development was required with external support. A suitable procedure was developed and then MAF staff were trained in its use. Due to difficulties in accessing the GoTL LAN, a separate CliDE system was installed in MAF. This allowed piloting of automatic data transfer from weather station sites, to Hobolink, down to CliDE and then public access through the internet without the need for staff intervention in data processing. Periodically, the data would need to be transferred in bulk to the DNMG CliDE.

Developing a collaborative approach

A collaborative effort is required for monitoring climate in a developing country context. It is

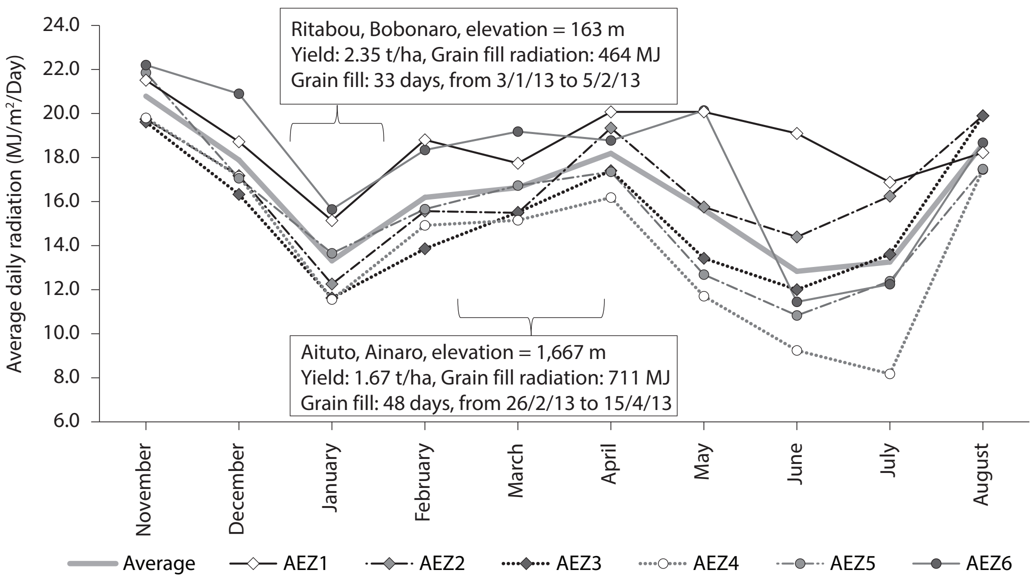

Figure 4. Solar radiation compared across AEZs indicating that the impact on maize yields depends on the length on timing of the grain filling period.

important for all projects and government departments to be aware of other organisations that are collecting weather data, where the stations are located and where the data are located. All activities should work toward open data sharing and there should be an established weather data repository held within government. All data should be saved into simple formats such as comma separated values (csv) files and shared freely especially across government departments, universities and neighbouring countries such as Australia and Indonesia. This would ensure data is not lost. Good access to the data and reliable weather reporting will reduce the need for organisations to invest in their own systems in isolation.

Discussion

Applications for the agriculture sector

Access to reliable weather data is essential for a variety of agricultural applications. Climate data can be used in decision-making on the types of crops that are grown. New crops can be considered by farmers by comparing the optimal climate range of the crops with climate information for their local area. Larger scale investors can assess the risks and potential of various crops based on climate data. Long-term daily weather data compared with crop yields assists farmers to balance the risk of their crop management practices. Understanding the likelihood of dry periods in the crop season or spikes in maximum temperature allows selection of crop management practices that minimise risk for an acceptable return. For example, a farmer may be able to increase yield with a higher plant density but they can balance this with a consideration of the likelihood of water stress in the cropping season which requires a reduced plant density. All stages of crop management including planting, weed management, fertiliser application, pest management, harvesting, storage and transport can be improved with timely access to weather data. Subsistence farmers can start by noting crop activities and crop performance and comparing against local weather data to improve understanding of issues such as soil water balance after rain events at different stages of crop growth. At agricultural research level, reliable weather data are crucial for developing crop models that can indicate possible yield gains of new varieties and alternative management practices.

Applications for research

The high-quality agro-meteorological data that were obtained in Timor-Leste were used to successfully assess the impact of climate on maize yields through the use of APSIM. The impact of radiation was investigated as it was known anecdotally that higher altitudes had less radiation due to increased cloud cover. Radiation also varied locally depending on aspect and proximity to surrounding mountains in the rugged terrain. However, the impact of solar radiation on maize yields depends on planting times, rate of development dependent on temperature and seasonal climatic variation of cloud cover. At higher elevation sites, maize can receive more radiation during critical stages of flowering and grain filling due to delayed planting date and more days overall in the grain filling phase. Understanding the impact of climate on crop yields requires an understanding of the complex interplay between factors such as temperature, radiation and crop phenology.

Using the weather data with the APSIM maize model enabled analysis of the impact of nitrogen and temperature on maize yields to improve understanding of the factors impacting yields at high altitudes. The effect of soil temperature in slowing down nitrogen mineralisation of soil organic matter has particular relevance for low-input subsistence farmers at higher altitudes. This highlighted the need for high-altitude farmers to increase nitrogen input either through increasing soil organic matter or micro-dosing with chemical fertiliser. This research was then expanded to take into consideration the impact of warming temperatures across all AEZs. With increased temperature farmers can expect increased nitrogen mineralisation but also shorter crop durations. In coastal areas, farmers are particularly at risk of high temperatures resulting in decreased yields.

Another area currently under investigation is aflatoxin risk modelling for maize production. The potential for aflatoxin contamination is dependent on temperature, rainfall and humidity especially around harvest time. This is particularly relevant for growers in the bi-modal rainfall areas of AEZs 5 and 6 where the highest levels of maize production occur. APSIM has been used for peanut growers in Australia, to inform them on the optimal time for harvest to minimise the risk of contamination (Chauhan et al. 2010). This could be applied to peanut growers in Timor-Leste and modified for maize growers. Commercial food producers are particularly interested in aflatoxin risk and could use an integrated climate and crop model for alerts to areas that may have higher risk of aflatoxin which would require more rigorous sampling and testing before purchase from farmers.

Applications for the future

Automated data transfer is considered a vital component for sustainability, reliability and timely access to data. It also opens the opportunity for a variety of different applications that can be developed in collaboration with other nations across the South Pacific who are using the same system. For example, daily weather data can be made available on the internet uploaded at 3 hourly intervals. This can be accessed by television and radio networks as well as government departments monitoring weather risk. Internet access to data reduces staff time spent on responding to requests for data. As more farmers become involved in commercial farming enterprises, the applications of daily weather data access and modelling become more meaningful. For example, in Australia models are already in use to assess aflatoxin risk in peanuts to provide information to farmers on the best time to harvest (Chauhan 2004). This depends on the maturity of the peanut and the soil moisture conditions in the lead up to harvest.

Reliable and timely weather data are essential for disaster response planning. In 2013, a severe flood occurred in Viqueque which destroyed large crop areas as well as infrastructure such as roads and buildings. SoL was operating two weather stations in the area which showed heavy rainfall over a 24-hour period along the coastal plains immediately followed by heavy rains in the mountains. The rainfall data confirmed that this was the heaviest rainfall event ever recorded in the area which supported a more concerted disaster response effort. During the 2015–2016 El Niño event, access to daily rainfall and soil moisture data combined with knowledge of farmers' planting practices is allowing improved monitoring of climate-vulnerable areas. During these climate disaster events, weather data become an essential component for driving early warning systems and timely response for delivery of assistance to farmers in need.

There is a growing interest in agricultural index insurance for developing countries. Traditional crop insurance considers crop losses based on site investigation and has been shown to be fraught with issues of fraud and high administration costs (Hess and Syroka 2005). The move towards index insurance is based on objective, measured weather events such as rainfall deficit. There is no need for a field visit and crop yield assessment, as payouts are triggered by weather data directly (Osgood et al. 2007). For example, a direct insurance payout may be transferred to the farmer based on extreme weather data such as low rainfall in the cropping season, high temperature in the normal month of flowering or strong gusts in the late crop season. Improved data collection combined with satellite data, historical weather data and modelling will strengthen consideration by insurance companies for these sorts of ventures which can in turn encourage greater investment in agriculture.

Improved crop management practices can be implemented based on timely access to weather data integrated into a crop modelling platform. Farmer advice could be given on strategic application of micro-dosing fertiliser rates based on planting dates, variety, soil data and weather data, so that crops like maize can receive nutrients such as nitrogen when they need it most. This means that client-specific advice can be generated for a particular season. With the rapid development of mobile phones and internet access, this sort of information is more likely to be accessed through websites rather than text messaging systems so that the main cost is data access for the user. For example, farmers could test various fertiliser application rates on a simple web-based platform providing yield forecasting and profit margin information.

There is a growing field of applications of the integration of weather data with crop data, especially in more developed countries, but there is still plenty of scope for the next generation in Timor-Leste to develop relevant applications for their own situation. These future applications will depend on the quality of data that is collected today.

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The impact of elevation on postharvest losses of maize in Timor-Leste

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Abstract

Postharvest losses of the staple food maize are high in Timor-Leste where traditional storage methods are commonly used. These methods include: (a) hanging whole cobs in a tree; (b) storage of whole cobs above the fireplace; (c) storage of whole cobs in an elevated house; and (d) storage of whole cobs in sacks stored inside the house. None of these practices adequately protects the grain from damage by insects, rats, moisture, mould, chickens and other farm animals. The study described in this paper evaluated how maize was affected when stored in traditional grain storage facilities located at different altitudes from sea level to 1500 m above sea level (asl). The main factor damaging the grain was weevil damage. This was followed by damage by rats, mould and chickens. The effects were evenly spread across all storage sites but weevil damage decreased at high altitudes. This decrease in insect activity may be due to the prevailing lower temperatures at altitude.

Introduction

Postharvest grain losses occur world-wide. The losses can be quantitative (weight or volume) and/or qualitative (loss in nutrient value or deterioration in colour, texture, taste or visual features). They may be due to physical factors (e.g. temperature, humidity and water) and/or biological factors (e.g. fungi, insects and rodents) (Guterres and da Costa 2014). Losses are particularly significant in developing countries where storage facilities may be substandard or, in some cases, non-existent. In continental Africa, for example, postharvest losses account for 15–30% of stored goods (Aulakh and Regmi 2013; Khan 2010; World Bank 2011). In Pakistan, losses in rice are estimated to be as high as 30% (TDAP 2010). In subsistence farming environments, losses of such magnitude can exacerbate household food insecurity. There is an urgent need to address this issue in Timor-Leste where most farmers live a subsistence existence and often struggle to maintain food security for the whole year. Nationally, postharvest maize losses have been measured to range from 12% (Da Costa et al. 2013) to 30% (Guterres and Williams 2006)—food which the nation's poor farmers cannot afford to lose. Crop failures are already high due to variable climatic conditions and these are predicted to worsen with global warming (Molyneux et al. 2012). Predicted higher ambient temperatures will also accelerate a deterioration in postharvest storage conditions.

In municipalities where crop failure and postharvest losses are high, farmers suffer more from food shortages. It is important that these municipalities gear their policies and technologies towards reducing food losses. The research presented in this paper addresses one factor which may influence postharvest maize losses. The objective was to investigate whether postharvest losses in traditionally stored maize vary with elevation. The study was conducted in the municipalities of Aileu, Manatuto, Viqueque, Manufahi and Ainaro. These were selected because they have a large population of subsistence farmers growing maize, and they span from sea level to higher elevations in Aileu and Ainaro.

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Methods

The study was conducted over a 10-month period from mid-May 2013 by researchers from the National University of Timor Lorosa'e (UNTL). Researchers worked with farmers to record the quality of maize stored under traditional storage conditions on 75 farms. Traditional storage methods include: (a) hanging whole cobs in a tree; (b) storage of whole cobs above the fireplace; (c) storage of whole cobs in an elevated house; and (d) storage of whole cobs in sacks stored inside the house. At each site, 72 cobs of locally grown maize were marked and then stored according to the local manner. Across the sites there was a range of local and recently introduced varieties. There was also a range of storage methods, as described above. Qualitative and quantitative measurements were made monthly. Measurements included assessment of damage due to rats, weevils, mould, rot, premature germination and other obvious factors causing deterioration in grain quality or quantity. The results were grouped according to the altitude of the storage sites. High elevation was considered to be above 1000 m above sea level (asl). High-altitude sites were located at 1,247–1,493 masl in the subdistricts of Maubissi, Remexio and Leguidoe. Medium elevation was considered to be between 500 and 1,000 masl, and sites were 559–999 masl in the subdistricts of Hatubuilico, Aileu Vila, Laulara, Soibada and Ainaro. Low-altitude sites were considered to be at elevations below 500 masl, with sites in the subdistricts of Alas, Uatulari, Uatukarbau, Viqueque Vila, Same and Hatudo.

Results

Observations for the 75 farms were combined to determine overall maize deterioration. There was 15% damage after 1 month of storage which steadily increased to a maximum of 57% after 12 months of observations (Figure 1). Using a linear regression, losses equated to approximately 3.6% per month.

The biggest factor contributing to postharvest losses was grain-eating insects (Figure 2), primarily the maize weevil (*Sitophilus zeamais* Motschulsky) but also the grain moth (*Sitotroga cerealla* (Oliv.)). Losses due to weevil damage in all study sites was highly significant ($P < 0.001$).

Rat infestation also caused significant damage ($P < 0.001$) at all elevations and damage increased with storage time (Figure 2). The rodents ate some of the grain and reduced the quality of the remaining cobs with their urine and hair. Researchers reported that in some cases that the rats also caused indirect grain loss by opening holes in the house roof allowing rain to penetrate and spoil cobs.

Chickens and germinating grain also caused very small losses (1% and 0.4%, respectively), and damage was consistent across all altitudes.

The amount of mould damage measured was comparatively low (3%), and varied across altitudes.

The significant relationship between weevil damage and total damage is presented in Figure 3.

Mean weevil damage across the sites and elevations indicated that damage decreased with elevation (Figure 4). When the sites were divided into high (>1,000 masl), medium (500–1000 masl) and low (<500 masl) elevation sites, weevil infestation was 10%, 14.6% and 16.8%, respectively ($P < 0.05$; Table 1).

Maize varieties measured during the research included: (a) local traditional maize (78% of all samples); (b) new varieties (e.g. Sele and Noi Mutin; 20%); and (c) a mixture of local and new varieties (2%). Damage varied across variety type. Grain damage due to weevil and bird damage and early germination was higher for the new varieties (Sele, Noi Mutin) than for local varieties (Table 2).

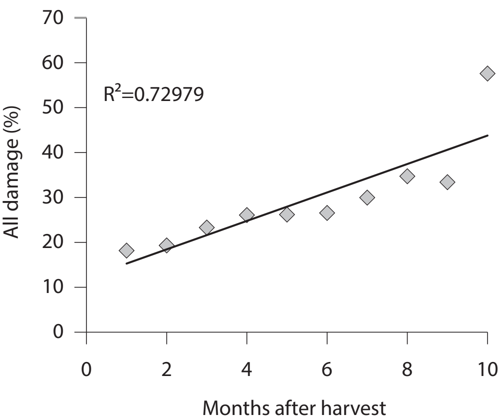

Figure 1. Linear regression of stored maize losses, 2013–14.

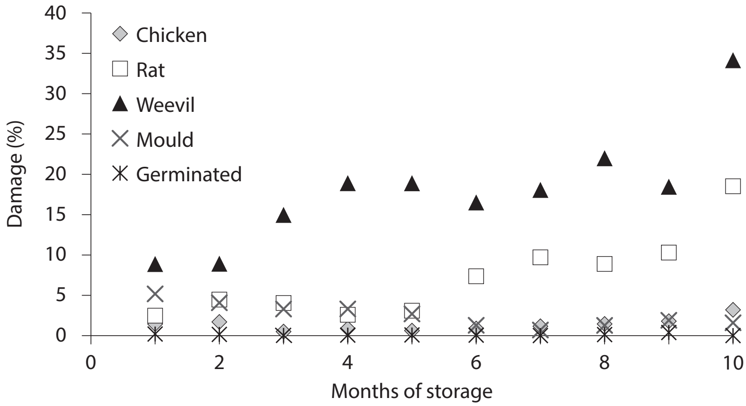

Figure 2. Losses of maize grain in storage over 10 months by cause of damage.

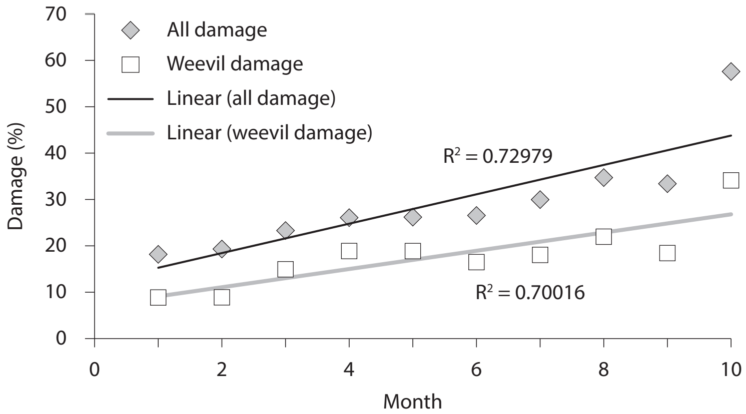

Figure 3. Linear regression of weevil damage with total postharvest losses over time.

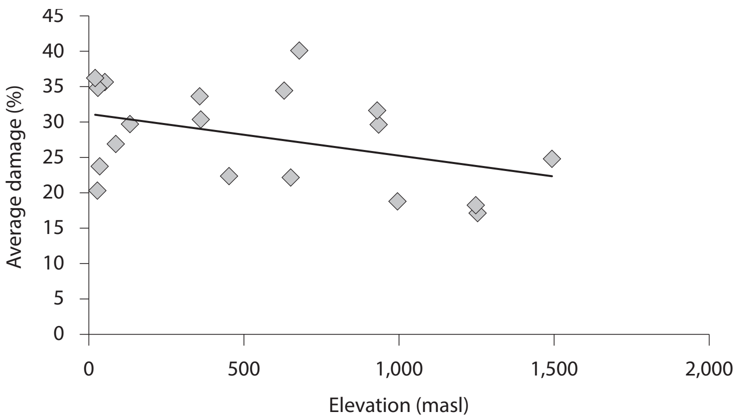

Figure 4. Average maize damage by elevation (masl).

Table 1. Weevil damage by altitude category (high, medium and low).

Altitude (masl)	Mean weevil damage to stored maize (%)
High (>1,000)	10.0
Medium (500–999)	14.6
Low (<499)	16.8

Table 2. Postharvest losses across varieties or variety mixes.

Variety	Weevil damage	Rat damage	Bird damage	Mould	Germination
New	20	7	1.9	2.9	0.22
Mixed	15	12	1.5	4.2	0.14
Local	17	7	1.2	2.4	0.09
F prob	0.01	<0.01	0.03	0.01	0.04
LSD ($P < 0.05$)	2.1	1.3	0.6	0.6	0.11

Discussion

The combination of low maize yields (1.5–2.0 t/ha) and high postharvest losses in many parts of Timor-Leste causes some farm households to experience food insufficiency for a few months each year (Lopes and Nesbitt 2012). This study, and others, indicate that postharvest losses are very significant in maize and increase over time when Timorese farmers use traditional storage methods. Overall losses were shown to be up to 57% after 10 months, or an average of 3.6% each month, in this study. This study and those of Guterres and da Costa (2014) and Guterres et al. (2015) show that the traditional storage methods of placing maize cobs above the fireplace, hanging cobs from trees, storing them in an elevated house or placing them in sacks and storing inside the house are inappropriate and fail to effectively protect food stocks.

In this study, the majority of postharvest losses were caused by insects, mainly weevils (19%), and also by rats (6%) and mould (3%). Spoilage by rat urine and hair, although not found to be widespread in this study, can also be significant. In addition, the presence of humid conditions can lead to mould developing in the grain making the grain smelly and unappealing. Should the fungi *Aspergillus flavus* Link: Fr. and *Gibberella fujikuroi* (Sawada) Wollenw be present, dangerous toxins such as aflatoxin and zearalenone may develop and render the grain unfit for human consumption (Manandhar et al. 2000).

This study clearly demonstrates that weevil damage of maize stored using traditional methods decreases with altitude. The highest damage due to weevil infestation was at low elevations with a mean of 16.8% damage. Above 1,000 masl damage was reduced to 10%. This suggests that losses due to weevil infestation are influenced not only by maize variety and storage method but also by temperature. Ambient air temperatures are known to decrease by approximately 0.65°C per 100 m of elevation. If the climate change prediction of higher ambient temperatures in Timor-Leste proves true (Molyneux et al. 2012), more grain stored under traditional methods will be affected by postharvest damage.

Considerable variation in damage was also observed among the maize varieties. Losses due to *S. zeamais* were greater in modern maize varieties compared with traditional varieties. This observation was also made in earlier studies (Guterres and Williams 2006; Guterres et al. 2015). Seed size of local maize varieties is small compared with improved maize varieties. Smaller seeds which are harder and more compact could be more resistant and less attractive to maize weevils. The tight husks of local varieties is probably also a factor (Eden 1952; Guterres et al. 2015).

Conclusions

This study confirms that postharvest losses in maize grain stored using traditional methods in Timor-Leste are high and are of concern. Most losses are due to weevils damaging the grain. Importantly however, damage from this pest was reduced when maize was stored at higher altitudes. This is most likely due to lower temperatures at higher elevations reducing insect activity. Where possible, farmers could be encouraged to store their maize in cooler environments. Because higher yielding varieties are more susceptible to postharvest losses, it is preferable for farmers to store their grain in air-tight containers which kills off all insects as oxygen levels drop. Storage in solid containers such as drums would protect against rats and other animals resulting in less grain consumption and spoilage from these animals. The grain would also remain dry reducing mould build-up.

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Section 5: Communication of agricultural innovations

Agricultural extension in Timor-Leste: experiences of the Fourth Rural Development Program (RDP IV)

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Abstract

The dissemination of improved agricultural innovations and management systems to rural communities is known to help improve national food security in developing countries. In recognition of this fact, the Government of Timor-Leste established a national extension system to provide an avenue for Ministry of Agriculture and Fisheries personnel to interact with the farming community. A new directorate was established in 2008 and around 400 agricultural extension officers were assigned to serve rural communities. During that time a rural development program (RDP II) funded by the European Union (EU) was active in the country and supported the ministry in developing an extension policy, strategy and handbook. From 2012 on, the EU funded another rural development program (RDP IV) to strengthen the agricultural extension service. This program followed the policy framework for agricultural extension formulated by the Government of Timor-Leste. The development program consisted of the following components: agricultural education, capacity building, improvements to extension management to facilitate the interaction of extension staff with the farming community, and the implementation of agricultural campaigns. This paper describes some of RDP IV's experiences during its implementation between 2012 and 2015 and makes recommendations to improve the service in its next phase of development.

Introduction

Despite significant progress in many areas, the young nation of Timor-Leste still faces many challenges in trying to achieve prosperity for its quickly growing population. As recently as 2015, Timor-Leste ranked 133 out of 188 countries in the Human Development Index (UNDP 2015). Much of the poverty in the country is concentrated in the rural areas where more than 70% of the 1.2 million population live and work. Around 125,000 people engaged in agriculture, forestry or fisheries (FAO 2016) can be considered to be in vulnerable employment (MoF 2013) and are persistently poor. Poor in this context means that people live below the national poverty line of US$0.88 a day (ADB 2011). There is also a high level of infant malnutrition (von Grebmer et al. 2014). Additional problems in many rural areas include food shortages, lack of employment opportunities for young people, and low income. Subsistence agriculture dominates the sector with the average family owning less than 2 hectares of land. Overall the agriculture sector contributes only around 30% to the non-oil GDP of the country (MoF 2010). This indicates a low level of agricultural productivity and production.

The Government of Timor-Leste recognises the need for agricultural development to be part of broad-based economic growth to pursue sustainable reductions in poverty (GoTL 2002, 2011), and established the Ministry of Agriculture and Fisheries (MAF) in 2002 to address issues and constraints to developing a sustainable agricultural, forestry and fisheries sector. The establishment of a public extension service in 2008 was essential for the development of the agriculture sector (World Bank 2011) and was part of the vision.

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History of agricultural extension in Timor-Leste

Agricultural extension in Timor-Leste began in 1975 and expanded during the period of Indonesian government through to the independence referendum in 1999. The extension network comprised at this stage over 700 field agricultural extension workers servicing all villages with technical advice, promotion of country-wide programs, and the provision of a range of input and market support services (MAF 2008). A training and visit system was employed in the service and much of the information was delivered to the farmers using a top-down approach (Anderson et al. 2006).

Few extension services were provided under United Nations control (1999–2002) and subsequently (2002–08) most agricultural extension was provided by local and international NGOs.

In 2008 the MAF completed a policy framework for agricultural extension (MAF 2008). The policy included an extension service designed to deliver goods and services to the farming community using a participatory model—a clear contrast to the top-down training and visit system used earlier and unsuccessfully. The new extension system was designed to guide (not 'train' or 'teach') farmers to help them to learn about the potential benefits of new technologies. It was to be built around a detailed analysis of farmers' production problems, constraints and potentials.

The goals of the new system are primarily: (a) sustainable increases in national food production, food security and nutrition; (b) sustainable increases in farm incomes; (c) improved marketing of agricultural produce and the commercial development of agriculture; and (d) improved capacity of farmers to participate in and benefit from development.

The new agricultural extension system was designed to be phased in over a period of time. The foundation phase ran from 2008 to 2012. During this period, the objectives were to establish a national structure for the system and successfully integrate agricultural extension into the MAF (GEL 2016). During 2008 MAF posted around 250 agricultural extension staff in the villages (*sucos*), and an extra 150 were added during the following year. Agricultural extension personnel reported to the National Directorate for Agricultural Community Development (NDACD) within the MAF. This initial phase was supported by the Second Rural Development Programme (RDP II) implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. One of the outputs of the program was the formulation and publication of the national agricultural extension manual in 2011.

The development phase of the Timor-Leste agricultural extension system ran from 2012 to the end of 2015. The focus of this phase was to improve the capacity and management of the system including streamlining procedures and inter-agency coordination. Capacity building of the extension officers was a high priority during this phase, through meetings and training as well as the dissemination of technical information. The program was implemented in 12 of Timor-Leste's 13 municipalities. Assistance was provided to MAF between February 2012 and December 2015 by the Fourth Rural Development Programme (RDP IV). This program was closely aligned to the strategic planning of the Government of Timor-Leste and directly contributed to the NDACD mission, which aimed to:

- build social capital through encouraging group formation, participation and cooperation;
- improve planning, organisational and leadership skills in communities;
- facilitate access to information and new technologies;
- support self-reliance and build problem-solving skills;
- build business management, marketing and financial skills;
- manage natural resources sustainably.

Specifically, the objectives of RDP IV were to:

- support agricultural education;
- build the capacity of extension staff and technical experts;
- improve the extension management system at national and municipality levels; and
- support agricultural campaigns together with the respective national and district level sections of the partner ministry.

The program was co-implemented by Germany's GIZ and the Portuguese Camões Instituto para a Cooperação e Língua (CICL). It was funded by the European Union (EU) under the 10th European Development Fund (EDF).

Impacts of and challenges to the agricultural extension program under RDP IV 2012–15

RDP IV and NDACD activities were spread across the nation. They were considered by Rüttinger (2014) to have contributed significantly to consolidating peace and stability in the rural areas of the country. The major impacts of and challenges to the program are described below, aligned with the objectives of the agricultural extension component of RDP IV.

Supporting agricultural education

RDP IV provided significant support to agricultural secondary schools in Timor-Leste, with construction and provision of equipment. It also contributed to the national curriculum for applied agriculture topics. The program also boosted the capacity of teachers in collaboration with (among others) the Asian Institute of Technology, further raising the quality of agricultural education. These activities were important steps towards long-term development in this sector. However the curriculum, although rich in content, did not lead to graduates immediately looking for employment in the agriculture sector, because the qualifications were seen primarily as a step towards university. The additional professional agriculture courses offered by the high schools helped bridge the gap between employment and an opportunity for further higher education. While these courses were recognised to some extent by the education authorities, they were not part of the national education structure.

Building capacity of extension staff and technical experts

RDP IV strengthened the capacity of *suco* extension officers, subject matter specialists and technical personnel, helping them to perform their jobs according to their job descriptions. They were also trained in good agricultural practices with a focus on maize, coffee, rice, soy, mungbeans, forestry and horticulture, using demonstration plots, farmer field days and other practical activities. Additional soft skills training was organised to promote participatory community planning and cross-cutting issues like gender and peace and conflict transformation. Training for the extension service was also provided by a number of other development partners, to the extent that there were some signs of 'training fatigue'. There was also little standardisation among the development actors in terms of financial incentives for extension staff to participate, which encouraged extension workers to collaborate more with some organisations and less with others. Efforts to better coordinate between development partners at the municipality and national level were made, particularly through development partner harmonisation meetings, that should lead to better coordination in the future.

Improving the extension management system at national and municipality levels

RDP IV worked entirely within MAF and utilised the national system to implement activities. By doing so, extra operational funds were made available for the extension program and the capacity of the management system was enhanced. For example, municipality program coordinators were placed within MAF and participated in all relevant meetings with their counterparts. As a consequence, joint coordination, planning and implementation structures and routines were established which contributed positively to the program implementation and an increasing degree of ownership. By the end of the 4-year program MAF staff were competently leading RDP IV-related meetings and national commodity workshops.

Supporting campaigns on good agricultural practices

A nationwide public demonstration of good agricultural practices on 3,141 demonstration plots and comparison plots as well as in farmer fields was the major activity of RDP IV to improve the capacity of the extension system and encourage streamlining of procedures and inter-agency coordination. The good agricultural practices were also mainstreamed into many other programs and initiatives. Overall, more than 56,000 farmer participations were counted in trainings organised by the extension service in RDP IV working areas. The results of the maize, coffee, rice, soy and mungbean, forestry and horticulture campaigns showed that, in general, a 50% or higher production per hectare can be achieved if good agricultural practices are applied. Two impact assessments and qualitative case studies for all supported commodities came to the conclusion that farmers advised by the program had a significantly higher knowledge of good agricultural practices and were obtaining higher yields and, in many cases, increased income (Senanayake 2014; Senanayake et al. 2015; Belun 2015). This additional income is used to support the family, send children to school, invest in a business or savings and credit scheme, or to buy private goods. Implementation of good agricultural practices increased as the program progressed. For example, the adoption of good agricultural practices for rice increased from seven households during the 2013–14 wet season to 120 households in 2014–15 in one area of the Baucau municipality (RDP IV data).

Apart from increasing agricultural production, the program strove to integrate marketing aspects into the operational work in order to increase the income of farmer households. A number of get-togethers were organised for relevant actors at farm and national levels and the private sector. Six national workshops were organised over the 4-year period where farmers and marketing organisations, such the agri-business firm Acelda (rice), the Hummingfish Foundation (coffee) and Maubere Mountain Coffee, were able to discuss trade of commodities. Value chains were established and can be further built upon in the future.

MAF offered free ploughing to farmers in most municipalities who decided to implement good agricultural practices. While this approach is not a long-term solution, it promoted good agricultural practices as an official MAF approach, connected MAF staff and farmers, and helped the farmers familiarise themselves with the practices over time. MAF representatives repeatedly stated their will to continue to promote the good agricultural practices and implement the training approach used during RDP IV. The promotion of savings and loans schemes was also very successful, particularly where farmer groups were interested in buying agricultural machinery. For example, 39 high-performance farmer groups (31 from RDP IV and 8 from the GIZ-supported agro-biodiversity program) contributed 50% of the total procurement price of around US$35,000 for equipment from their own savings. These developments indicate that such activities may well continue in a sustainable manner in the future.

Lessons learned from the implementation of RDP IV, and recommendations

- **Support agricultural education:** Agricultural education is an essential component for improving food security in Timor-Leste and for the extension program in general. More investment is needed to support agricultural schools. It is suggested that future support is given to the setting up of relevant structures which allow graduates to enrol in higher institutions and courses which are formally recognised by the educational system.
- **Improve quality of dialogue and engagement processes:** Collaboration needs to be further strengthened between MAF technical directorates and also between MAF and development partners to improve the capacity of the extension system to operate more effectively. The relevant actors need to be functional and effective in guiding and harmonising national agricultural sector investment and planning.
- **Strengthen planning at national and municipal levels:** Participatory strategy development, planning and monitoring should be conducted at all levels to increase ownership and sustainability of activities in agricultural extension. Integrated and decentralised planning needs to be conducted and followed up, and staff need to be trained accordingly. A mapping and analysis of municipal services would provide a capability assessment of potential public and NGO service providers and a basis for prioritisation. Then, under the increasing lead of MAF, various actors can take responsibility for agreed areas and activities under a coordinated and harmonised implementation plan.
- **Regularly assess budget allocation and staff capacities in MAF:** It is recommended that the type and scope of extension service being provided to the rural sector be regularly evaluated and matched with the country's resources and vision. Improved data management and records will improve the capacity to implement the reviews.
- **Promote active and participatory training approaches:** Instead of the rather top-down extension training previously used, a shift to a mentoring or facilitating mode is advised. This involves close-up, participative and continuous capacity building to ensure skills are acquired, practised and internalised. This approach will be comparably time consuming and involves revisiting existing assumptions for project outputs and indicators. Areas to look into are innovative 'training of trainers' approaches, re-evaluating conditions of service, and introducing real performance incentives for extension staff. Further, it is recommended to foster soft skills development, especially for extension staff interacting with growers.

- **Involve farmers and farmer groups:** Farmers should be made familiar with any given approach and, if interested, be involved in and drive the planning of activities in their communities. Their opinions and knowledge should be the basis for future steps. Also, it is considered important that farmers are not seen merely as the recipients of handouts but should instead make contributions to increase their ownership and sense of accomplishment.
- **Promote farmer-to-farmer training:** Extension approaches have a higher chance of being successful when they put the clients and their needs and demands at the centre. Instead of thinking of farmers as recipients of information, their knowledge is valuable and the exchange of knowledge with other farmers should be promoted.
- **Upgrade MAF staff competencies and skills and improve incentives for good performance:** Roles, responsibilities and relationships across MAF and partners need to be clarified. Skills audits are required as well as revamping of job descriptions, team development and in-service training. It would also be beneficial if good performance was recognised to encourage personnel in their daily activities.
- **Increase decentralisation**. More focus on local levels presents major opportunities to improve service delivery. Agricultural extension personnel will work more closely with farmers. Systems may be more flexible and better able to respond to changing conditions. With recurrent budget limitations affecting the payment of field allowances and thus the mobility of field staff, deployment of personnel at the local level will be more affordable and effective.
- **Implement data management and wider knowledge systems:** Using decentralised service delivery mechanisms, standardised templates for essential datasets need to be introduced. Basic records should be maintained at all levels from farmers, agricultural extension officers, chief of extension up to municipality director level. Municipality services mapping and analysis exercises will enable access to more reliable annual budget and expenditure data to arrive at accurate costings and attributions for key activities.
- **Stronger integration of the private sector:** The commercial private sector in Timor-Leste is still in an early stage of development but has high potential to stimulate productivity and production. Therefore, it is advised that future interventions aiming at improving the extension service should comprehensively integrate marketing, linking farmers to markets and establishing value chains into the approach.
- **Promote business development skills**. There is a need to boost organisational development and market and agribusiness orientation, in addition to agricultural production and productivity. Farm business development skills could be supported across the sector through farmers' associations. These skills include business planning, financial management, savings and credit, market development, agribusiness systems, group and organisational development, record keeping, and gross margin analysis.
- **Clarify land right and land ownership issues**. This area needs more attention, especially for interventions which require long-term commitment from farmers (e.g. forestry). Solutions to the problems of land rights and ownership lie in already existing mechanisms of communities, for example the traditional conflict resolution system *tara bandu*.

Conclusions

The capacity of the Timor-Leste agricultural extension service has grown considerably since its inception in 2008. During the initial four years of development, personnel numbers expanded from zero to 250 and finally to 400. The main objective of this foundation phase was for the extension service to integrate successfully into the MAF. This was achieved by 2011. In the following development phase (2012–15), RDP IV and partners supported both the education of agriculturalists and implementation of the agricultural extension system itself. Assistance was provided to government agricultural schools to upgrade the skills of teachers and students. Many of these young graduates will either be direct recipients of the technology transfer system or will train at a higher level to gain employment in private or government sectors. Within MAF, support was provided to management, technical specialists and extension personnel, particularly at the municipal and village level. Coordination, planning and implementation structures were developed and supported to a level where NDACD/NDECD staff were competently organising and leading workshops and meetings by the end of 2015. These skills have been carried over to the agency responsible for agricultural extension from 2015 and beyond in the National Directorate for Agriculture, Horticulture and Extension (NDAHE).

The intention of the policy framework for agricultural extension (MAF 2008) was for a participatory model to be implemented. As part of this policy, RDP IV supported MAF to implement a national campaign for extending good agricultural practices. Personnel within MAF improved their management, technical and extension skills using a 'learning by doing' approach, and at the same time helped farmers improve yields in maize, coffee, rice, soy and mungbeans, forestry and horticulture.

The strengthening of the Timor-Leste government agricultural extension system from inception (2008) to the end of 2015 has resulted in a MAF directorate with the capacity to reach the entire national farming community. It is recommended that the issues discussed in this paper be addressed to enable the extension system to further improve its efficiency beyond 2016. In the future a strong extension system can play a major role in mastering the challenges that lie ahead for the country. To be able to do so the system needs to be well managed, equipped with sufficient (operational) funds and able to constantly enhance its human resource capacity.

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Gender in crop production in Timor-Leste

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Abstract

This paper summarises women's roles and gender-specific trends and constraints in Timor-Leste's crop production system. The study uses data and information gathered by the Seeds of Life program. The findings suggest that the gender roles and the nature of gender gaps in Timor-Leste's crop production system are in many ways similar to those prevailing in South-East Asian countries and contrast with the systems in South Asia and Africa. The study reveals a balanced gender role with men and women spending equal amounts of time performing different roles in crop production. During the crop production cycle, generally men play a larger role in land clearance than women, the genders have an equal role from planting to harvest, and women play a greater role in post-harvest. Men and women play equal roles on the choice of planting material, and consequently the adoption of new varieties in Timor-Leste was found to be unrelated to the gender of the head of household. Mixed evidence was found regarding the gender and food security nexus. Women's participation in agricultural groups and women's access to extension services were significantly lower than men's.

Introduction

Women play important roles in crop production in developing countries as cultivators, labourers and family workers. Women contribute at least 40% of the global agricultural labour force (Doss 2014). Women's roles are, however, defined by socio-cultural norms and gender systems across the globe. In South Asia, men take the lead in land preparation, crop management, machine operation and marketing, while women are primarily involved in postharvest activities (Ahmed et al. 2013). In Africa, women are responsible for feeding the family and thus grow subsistence food crops; by contrast men are most active in cash crop production as they are responsible for generating cash income (Hill and Vigneri 2014). Men and women work on clearly demarcated plots; they are responsible for their own inputs and control the outputs. Women's ability to generate income and attain food security through higher agricultural productivity in South Asia and Africa is disproportionally affected by their low social empowerment, weak community influence and lack of control over and access to land, income, resources and information (Quisumbing et al. 2014; Akter et al. 2015). Women and girls in these regions are thus particularly vulnerable to food insecurity (Kumar and Quisumbing 2013) and consequently they suffer from malnutrition which leads to high rates of maternal, infant and child mortality (Haddad et al. 2014).

Gender roles in the crop production systems of South-East Asia are different from the widely studied systems in South Asia and Africa (Rutsaert et al. 2015). In South-East Asia, husband and wife work together in the same fields and agricultural inputs are shared. Men take a lead role in land preparation and the application of pesticides and fertiliser, while women are primarily involved in crop establishment, weeding, harvesting and postharvest activities (Rutsaert et al. 2015). Most valuable assets such as land and house are jointly owned and control over income is disproportionately concentrated towards

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women. Although no evidence of a gender gap was observed in terms of women's access to and ownership of resources and control over income, in some South-East Asian countries a gender gap was observed in terms of women's access to extension services. While women are active in agricultural groups and have equal access to extension services in Thailand and the Philippines, a lack of access by women to extension and information is common in Indonesia and Myanmar (Rutsaert et al. 2015).

Given the diversity of gender systems around the world and the different nature and extent of gender inequality across countries, communities and regions, the study of different gender systems is important to capture the cross-cultural variation in gender-specific needs and constraints (Rutsaert et al. 2015). This paper aims to increase understanding on the nature of gender in crop production in Timor-Leste. The paper summarises and integrates information gathered by the Seeds of Life (SoL) program since 2006 on gender in crop production. The country is a new, small, tropical and mountainous nation with a population of approximately 1.1 million. About 80% of the national labour force is engaged in agricultural activities (FAO 2011a) with the majority relying exclusively on non-mechanised low input/output subsistence farming (da Costa et al. 2013). The share of the economically active female population in Timor-Leste's agriculture was 45% in 2010—close to the average (43%) in South-East Asia (FAO 2011b). Overall women's role in agriculture in Timor-Leste is poorly documented.

Background: farming in Timor-Leste

Most farm households in Timor-Leste comprise between five and nine members. The head of household is considered the most senior person in the house and while usually male, 30% and 26% of households were headed by women in surveys in 2008–09 and 2009–10 (da Costa et al. 2013). Households function as agricultural production units with each household member playing a role in farm operations. With agricultural labour limited in Timor-Leste, in rural areas most fit adults undertake work in the field especially during times of peak labour demand such as weeding (da Costa et al. 2013).

Farmers grow a wide range of crops in order to spread the risk of crop failure. The most frequently grown crops are maize (*Zea mays* L.) (99% of households), cassava (*Manihot esculenta* Crantz) (91%), sweetpotato (*Ipomoea batatas* (L.) Lamb.) (76%), rice (*Oryza sativa*) (31%) and peanut (*Arachis hypogaea*) (35%) (SoL 2014). Despite the spread of production risk, many rural households in Timor-Leste are subject to chronic seasonal food insecurity experiencing a hungry season prior to maize and rice harvests (da Costa et al. 2013). Part of the issue is the low productivity of crops: for example maize, the most important staple, had an average yield of 1.4 t/ha in Timor-Leste compared to the overall mean of 4.1 t/ha for South-East Asia in 2013 (FAO 2016). With this scope for increased production, agricultural research and extension are crucial for development. Following independence it was necessary to completely rebuild agriculture extension in Timor-Leste. From 2008 the Ministry of Agriculture and Fisheries (MAF) dramatically increased support to extension and there are now approximately 400 MAF village (*suco*) extension officers working to encourage farming communities to use improved agricultural techniques.

Information sources

A range of information sources—primarily surveys conducted by the SoL program—were used for this paper, as follows.

1. An early adoption survey of 90 households by SoL researchers conducted during May/June 2009 in the four districts where SoL implemented on-farm trials for the first time 3 years earlier (2005–06 season: Manufahi, Aileu, Liquiça, and Baucau) (Lacoste et al. 2012).
2. A market survey conducted at Bacau and Manufahi markets by SoL researchers with approximately 100 sellers each month from September 2009 to August 2010 (SoL 2010).
3. A baseline survey conducted in October 2011 of 1,511 households across 11 districts by the Direcção Nacional de Estatística (DNE, National Directorate of Statistics) (Jensen et al. 2014; SoL 2012).
4. A mid-term survey conducted during June–July 2013 by face-to-face interviews with 672 randomly selected households from 13 districts of Timor-Leste (SoL 2013).
5. An adoption survey conducted during August–September 2014 by face-to-face interviews with 702 randomly selected respondents from 13 districts of Timor-Leste (SoL 2014).

6. A survey on gender impact of the use of labour-saving devices in maize seed groups in 2015 with 50 men and 24 women members of commercial seed producers (CSPs) and community seed production groups (CSPGs) in eight districts (SoL 2015a).
7. SoL's monitoring and evaluation data 2011–15 documented in the gender assessment report (SoL 2015b).
8. A longitudinal survey on the profile of eight CSPGs (SoL 2016).

Gender roles in the crop production cycle

Like most South-East Asian countries, farm work responsibilities in Timor-Leste are generally split along gender lines (SoL 2015a, 2016). Almost half of the total work was performed by women members (including food preparation) which is different to Africa where men and women grow different crops, and to South Asia where women's role is confined to the postharvest phase. Women are more involved in the production of vegetables such as string beans, pigeonpeas and root crops such as peanuts, taro and sweetpotatoes (SoL 2016). In the majority of cases men and women work together to cultivate crops; they may perform different tasks, or they may share equally the same task (Table 1). Gender division of labour is the result of the physical nature of the task and its labour intensity, and rarely the result of the local belief system or custom. Women are involved in all activities of crop production but are particularly active in postharvest operations including crop processing, storage and seed selection.

Table 2. Gender balance in decision-making (SoL 2016).

	Men	Both	Women
Who decides which varieties to grow?	17%	69%	14%
Who selects seeds?	10%	61%	29%
Who decides when, where and at what price to sell the harvest?	22%	45%	33%

Regarding the choice of variety and seed for planting, the baseline survey conducted in 2011 and the recent study of eight CSPGs revealed that both men and women are active in corn variety and seed selection (SoL 2012, 2016). The most common situation is that men and women take decisions together (Table 2). This is similar to the situation observed in Thailand and the Philippines where the majority of agricultural decisions are made jointly, and unlike the situation in Indonesia and Myanmar where important decisions about agriculture are made by the community where women tend to have minimal influence.

Women tend to make decisions about selling crops because in Timor-Leste marketing is traditionally a woman's job (MDF 2014). Most sellers in the local markets are women. During 2009–10 a focus group discussion study was conducted in four communities in the districts of Manufahi, Baucau and Ainaro (SoL 2011). A major issue examined was the differences in the livelihood strategies adopted by communities in different ecological and geographical contexts with an emphasis on the different roles played by men and women in marketing and subsistence activity. The market component of the study showed that, as

Table 1. Crop production activities across gender in Timor-Leste and South-East Asian countries.

	Indonesia		Myanmar		Philippines		Thailand		Timor-Leste	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Land preparation		×		×	×			×	×	×
Crop establishment	×	×	×	×	×	×		×	×	×
Weeding	×	×	×	×	×		×		×	×
Harvesting	×		×	×	×			×	×	×
Preparing food for farm workers	×		×						×	
Postharvest activities	×				×	×			×	×

Source: Rutsaert et al. (2015) and SoL (2015a).

part of this strategy, women play a dominant role in selling farm surplus in the market. In Baucau, 99% of the sellers were women and 1% men, while in Manufahi 97% were women and 3% were men. The pattern from Baucau is presented in Figure 1. The predominant role of women in marketing is critical to understand and/or encourage a shift in agriculture from subsistence into income-generating farming.

Gender and varietal adoption

Varieties selected by SoL were released by the MAF starting in 2007. Adoption rates of these varieties have been monitored since 2011 in three household surveys, namely a baseline survey in 2011, a mid-term survey in 2013 and an adoption survey in 2014. Data collected on adoption in these three surveys were gender-disaggregated to determine whether male and female headed household presented different adoption rates.

Table 3 presents the adoption figures from 2011 to 2014. It is evident that the adoption rate has increased over time. In 2014, it is estimated that 32.5% of Timorese crop growers grew at least one of the 12 varieties released by MAF which is substantially higher than the adoption rate in 2011 (17.9%) and 2013 (24.6%).

No systematic trend appears in terms of the difference in adoption rate between male- and female-headed households. The baseline survey

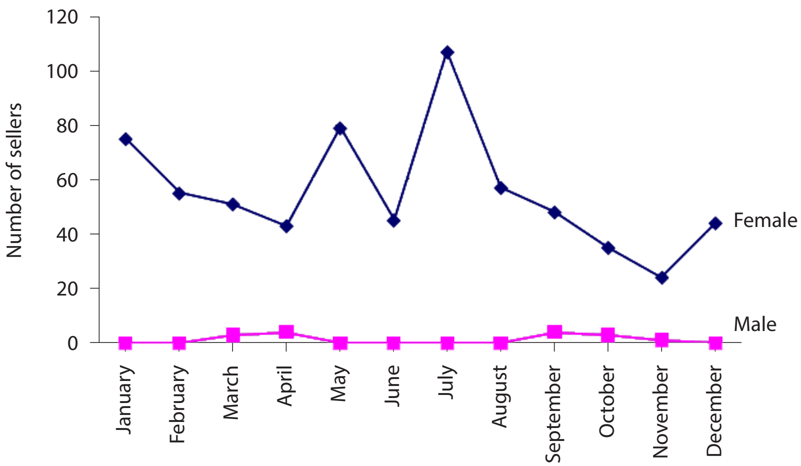

Figure 1. Gender disaggregation of food sellers in Baucau market (SoL 2011).

Table 3. Adoption rates of MAF varieties by gender (SoL 2014).

	No. of crop growers surveyed	MAF variety adopters (no.)	MAF variety adopters (%)	% male-headed household adopters	% female-headed household adopters
Adoption survey (2014)	702	228	32.5	31.8	37.4
Mid-term survey (2013)	672	165	24.6	25.4	14.3
Baseline survey (2011)	1,510	270	17.9	17.9	17.2

showed almost equal adoption rates by male- and female-headed households. In the mid-term survey, the adoption rate among female-headed households was substantially lower than male-headed households. Finally, the adoption survey showed a higher adoption rate among female-headed households relative to male-headed households. However, none of the differences in adoption rate between male- and female-headed households in the mid-term and adoption surveys were statistically significant, meaning that the difference is too small to actually conclude that male- or female-headed households are more or less likely to adopt the improved varieties. In other words, gender of the household head does not influence varietal adoption.

Gender and food security

The baseline, mid-term and adoption surveys showed 78%, 84% and 82% households experiencing hungry seasons, respectively. Note that the baseline survey measured hungry period within the past 4 weeks from the time of the survey as opposed to the occurrence of hungry periods in the past 1 year from the time of the survey in the mid-term and adoption surveys. The evidence supporting the relationship between gender and food security in these three surveys is mixed. The baseline and mid-term surveys consistently showed no significant difference in food security and gender of the household head (SoL 2012, 2013). In other words, both male- and female-headed households were equally likely to experience hungry periods. However, the adoption survey in 2014 showed that female-headed households were significantly more likely to experience a hungry season than the households that were headed by a male (SoL 2014). In 2014, 89% of the female-headed households experienced at least 1 month of food shortage against 79% of male-headed households ($chi^2 = 4.705$, $p < 0.05$). Given this mixed evidence it is not possible to draw any concrete conclusion about the food insecurity of female-headed households in Timor-Leste. It is plausible that female-headed households are becoming more vulnerable to food insecurity over time due to the prevailing inequality and gender-specific constraints. However more evidence, particularly longitudinal data, is needed to test the robustness of such a pattern.

Gender and group participation

Baseline survey data showed that on average, 23% of the households participated in one or more groups, but with a noticeable difference between the answers obtained from male respondents (27%) and from female respondents (17%) (SoL 2012). The highest percentage overall is for farmer groups or associations (54% of the households participated in such a group) but with a markedly higher participation by the households of male respondents (76%) than those of the female respondents (24%). Women's participation in agricultural groups improved slightly over time. In the mid-term survey 30% of the respondents mentioned being members of agricultural groups and 14% were members of seed production groups (SoL 2013). Among the households who were members of the seed groups, 65% of male respondents were members compared with 35% of female respondents. In the case of farmers' groups, 69% of male respondents were members compared with 31% of female respondents. The mid-term survey also asked if other household members held membership of different groups. The response to this question significantly boosted the percentage of women participating in agricultural groups (seed group: 84% men and 67% women; farmers' group: 87% men and 70% women) although it was still significantly lower than the percentage of the male membership.

SoL's monitoring and evaluation data tracked women's participation in contract, commercial and community seed production groups (SoL 2015b). During the 2014–15 cropping season, women comprised 34% of the contract seed growers, 31% of the members of the CSPGs and 36% of the members of the CSPs. Women's participation in seed production groups increased over time (2013–14 and 2014–15). Women's participation in CSPs increased from 31% to 36%. Although women's participation in CSPGs slightly decreased (from 32% to 31%), the number of women in the top three leadership positions in CSPs and CSPGs (i.e. chief, secretary and treasurer) rose considerably. Women's participation in contract seed production decreased from 38% to 34%. Of the 1,191 CSPGs that existed in late 2015, 78% were mixed groups and 21% were gender-restricted groups. Women-only groups accounted for 3% of the total, and 19% were men-only groups (SoL 2015b). The proportion of mixed group CSPGs declined from 85% to 78% and the proportion of men-only groups increased from 12% to 19%.

Gender and agricultural extension

Less than half of the respondents (43%) in the baseline survey mentioned that they knew the *suco* extension officer (SEO) (SoL 2012). This number increased significantly to 61% in the mid-term survey in 2013 (SoL 2013). The mid-term survey questionnaire also asked if another member in the family knew the SEO, which increased the proportion of households knowing their SEO to 66%. Although no significant difference in access to extension services was observed across male- and female-headed households, women members of the households had significantly lower access to extension services than men. In both baseline and mid-term surveys, two-thirds (67%) of the respondents who knew the SEO were men. One reason for this difference is the low rate of women's participation in agricultural groups (as described in the previous section). Agricultural extension activities in Timor-Leste are targeted primarily at farmer groups and not at farmers individually, and there are roughly 10 times as many male SEOs as female SEOs. In order to get access to free inputs (seed, tools, hand tractors), training, or visits by the extension worker, farmers had to belong to a group. In the mid-term survey data, a significant positive association was observed between membership of a farmers' group and access to extension service ($chi^2 = 38$, $p < 0.0001$). A majority (80%) of the farmer group members knew the local extension worker compared with 56% of non-members. Since women are significantly less likely to be members of farmers' groups, women were also less likely to have access to extension services.

Conclusions

The findings suggest that, as in other South-East Asian countries, women play important roles in crop production in Timor-Leste. Women contribute almost half of the total agricultural labour in Timor-Leste. Also consistent with the evidence from other South-East Asian counties, women in Timor-Leste are highly empowered in terms of decision-making in crop farming. Women have equal decision-making power when it comes to variety selection. Consequently, no significant difference was observed between male- and female-headed households in terms of adoption of improved varieties. Women have greater power in seed selection and the decision to sell agricultural produce than men. Evidence to support the relationship between gender and food insecurity was limited. One of the three large-scale representative household surveys showed female-headed households were more likely to experience food insecurity than male-headed households. A significant gender gap persists in terms of women's participation in agricultural groups and access to agricultural extension services. Women were less likely to be members of agricultural groups than men and thus women were excluded from extension services. This situation is similar to Indonesia and Myanmar where women play an active role in agriculture but agricultural groups and extension services are dominated by men.

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Planting the idea: a comparison of channels to communicate food security innovations to farmers in Timor-Leste

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Abstract

How can communication to diffuse new agricultural technologies be improved in the developing world? This article compares 20 communication channels used to raise awareness of new cultivars among farming households in Timor-Leste, a poor, food-insecure country. The channels were evaluated on value for money, reach, impact to change behaviour and overall effectiveness. Channels found to be highly effective in terms of reaching rural communities and raising awareness, and affordable, were a community magazine, cinema sponsorship and mass media. Interpersonal channels (village extension officers and word of mouth) are highly trusted and valued, rendering them influential. The advice is to use a diverse mix of channels focusing on interpersonal networks.

Introduction

Knowledge has become an increasingly significant 'factor of production' in the information-intensive agriculture sector, alongside land, labour and capital (Rao 2007). Kharninar (2003, in Abdon and Raab 2005) suggested that farmers need to know what to grow, when to grow, how to grow more, how to store and preserve their produce, when to sell, where to sell and at what price to sell. Access to agricultural information is critical for farmers to make appropriate decisions about inputs, market transactions, farm practices and postharvest operations (Rao 2007). Information is also critical to the uptake of new agricultural technologies in developing countries that can lead to higher productivity, economic growth and improved well-being for rural people (Agunga 2012; Molnar and Jolly 1988; Wossen et al. 2013). With no information exchange, innovation is unable to spread (Abdon and Raab 2005). Studies of technology diffusion in developing countries have found that communications help increase awareness and reduce risk aversion, thereby positively influencing adoption of new technologies (Das 2012; Jensen et al. 2014; Rogers 2003). Conversely, the absence of information results in farmers adhering to traditional systems of labour-intensive agriculture with poor yields (Ugwoke 2013). In developing countries this mostly affects poor, smallholder farmers and is attributed to low levels of literacy, little mass media consumption and rural isolation.

Reaching information-poor farmers requires special effort and targeting (Abbott and Yarbrough 1992). One of the challenges for development communicators is how to make available the required information/knowledge to those who most need it (Abdon and Raab 2005). Smallholder farmers typically access information through their own localised knowledge system, which is based on indigenous experience, knowledge and experimentation. This is

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supplemented with information and knowledge from diverse sources such as family, friends, neighbours, other farmers, extension agents, community organisations, private input suppliers and cooperatives. Together with information from mass media such as radio and TV broadcasts, these form the local knowledge system for decision-making that is accessible to a small farmer (Rao 2007).

Key to the effective delivery of agricultural information is the recognition of farming households' needs and an understanding of how best to provide them with information (Das 2012). Before adopting an innovation, farmers need information on a variety of topics at a variety of stages (Aker 2011). The subsequent impact of information depends on its quality and availability (Jensen et al. 2014). Ideas must be credible and the communication sources considered trustworthy by the farmer (Pontius 1983).

A system to communicate agricultural technology improvements to farmers has been slow to develop in Timor-Leste since it formed its first constitutional government in 2002. The agriculture sector—which is the largest contributor to non-oil GDP and provides employment for 84% of the labour force—is seen as key to decreasing poverty and boosting rural development (Inder et al. 2014). However, only 3% of the national government budget is invested in agriculture. A very small proportion of this has been made available for extension and communication. As a result, the formulation of a national communication system has been ad hoc and dependent on external funding from development projects funded by, for example, the United Nations through the Food and Agriculture Organization (FAO) and non-governmental organisations (NGOs). Communication within the private agriculture sector is typically limited to the distribution of labelled seed packets and agricultural chemicals.

Agriculture in Timor-Leste is mainly at a subsistence level and the country has some of the lowest yields in South-East Asia. The majority of farming households rely exclusively on low-input, low-output, traditional subsistence cropping systems (Lopes and Nesbitt 2012). Subsistence farmers are unable to produce enough staples (maize and/or rice) to last a whole year (WFP 2006). As part of its strategy to raise agricultural productivity, the Timor-Leste Government has ensured constant access to improved seed of staple food crops to farming households, a strategy which has successfully improved food security in other post-conflict countries (Borges et al. 2009; Lopes and Nesbitt, 2012). Since 2007 the Ministry of Agriculture and Fisheries (MAF) has released 12 varieties of staple food crops (maize, rice, peanut, sweetpotato and cassava) with 24–131% yield advantages compared to other varieties. The varieties are adapted to the soil and climate conditions, are in the public domain, have been rigorously tested, and can be saved by farmers for replanting. Agricultural communications took place to raise awareness of the new cultivars, reduce risk aversion and encourage adoption.

Numerous studies have evaluated the factors linked to adoption of the new cultivars in Timor-Leste (Jensen et al. 2014; SoL 2012, 2013b, 2014) but none has focused solely on the impact of communication. This paper evaluates the effectiveness of different, diverse communication channels to positively inform and influence farming households in Timor-Leste about the new cultivars and better farming practices. The aim of the study is to recommend the best channel mix for practitioners carrying out agricultural communications in Timor-Leste. These communication channels may be suitable for use in other developing countries.

Analysis of the target audience

Analysing the characteristics, attitudes and behaviour of the target farming household audience was the first step in approaching the communication of newly released varieties and other improved agricultural technologies.

Households and agricultural production system

Farming households, which represent over 60% of the total population or 130,000 households, are located in rural areas across all 13 districts (SoL 2013a). Households have an average of 6.8 members, and function as production units where all members participate in the work, though they have a senior person who is considered the head of the house (da Costa et al. 2013; SoL 2013a). Such households typically practise diversified small-scale production, with low productivity and insufficient food production to meet their basic needs (Inder et al. 2014). They follow traditional practices, are often unable to participate in markets, and suffer high postharvest losses (Inder et al. 2014).

Staple crops are maize, cassava, sweetpotato, rice and pumpkin, which are complemented with common bean, peanut and other traditional crops (SoL 2013b). Farming families minimise the risk of one or more of their crops failing by growing a wide range of crops, using intercropping practices and trialling new varieties in small plots first (da Costa et al. 2013; SoL 2013a). Farmers typically save and reuse their own seed, which is often also shared among family members and (less so) with neighbours (Jensen et al. 2014; SoL 2012, 2013b, 2014).

The key influence on adoption of a new cultivar is the grower having experience with that cultivar (Jensen et al. 2014). Other positive factors include knowing about a seed production group in their village, receiving seeds from an extension officer, participating in a seed production group, and knowing the extension officer (SoL 2013b).

Many farming households are members of farmer groups, though male participation is significantly higher than female participation (SoL 2013b). Women work alongside men in the fields, often weeding, watering and harvesting—and men support women's activities by preparing land for vegetable production and taking livestock to market to sell. Both men and women are involved in choosing which varieties to plant and seed selection (SoL 2012).

Literacy, language and information access

There are over 20 different languages in Timor-Leste. Despite Tetun being an official language, many farmers do not speak or understand it well (UNMIT 2011). Among the rural population 44.6% are literate in Tetun, 31.8% in Bahasa Indonesia, 18.3% in Portuguese and 7.6% in English (NSD 2011). The younger generation tends to be better educated than older family members, with literacy levels reaching 79% for one or more of the four languages (NSD 2011). Tetun is the preferred language for mass media, followed by Bahasa Indonesia, then Portuguese (UNMIT 2011).

Radio and television are the two information sources with the highest reach among farming households, which tend be low consumers of mass media overall (UNMIT 2011). From 2012, national electrification has serviced farmhouses with affordable power. However, the cost of purchase of radios and televisions remain a barrier to their widespread penetration. Farm households with larger fields (1.2 ha on average) are richer and have greater access to information than farmers with smaller fields (< 1 ha) (SoL 2013b). Sixteen per cent of the population do not access any mass media, relying heavily on traditional leaders and word-of-mouth (UNMIT 2011).

The most trusted source for information about government or NGO agricultural programmes is community leaders (38%), followed by national television (22%) and radio (11%) (UNMIT 2011). The mobile phone is the fastest growing communication tool in Timor-Leste, jumping from 5% penetration in 2006 to over 70% in 2014 (SoL 2014).

Summary of the analysis

Analysis of the target audience revealed:

1. It is possible to target various household members, including youth and school aged children;
2. Subsistence farmers' reliance on traditional practices and inherent risk aversion makes them cautious of adopting new technologies;
3. Social relationships and groups present a key opportunity to share information and influence adoption;
4. Low literacy and lack of fluency of Tetun can be a barrier to information access and comprehension;
5. Special targeting is required to reach the poorest and most isolated farming families;
6. Mass media channels have increasing reach, but interpersonal sources are still highly valued and influential.

Key elements of the communication strategy

The communications section of the Ministry of Agriculture and Fisheries (MAF) decided on three core elements for communication of the new varieties and better farming practices.

1. Repetition of simple messages

All communications were to consistently reinforce the correct variety names, benefits of the new varieties, good farming practices, and where to access the new varieties. Constant repetition was intended to slowly overcome any risk aversion and build awareness. Emphasis was on highly visual materials, simple language, and accurate reflection of gender roles.

Correct variety names and photographs

Communications contained both the variety names and photographs of the varieties—to overcome literacy issues and allow easy varietal identification.

Emphasis on benefits

High yield is valued but is not always top priority; therefore other benefits were also promoted, including root size, eating quality, speed to maturation, crop height, crop fragrance and grain colour (Borges et al. 2009; Lopes and Nesbitt 2012). It was also emphasised that farmers can use their current production methods to reproduce the varieties without any extra inputs or labour, and that income can be made from selling surplus produce in the market.

Good farming practices

These included simple, practical ways for farmers to improve crop productivity such as planting in rows, using two seeds per hole, fully drying grains after harvest, and using airtight storage such as metal silos. Inter-cropping with legumes such as velvet bean was promoted as a natural way to improve soil fertility.

Where/how to procure the new varieties

Farming families were advised to contact their local ministry office or village extension officer to access seed of the new varieties. Following the formation of many community seed production groups in 2014, communication materials also encouraged farmers to contact their local group or commercial seed producer.

2. Diverse mix of communication channels

It was decided to use a diverse range of channels as not all Timorese farmers have access to all information sources, nor do they learn equally through a given medium. Visual materials were chosen for simple messages, printed materials for more technical content, and audio communications to allow for interaction and storytelling. Inclusion of both one-way and two-way communications was intended to encourage both the comprehensive transfer of the message and to improve empowered decision-making. New channels such as mobile phone animations and community theatre were also trialled in response to greater phone penetration and the high value placed on interpersonal channels.

3. Adaptability

Underpinning the communication elements was the intention to adapt messages and the channel mix based on experience and feedback from farming households. This flexibility was further needed because of the rapid ongoing changes in Timor-Leste, as mobile phones, the internet and television became increasingly popular.

Limitations to communication

The paper authors acknowledge that the communication approach had a number of limitations.

- Large, undifferentiated target audience: MAF required an equitable dissemination in the promotion of new cultivars to all farmers nationally. Communications were therefore targeted at all 130,000 farming households, necessitating firstly an emphasis on value-for-money communications, and secondly standardised materials without differentiation based on age, gender or location.
- Language: All communications were written in 'Tetun Dili', despite many rural farmers not understanding it well. The funding required to translate materials into the more than 20 local languages and dialects was unavailable.
- Distribution of printed materials: Distributing printed materials to dispersed rural farming households in a mountainous country with often-poor road conditions was a major logistical problem. Emphasis was therefore placed on centralised distribution such as to farming groups and MAF district offices.
- Complications relating to the names of the cultivars: A factor impacting on the receptivity of communication messages was the inherent problems linked to the varieties and their names. For example, a number of the varieties use the generic name for the crop in a local language, such as *Utamua* (the name of a newly released peanut variety), which means 'peanut' in Makasae language, or *Ai-Luka* (the name of a newly released cassava variety), which means 'cassava' in Tetun Terik (used on the south coast).

Communication channels, data sources and analysis

The communication channels used to inform and influence farming households in Timor-Leste about the new cultivars and better farming practices are briefly described in Table 1.

The data used for this study are based on the communication team's collective experience of implementing communications on new cultivars of food crops in Timor-Leste using a wide range of channels from March 2013 to December 2014. Communication evaluation was primarily based on MAF staff feedback, ad hoc feedback from farmers, results from surveys conducted by the Seeds of Life (SoL) program, and other small-scale communication surveys.

Table 1. Communication channels used to inform and influence farming households in Timor-Leste about the new cultivars and better farming practices from March 2013 to December 2014.

Channel group	Type	Characteristics
Audiovisual	Animations (for mobile phones)	A 3-minute animation outlining good practices for growing and storing maize produced for free by students from Charles Sturt University, Australia. Designed for use on mobile phones, visually engaging, no voices used. Created as a trial to see how and if farmers would share the video and find it useful.
Interpersonal	Community theatre	45–60 minute shows using storytelling and participatory techniques to share good practices for planting maize. Performed in Tetun language in village markets in Aileu and Manatuto districts by locally hired actors from Theatre of Timor-Leste.
Interpersonal	Extension officers	Approx. 400 MAF extension officers gave advice and training to Timorese farmers across all districts about the new varieties and farming practices during visits to their fields.
Interpersonal	Word of mouth	An organic channel, whereby farming families shared agricultural information with relatives, neighbours and friends.
Mass media	Media publicity	Mentions of the varieties and MAF's activities in mass media including national television, radio and newspapers.
Mass media	Radio drama	Two series with 6 × 10-minute episodes based on interactions between parents and children of a Timorese farming family. The first focused on good planting practices for *Hohrae* sweetpotato varieties, and the second explained how to plant, weed, harvest and store *Sele* and *Noi Mutin* maize. Created by local production companies and broadcasted on community radio stations.
Mass media	Radio talk show	30-minute talk shows about the varieties broadcasted on community radio stations in all 13 districts, during which farmers could call in and have their questions answered by a MAF representative.
Mass media	TV broadcasts	Broadcasted approx. 20-minute films on national television during MAF's one-hour slot on Sunday afternoons. Films shown included one highlighting the role of women in agriculture and another promoting the varieties and ways families could access the seed.
Online	Social media	Involved the posting of photos, videos and interesting facts about the varieties and good practices to Facebook and Twitter.
Online	Website	A well-maintained website featuring comprehensive information on the varieties and other useful agricultural resources for free download—www.seedsoflifetimor.org
Print	Banners	60 large promotional banners (5 m × 1.5 m and 1.5 m × 1 m) featuring the names and photos of all varieties displayed across the main roads in all major towns and outside a number of MAF district offices.
Print	Booklets	Over 50,000 simple language, highly visual A5 booklets outlining good planting and storage practices for maize and sweetpotato varieties distributed to farming families, primarily through the International Fund for Agricultural Development (IFAD) maize storage drum project.
Print	Brochures	A small number of trifold A4 brochures for each variety, detailing the technical characteristics and benefits, given to farmers at MAF events.
Print	Lafaek magazine	A one-off opportunity to contribute two pages of free content to the November/December 2013 edition of CARE's Lafaek community magazine, distributed to 22,000 households in four districts (Bobonaro, Ermera, Liquica, and Covalima). Content included the names, photos and benefits of the varieties, along with a farmer success story.
Print	Posters	Over 1,000 A1 posters given to community seed production groups listing the crop varieties they grew, for display in front of their field.
Print	Seed labels	Labels used to brand 1 kg and 5 kg packets of *Sele* and *Noi Mutin* maize and *Nakroma* rice included short tips on planting and storing seed. Such seed packets were distributed to thousands of Timorese farming families.
Print	Wall calendars	10,000 A2-sized wall calendars including photos, names and benefits of the varieties were distributed to seed groups and MAF district offices annually.
Promotional item	Fans	500 branded leaf-shaped fans were distributed to farming families on an ad hoc basis as a thank-you for participating in an interview or other activities.
Promotional item	Pens	500 branded pens were distributed to farming families on an ad hoc basis as a thank-you for participating in an interview or other activities.
Sponsorship	Cinema Lorosa'e	One-year sponsorship of local NGO Cinema Lorosa'e enabled the screening of a 20-minute agricultural video about the varieties at their free movie nights held in villages across all districts.

Data on each of the 20 channels are of two types: (1) assessment of key positive and negative features; and (2) evaluation based on consensus scores for three criteria. Given the difficulty of systematic data collection in a post-conflict environment such as Timor-Leste, the authors decided that a consensus approach to evaluation was the most appropriate. Evaluation was on a 1–5 score for the following three attributes:

- Value for money—is it affordable either as a one-off activity or on an on-going basis? (1 = poor, 5 = good);
- Reach—does it reach a large number of rural farming families? (1 = few, 5 = many);
- Impact—does it have a positive influence on recall of the variety names, adoption of the new cultivars or use of better agricultural practices? (1 = low, 5 = high).

Channel effectiveness was the average of these three attributes, both for individual channels and media channel clusters.

For statistical analysis a one-way ANOVA of effectiveness was conducted on the basis of media clusters. Additionally, an ANOVA of effectiveness was done on the basis of channel type across component attributes. Pearson correlation coefficients were computed among attributes.

The authors acknowledge that the evaluation scores are subjective and variable. Over time various channels will become more or less effective as the country develops, new technologies become available, and communication activities fluctuate in price. Therefore these scores relate specifically to the implementing period (March 2013 to December 2014).

Results

The results are summarised in Tables 2 and 3. Table 2 identifies the key positive and negative features of the various communication channels, while Table 3 shows a comparison of channel effectiveness on the basis of value for money, reach and impact.

In Timor-Leste, the effectiveness of each communication channel depends on a combination of factors: cost, the number of people reached, and strength of people's engagement with the channel. The 20 channels used in the communication strategy were observed to vary significantly in their overall effectiveness (Table 3).

Table 2. Assessment of the key positive and negative features of the communication channels used to inform and influence farming households in Timor-Leste.

Channel cluster	Type	Positives	Negatives
Audiovisual	Animation (mobile phones)	Simple and engaging Images and limited text suited to low-literacy viewers Farmers can replay providing potential for strong impact	Many farmers do not have smart phones New channel so extension officers need to be trained and encouraged to share
Interpersonal	Community theatre	Unique, engaging channel 'Playback' form of theatre encourages active audience participation	Significant planning required Information recall not strong after seeing one show Expensive
Interpersonal	Extension officers	Highly trusted source of information so high impact Good channel for technical information No direct cost, as extension officers are MAF employees Collective reach is high	Need to provide information, resources and ongoing support Officers work with many NGOs, sometimes with conflicting messages Individual reach not extensive
Interpersonal	Word of mouth	Highly valued and trusted information source Strong group culture among farmers—great network for information sharing	Hard to influence and monitor

(continued…)

Table 2 (cont'd). Assessment of the key positive and negative features of the communication channels used to inform and influence farming households in Timor-Leste.

Channel cluster	Type	Positives	Negatives
Mass media	Media publicity	Extensive reach (but mostly well-off people) Generally good recall so significant impact	Limited reach in rural communities Journalists typically focused on stories involving ministers Limited influence over content Content sometimes biased or inaccurate
Mass media	Radio drama	Storytelling is an engaging tool Good reach as radio has high penetration Due to lack of content, stations often repeat broadcasts of dramas	Hard to monitor audience size and impact
Mass media	Radio talk show	Encourages two-way communication Good reach as radio has high penetration	Hard to monitor audience size and impact
Mass media	TV broadcasts	Good reach High impact	Can be expensive Television access limited in rural areas (but growing)
Online	Social media (Facebook, Twitter)	Free Enables two-way dialogue, good potential impact Popular among youth	Farmers have limited access to internet and data costs prohibitive Farmers do not use social media to engage with NGOs
Online	Website	Affordable and effective way to share information with stakeholders	Farmers have limited access to internet and data costs prohibitive Farmers do not use NGO websites as an information source Literacy barrier
Print	Banners	Cheap and quick to print Easy to produce	Limited reach Low impact
Print	Booklets	Cheap and quick to print Suited to more detailed information	Literacy barrier Can be difficult to distribute, limits reach
Print	Brochures	Cheap to print Easy to produce	Technical content of limited use to farmers Literacy barrier Farmers unlikely to store so limited impact
Print	Lafaek magazine	Existing publication, well regarded High impact Good reach—22,000 magazines distributed in four districts, three times a year Widely read and shared	Messages sometimes lost among diverse magazine content
Print	Posters	Cheap to print Easy to produce, durable Suited for sharing information with groups	Not suitable for individual farmers due to cost
Print	Seed labels	Used on all improved variety seed packs, therefore large reach	Low impact as farmers receive only once a year
Print	Wall calendars	Affordable to print High impact as farmers keep on display for at least a year	Difficult to distribute to farmers
Promotional items	Branded merchandise	Useful as giveaways to thank farmers for assisting with project activities Items generally well appreciated Suitable for distribution at events	Limited reach Can be costly based on per unit price Some items such as pens have limited space for messages
Sponsorship	Cinema Lorosa'e	Build on existing and well-aligned activities to promote project messages Few resources required to manage Extensive reach	Need to ensure monitoring occurs and feedback is given

Table 3. Comparison of the channels and media clusters on the basis of value for money, reach, impact and their effectiveness (mean of value for money, reach and impact).

Channel cluster	Type	Value for money (1 = poor, 5 = good)	Reach (1 = few, 5 = many)	Impact (1 = low, 5 = high)	Effectiveness of individual channels (1 = worst, 5 = best)	Effectiveness of media clusters (1 = worst, 5 = best)
Audiovisual	Animations (mobile phones)	5	1	3	3.0 bcd	3.0 ± 0.72
Interpersonal	Community theatre	2	1	2	1.7 e	3.2 ± 0.42
Interpersonal	Village extension officers	5	3	5	4.3 ab	
Interpersonal	Word of mouth	5	2	4	3.7 abcd	
Mass media	Media publicity	5	3	4	4.0 abc	3.8 ± 0.36
Mass media	Radio drama	4	4	3	3.7 abcd	
Mass media	Radio talk show	4	4	3	3.7 abcd	
Mass media	TV broadcasts	4	4	3	3.7 abcd	
Online	Social media	5	1	1	2.3 de	2.2 ± 0.51
Online	Website	4	1	1	2.0 e	
Print	Banners	4	1	2	2.3 de	3.0 ± 0.27
Print	Booklets	4	3	2	3.0 bc	
Print	Brochures	3	1	1	1.7 e	
Print	Lafaek magazine	5	5	4	4.7 a	
Print	Posters	4	3	3	3.3 abc	
Print	Seed labels	3	4	1	2.7 c	
Print	Wall calendars	3	3	4	3.3 abc	
Promotional item	Fans	1	1	1	1.0 e	1.0 ± 0.51
Promotional item	Pens	1	1	1	1.0 e	
Sponsorship	Cinema Lorosa'e	5	4	3	4.0 abc	4.0 ± 0.72
LSD (5%)					1.54	

Note: The same letters following effectiveness means indicate the means are not significantly different at 5% by least significant difference. Standard errors of means are indicated for cluster means. LSD = least standard deviation.

Considering value for money, the majority of channels were affordable when considered on a per-household cost, with the mobile phone animation, extension officers, word of mouth, media publicity, social media, Lafaek magazine and Cinema Lorosa'e found to be most affordable (all scored 5 out of 5) (Table 3). The least cost-effective channels were promotional items and community theatre.

In terms of reach, Lafaek magazine (5), radio dramas and talk shows (4), TV broadcasts (4), seed labels (4) and Cinema Lorosa'e (4) scored highest. Channels with poor reach among farming families were the mobile phone animation, community theatre, online channels, banners, brochures and promotional items.

Regarding impact (creating behaviour change), interpersonal sources, particularly extension officers (5) and word of mouth (4), were highly influential along with printed communications Lafaek magazine (4) and wall calendars (4). The poorest performing channels for impact were social media, website, brochures, seed labels and promotional merchandise. Impact scores were significantly correlated with those for both reach ($r = 0.547$, $P < 0.05$) and value for money ($r = 0.586$, $P < 0.01$).

For overall effectiveness, individual channel types are considered first. Lafaek magazine scored highest (4.7), followed by extension officers (4.3), media publicity (4.0) and Cinema Lorosa'e (4.0). The least effective channels were promotional items (pens and fans), brochures, community theatre, website and social media—the same channels that scored low on impact.

When the individual communication types were grouped by media channel cluster and their effectiveness scores averaged, sponsorship of Cinema Lorosa'e (4.0) and mass media (3.8) rated highest. The lowest performers were promotional items and online channels.

Discussion

A wide range of communication channels are available to transmit messages concerning new agricultural technologies. In the current digital era the options list is growing. This study compared 20 communication channels for effectiveness in diffusing information on new cultivars and farming practices in Timor-Leste.

Winners

Lafaek magazine

Promoting agricultural messages in the Lafaek community magazine, which is produced by the international NGO CARE, is highly effective. The full-colour, highly visual magazine is widely read by rural households and valued for its practical content. Many households keep and reread the magazines. Each edition is pretested with audiences before printing, to ensure the content is suited to low-literacy audiences and easy to comprehend. Since mid-2014 the number of annual editions of Lafaek magazine has been reduced from six to three, but distribution has expanded to 80,000 households in all 13 districts. Government organisations and NGOs can now contribute content for a sponsorship fee, meaning message recall can be enhanced by supplying regular content in each edition. The immense reach and low cost per household make this a very important and effective channel.

Cinema Lorosa'e

Partnering with Cinema Lorosa'e, a local NGO has effectively and efficiently run district film nights for the past four years, providing an affordable and sustainable communication channel. Key to its success is the shared objective and target audience between the organisations—to provide entertainment and useful information to farming families in rural communities. The screenings have an average of 450 attendees, demonstrating how much these events are valued, reinforced by attendee surveys showing that most people learned something new from the agricultural films. Well-aligned sponsorships like this should be continued to share key messages and as a distribution channel for audiovisual and printed materials. Sponsorships should be trialled on a one-year basis, and then turned into multi-year contracts if they prove to be successful.

Village extension officers

Extension officers are a powerful information source, enabling two-way information flow between researchers and farmers (Akpalu 2013) and overcoming information asymmetries experienced by poor farmers (Aker 2011). In the Timorese context, regular support from an extension officer is highly valued and trusted, and sometimes the only source of information for rural farmers. Studies show that extension officers are the primary way farmers learn about new varieties (SoL 2013b, 2014). This mirrors findings from research in Bangladesh, Ethiopia and South Africa that contact with agricultural extension services significantly increases awareness and adoption of new technologies (Akpalu 2013; Rahman 2003; Wossen et al. 2013). However, the young extension system in Timor-Leste suffers from problems relating to transport, scale, sustainability and levels of training and discipline. Supporting the development of this rapidly evolving system is crucial to the future effectiveness of this communication channel (Kelly 2013; Noltze et al. 2012).

A key strategy should be encouraging extension officers to regularly visit and provide technical training to the existing 1,000-plus seed production groups with over 12,000 members. These groups exist primarily to meet members' needs and to share new seed varieties in their community (Lopes et al. 2015). Research shows the most successful groups valued collective over individual action, held regular meetings to share knowledge, and used an inclusive decision-making process (Lopes et al. 2015). Therefore targeting such groups, with their existing information networks and strong social relationships, is a cost-effective way to widely share information and diffuse new technologies. Further, training extension agents in persuasive communication skills and community empowerment can help them build groups' skills in making consultative decisions, which is shown to improve group performance (Lopes et al. 2015). Extension officers must also continue focusing on reaching the resource-poor and women farmers to ensure equal access, and should use electronic sources of information such as TV and radio to strengthen information sharing.

Mass media—publicity, radio dramas and talk shows, TV films

Research in developing countries shows that mass media is a fast and efficient way of disseminating information about a new innovation, and is found to positively influence knowledge development, attitude formation and technology adoption (Gluesing 2012; Rahman and Mikuni 1999). Likewise, all mass media channels used in Timor-Leste—publicity, radio dramas and talk shows, and films on television—are found to be effective because of their extensive reach among farming families and being highly trusted. Media publicity proves to be very influential in raising awareness, as studies show this is a crucial way that families learn of the varieties and are able to recall their names (SoL 2013b, 2014). Given that news and current affairs are the most popular content on both radio and TV (UNMIT 2011), efforts should be made to strengthen relationships with journalists and media outlets to positively encourage regular and accurate reporting.

Community radio stations in Timor-Leste have excellent penetration in rural areas but are typically content-poor. Stations will often repeat content despite being paid to broadcast it only once. Communicators are advised to take advantage of this by creating radio plays and other resources featuring simple messages. Similarly, talk shows are highly valued as farmers can get immediate answers and access to ministry representatives. Community stations should be encouraged to foster closer links with MAF district staff and be paid to broadcast regular talk shows centred on new technologies.

The rapidly increasing reach of television across Timor-Leste (UNMIT 2011) suggests it will continue to be an influential channel in the long term. Resources should be created for broadcast on national television, though content must be crafted for rural audiences and feature real-life success stories. Inclusion of opinion leaders such as priests, chiefs, teachers and other respected individuals should be trialled as a way to increase engagement and recall of agricultural messages. A smallholder farm makeover reality TV program, which has proven highly popular in Kenya (CCAFS 2015), could also be piloted as an engaging and efficient way to reach many farmers.

Word of mouth

Studies repeatedly show that in regards to diffusion of agricultural innovations, interpersonal channels are highly influential in less developed nations (Akpomuvie 2010; Das 2012; Egbula 2010; Rogers 2003). At the persuasion stage, farmers are likely to look to family, friends and neighbours to assess the benefits of innovations (Gluesing 2012; Wossen et al. 2013). In Timor-Leste, studies show that having a relationship to a grower of an improved variety and knowing about a seed production group in their village are key factors in adoption (SoL 2013b, 2014; Jensen et al. 2014). In this post-conflict environment, word-of-mouth communications remain highly valued and community leaders are the most accessible and trusted sources (UNMIT 2011). However, this channel is hard to control and influence, and research shows farmers often do not share the name of varieties with others (SoL 2013b, 2014). Therefore communicators need to consider ways to better understand diffusion of new technologies through these powerful social networks.

Losers

Promotional items

Promotional items such as fans and pens are not an effective way for communicating with farmers. They are expensive to produce, have limited reach and include few messages, if any. When distributed to farmers as a thank you for being interviewed for a case study or photographed for a website story, the items were appreciated; though in no way did they increase awareness of the varieties or encourage improved farming practices. Therefore branded merchandise is better used as giveaways at events and targeted to other stakeholders. Suggestions for merchandise items suited to Timorese farming families include locally produced calico bags, wide-brimmed hats, and soccer balls for children.

Printed materials—banners, booklets, brochures and seed labels

Issues of reach, literacy, distribution and storage limit the effectiveness of printed materials. Banners are typically seen by few people, booklets are difficult to distribute in large quantities to individual households, brochures often have too-technical content, and seed labels are viewed once only before being discarded. In comparison, other printed materials such as wall calendars and posters are more effective because they are displayed prominently for long periods of time, are highly visual, and can be distributed more easily through farming groups. This shows that printed materials have a definite role to play in disseminating agricultural messages, though content must be highly visual with simple language and consideration given to affordable methods of distribution. In addition, materials that are read multiple times and retained for future reference can prove to be effective.

Community theatre

Community theatre is a form of traditional media that remains important for its effective interpersonal nature, particularly in low-income and low-literacy countries (Akpomuvie 2010; McGillion and McKinnon 2014). Surveys of theatre attendees in Timor-Leste show that theatre performances are a highly valued way to receive agricultural information (McGillion and McKinnon 2014). However, there was no evidence of long-term recall of what they had learned. Further, the minimal reach of each performance, high running costs and logistical challenges make this an expensive and inefficient way to share messages about the new varieties. The sustainability of this channel could be improved through the training of district-based theatre troupes and better promotion of the performances, however other channels are still likely to be more influential and cost-effective.

Mobile phone animation

The trial mobile phone animation showing good practices for growing and storing maize failed to yield significant results. Anecdotal feedback from MAF staff indicated diffusion of the video from MAF staff to farmers has been slow, if any sharing occurred at all. Until more farmers own video-capable phones, become familiar with using such materials as a source for agricultural information, and are more inclined to share videos, this remains an inefficient channel. Findings from a Mercy Corps' project came to the same conclusion—that using mobile videos to share farming practices in Timor-Leste is not financially sustainable at the moment (Mercy Corps 2015). Learnings highlight that videos should be short, self-contained and small in file size, with content localised to maximise learning and knowledge retention. Building a better monitoring system to track use and impact is key, along with encouraging MAF staff to use mobile phone videos as an extension tool.

Looking ahead

Online

This study found that farmers in Timor-Leste are yet to use online sources such as websites and social media to access agricultural information. Data costs remain prohibitive despite three telecommunication providers now operating, and many farmers cannot access computing facilities nor do they have the technical know-how. Regardless, this channel is likely to become increasingly popular in the face of ever-improving phone reception, phone handsets becoming more affordable, a jump in internet use among youth, and more NGOs incorporating online activities into their projects. Similarly, research by Akpomuvie (2010) shows the global spread of internet access is bringing new information resources and creating new communication channels for rural communities. It is fast, allows interaction and is independent of time and geography (Abdon and Raab 2005). However, Abdon and Raab (2005) emphasised that the absence of bare essentials—literacy, social and physical capital, electricity and physical infrastructure—in poor areas is a significant obstacle in using information and communications technology to serve smallholder agriculture. Communicators must consider ways to encourage widespread use to ensure that farmers do not get left further behind. At a minimum, organisations should maintain a comprehensive website with downloadable resources, and a number of social media profiles to engage the youth audience. Training of extension staff to access such resources and use them as extension tools would further increase awareness and encourage uptake by the farming community.

Mobile communications

Despite the mobile phone animation having limited success, use of mobile phones as an information platform is likely to increase. A 2014 study of 702 Timorese people in 60 villages across 13 districts found that 78% of farmers sampled said they or another family member owned a mobile phone (SoL 2014). As phone ownership continues to increase and coverage rapidly improves, this channel will have greater potential as a powerful communication channel. Already, the rapid rise of mobile phone ownership in most developing countries has caused this channel to be harnessed for agricultural development (Aker 2011; Graham et al. 2011). It complements traditional media (Akpomuvie 2010) and can significantly reduce the cost of obtaining agricultural information (Aker 2011). A key use in Timor-Leste could be an SMS-based extension service to collect and share agricultural information with farmers, such as market information, weather updates and farming advice. However, communicators must remain conscious of the literacy and technological skills of users, and ensure more nuanced technical information continues to be shared through more appropriate sources. Further evaluation of this channel will be required to understand whether it is more effective and efficient than other channels, and its long-term financial sustainability.

Conclusion

Information is a significant production factor in the agriculture sector, and key to the uptake of new technologies that improve livelihoods in developing countries. Communicators are therefore challenged to find the most effective and efficient channels to reach smallholder farmers—typically information-poor, low-media-consuming and rurally isolated households. This paper shows that in Timor-Leste, the most effective channel clusters in raising awareness of new cultivars and farming practices are interpersonal and mass media sources. Word of mouth and social networks are highly valued in the post-conflict environment, and mass media has good reach nationally given the high penetration of radio and increasing penetration of television.

The best individual channels are the Lafaek community magazine, because it is widely read and well regarded; and extension officers, due to the high level of trust placed in them and their strong ability to influence adoption of new technologies. Mass media and sponsorship of Cinema Lorosa'e were also found to offer good value for money and positively increase awareness. The least effective channels were promotional merchandise, printed materials such as brochures and booklets, community theatre and the mobile phone animation. These channels tend to have low impact and reach, a high cost per person reached, and can face logistical or distribution challenges.

These findings indicate that communication objectives are best served by using a mix of channels that includes a strong focus on interpersonal networks. Communicators are advised to consider online and mobile phone communications as new ways to complement existing channels in the future.

A general recommendation for communicators in Timor-Leste is to conduct targeted research on media ownership and use. Up-to-date statistics in the face of the rapidly developing population would assist NGOs to better tailor their communication strategy for their audience, budget and program objectives. Social networks are hugely influential, so research is needed to understand how to best influence relationships to encourage greater word-of-mouth sharing and positively increase adoption.

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Training and capacity building in agriculture: potential contribution to food security in Timor-Leste

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Abstract

Timor-Leste's food security situation is precarious, as shown by its ranking at 74 out of the 76 countries included in the 2014 Global Hunger Index. While the country desperately needs to improve in a range of sectors, there are good reasons to believe that strengthening agriculture will have the biggest impact on food security. Experts agree that this will require widespread adoption of improved agricultural technologies but a major impediment to their spread is the absence of a cadre of competent agricultural professionals in research and extension. Agricultural education and training (AET) will be essential but the country's AET system is weak. In response, the development community is incorporating training activities in a range of current projects. To document the impact of such interventions the capacity-building program of one project within the Ministry of Agriculture—Seeds of Life (SoL)—is examined in detail. Results indicate that the majority of graduates of SoL training events benefitted personally, that their organisations/associations were subsequently better off, and that they considered the application of their knowledge and skills to be of great benefit to society and a factor in addressing Timor-Leste's food security situation. There was also general accord that these benefits would continue at least in the near future. Longer term impact was, however, less certain given that relatively little attention has been paid to building the country's indigenous agricultural training capacity.

Introduction

> Timor-Leste's food security situation is precarious. Food insecurity is common due to several factors including low crop yields, lack of income generating activities, limited purchasing power, drought, lack of infrastructure, and underdeveloped markets. Over one-third of the population regularly experiences food shortages.
> (WFP 2016)

Food insecurity arises from an interacting mix of agronomic, environmental, cultural and institutional factors, and a country's food security situation affects the well-being of its citizens in equally diverse ways. Timor-Leste is particularly vulnerable to these factors and is ranked at number 74 out of the 76 countries included in 2014 Global Hunger Index, ahead of only Eritrea and Burundi (von Grebmer et al. 2014).

Efforts are being made to develop various sectors, but there are good reasons to believe that strengthening agriculture will have the biggest impact on food security. As Lundahl and Sjöholm (2012) state, "In the short run, and until a modern sector begins to emerge, improvements in agriculture constitute the only way of improving livelihoods in Timor-Leste." Improved technology is accepted as an essential prerequisite of agricultural development, but identifying, creating and disseminating agricultural technology is dependent on educated and skilled professionals, managers and famers. This is where agricultural education and training (AET) can make a difference. AET directly raises agricultural productivity by developing producer capacities and indirectly increases agricultural productivity by generating

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human capital for support services. Investments in AET enable research, extension and commercial agriculture to generate higher payoffs (Hartl 2011).

The development community active in Timor-Leste is well aware of the importance of AET. The results of a survey of a representative group of 15 donor-funded development projects indicated that each included education and training as a central part of its strategy.

Is this capacity building effort justified? Does AET make a difference in improving Timor-Leste's food security situation? If so, can these benefits be sustained into the future when project support is no longer available? An attempt to answer these questions is made by taking an in-depth look at the accomplishments and results of one program within the nation's Ministry of Agriculture and Fisheries (MAF).

Food security in Timor-Leste

> Food security exists when all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.
>
> (FAO 2009)

The above definition of food security is the most widely accepted and was agreed upon as part of the Declaration of the 2009 World Summit on Food Security. The Declaration maintains that food security has four pillars: adequacy of food supplies (enough food on a consistent basis, either through local production or imports or food assistance from outside sources); availability of food (ability of households and individuals to acquire food); stability of food supplies (resilience of food supplies to external shocks, such as natural disasters); and utilisation of food at the household level, especially by those with low incomes (requiring that people are healthy enough to process the food internally, have adequate safe water and sanitation, and have basic food hygiene and childcare skills). The Commonwealth Scientific and Industrial Research Organisation (CSIRO), in a study of food security in the Pacific and East Timor, suggests that in the Pacific context, safe and nutritious food (food that is fresh or properly preserved and contributes to a healthy diet) is equally important and includes it as a fifth pillar of food security for the region (SPC 2011; Figure 1).

Upon examination, Timor-Leste fares poorly in terms of each of these areas. Net food production per capita is falling as is the annual growth rate of agriculture. Timor-Leste has the lowest national fish consumption among the Pacific countries partially due to the present small size of the Timorese fishing industry but ultimately because of environmental factors. Based on average maximum sustainable coral reef yields, there is virtually no scope for increased production where reef area, a maximum of 300 km^2, suggests maximum yields of 900 tonnes of fish per year or less than 1 kg per person per year (SPC 2011).

Timor-Leste's approach to addressing food security issues

> Reducing poverty and increasing agricultural production in order to ensure food security are essential for development in Timor-Leste.
>
> (da Costa et al. 2013)

Timor-Leste's government is working to improve the food security situation in two main ways. One is to support seasonal food imports which help to ensure there is adequate food during lean times and that it is affordable. The second response has been to invest in programs to increase national agricultural productivity (da Costa et al. 2013). Local production of sufficient quantities and quality of food helps to make sure that food supplies are adequate, available, stable, safe and nutritious (particularly if traditional crops are grown). National production greatly minimises reliance on volatile global markets.

But there are many obstacles to overcome for Timor-Leste to improve its agricultural productivity. A major problem is access to technology. Timmer (2005) points out that no country has successfully transformed its agricultural sector and established strong rural–urban links to economic growth without sharply improving the level of technology used on its farms. This is especially relevant to Timor-Leste where population growth makes it imperative for farmers to shift from traditional slash and burn to more settled agriculture. In order to make this shift in Timor-Leste a number of new technologies will be required (Molyneux et al. 2012).

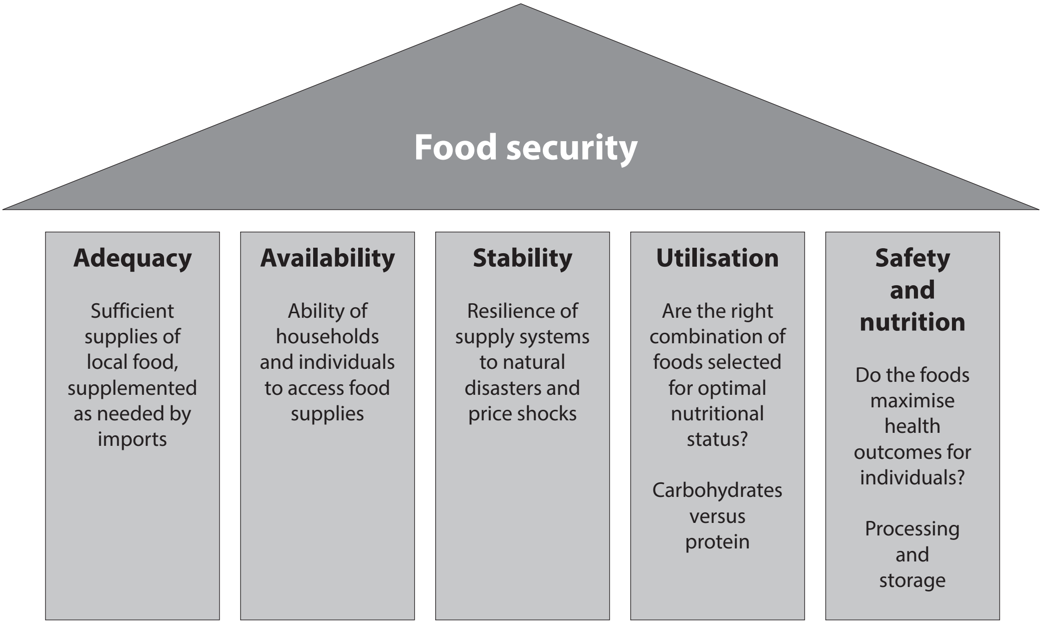

Figure 1. Food security for a country and its population depends on five pillars (SPC 2011).

Capacity constraints in agriculture

> Timor-Leste currently faces critical human resource constraints across most areas of our economy, as well as in government administration. The Timor-Leste Labour Force Survey 2010 shows low levels of education completion in all age groups. Of our population over 15 years old, 40% have not had any education at all and another quarter have not advanced beyond primary school level. This skills shortage will become more problematic as government programs expand in areas such as health, education, petroleum and agriculture, and private sector investment increases.
> (GoTL 2011)

Unfortunately there are relatively few affordable technologies available for improving productivity in Timor-Leste, but solid agricultural research and extension to find more successful agronomic techniques and seed and plant varieties, and to then disseminate them to the farming community, can make a difference (Lopes and Nesbitt 2012). While this may seem to be a straightforward solution, its realisation is constrained by a crippling lack of competent scientists, technicians and administrators. This situation is largely due to the country's long history of conflict and neglect. As noted by Gabrielson et al. (2010), "Timor has a plethora of essential needs that skilled scientists and engineers could help meet, if only the required competence existed."

This lack of capacity is obvious from an analysis of Timor-Leste's Ministry of Agriculture and Fisheries (MAF). As Wickramsinghe (2014) notes, capacity limitations make it difficult to determine who will address important constraints, and "There are serious concerns about the Ministry's ability to recruit and maintain the required quantity and quality of trained staff at all levels." Of the total 2,196 MAF employees, only 20% have an educational level above diploma, with most (56%) being secondary school graduates (Wickramsinghe 2014; Table 1).

Table 1. Educational profile of MAF personnel.

Educational level	No. of personnel	%
Primary	166	8
Pre-secondary	211	10
Secondary	1226	56
Diploma	163	7
Bachelor's	401	18
Post-graduate	29	1
Total	2,196	100

Academic qualifications are only part of the problem. There is also considerable concern that MAF staff do not possess the specific skills required to meet the ambitious goals outlined in national planning documents. Wickramsinghe's (2014) analysis of the human resources situation in MAF identified 14 areas with serious gaps in capacity and three critical areas without any expertise at all.

The need for training

> If you plan for a year, grow rice. If you plan for a decade, grow trees. But if you plan for a century, grow men.
> (Chinese Proverb)

It is clear that, if Timor-Leste's agricultural situation is to improve and benefit from technological advances, substantial investments are needed to upgrade the knowledge and skills of agricultural workers at all levels, and particularly within MAF. Traditionally, this role is performed by an AET system. AET covers a broad swath of mostly public sector education and training programs provided to those who work in and benefit from agriculture and rural development activities. It is an essential component for the preparation of skilled human resources for agriculture and rural development, and it is recognised that the AET system is the knowledge and skills backbone for scientific agriculture and commercial agricultural development (USAID undated).

Donors are aware of the limited human capacity in Timor-Leste's agricultural sector and a survey of a representative group of 15 development partners (DPs) indicated that each included capacity building as a major component of their efforts. Sixty-seven percent confirmed that building capacity within MAF was central to their approach and 80% conducted training for MAF extension agents. But support to other components of the AET system was much more limited. When asked to identify their main targets for capacity building, only 27% of DPs surveyed included capacity development of agricultural education institutions as a priority, and only one (Korea's KOICA) focused exclusively on this sector. A summary of DP capacity-building activities targeting MAF and agricultural education personnel is presented in Table 2.

Table 2. Numbers and percentages of development partners (DPs) targeting various levels and types of agricultural personnel in MAF and in agricultural education institutions (n = 15).

Target audience	MAF		Agricultural education	
	No. DPs	%	No. DPs	%
Senior officials	8	53	1	7
Municipal directors	5	33	0	0
Chiefs of departments	7	47	1	7
Researchers	3	20	0	0
Laboratory staff	2	13	1	7
Extension personnel	12	80	0	0
Support staff	1	7	0	0
Educators/trainers	1	7	3	20

From Table 2 it is clear that the primary target for the majority of these capacity-building efforts has been the MAF and this is to a large extent justified. There is widespread agreement that lack of institutional capacity across all of MAF's national and district directorates, and across all sub-sector disciplines, is the largest single constraint to sectoral development (Young 2014). But a potentially serious deficiency in this approach is that neglecting to concurrently build and strengthen the country's indigenous agricultural education system will prolong the country's inability to meet its future requirements for trained professionals in its own educational institutions.

AET in the Seeds of Life program

In order to better understand and appreciate the degree to which the training efforts of donor-funded agricultural projects can help to improve Timor-Leste's food security situation, the capacity-building program of one such project, Seeds of Life (SoL), is examined in detail.

SoL's goal is 'improved food security through increased productivity of major food crops' (SoL 2012). The program combines two synergistic components—relatively simple agricultural technology (identification, multiplication and dissemination of improved high-yielding varieties of maize, sweetpotato, rice, peanut, cassava and other crops), and AET. The technology is unquestionably beneficial.

To date, 12 varieties have been released that grown under normal farmers' practice are 25–130% higher yielding than local varieties of the same crops (SoL 2014).

Capacity building is central to SoL's approach. The objective of its capacity-building efforts is to strengthen and embed the skills, systems and institutional capacity required for the successful and sustainable operation of a national food-crop variety testing and seed management and distribution system within MAF (Abdon 2011). SoL had an active training program through both Phase 2 and Phase 3 (2005–16).

SoL's capacity-building achievements in numbers

SoL's capacity-building program focuses on four main target groups: staff of MAF, staff working in NGOs collaborating with SoL, national staff working directly for the project, and collaborating farmers and private seed producers. Preliminary analysis of SoL's training database indicates that, since 2006, the project provided 10,363 training opportunities to the various target groups with MAF staff the greatest beneficiaries (71%). The number of unique individuals participating was considerably lower (2,653) as most trainees attended multiple training events. On average, each SoL trainee took advantage of four training opportunities comprising some 13 days of training. Using unique individuals to look at numbers reached in each target audience group clearly shows that farmers comprised the largest group (55%) (Figures 2 and 3).

Of the 10,363 opportunities provided, 23% were taken advantage of by women trainees (29% if unique individuals are used) but there was wide variation in female participation depending on the target group. For example, among farmer collaborators women comprised almost 40% of those participating; while representation of women employed by MAF was much lower at 18% but close to the percentage of female employees in the ministry (20%). Female NGO and SoL staff trainee percentages were 20% and 36% respectively (Figure 4).

SoL provides training opportunities in a number of topics deemed to be essential for the efficient and effective functioning of a national seed program. The greatest numbers of training opportunities were provided in the area of seed production (Figure 5).

Impact

Numbers are one indicator of impact, but arguably more revealing are alumni views on the changes resulting from participation in training activities. In order to assess the effects of training, a number of interviews were carried out between 27 November and 17 December 2015. A total of 37 individuals representing all categories of SoL training alumni were interviewed in Dili as well as several districts throughout the country. Interview questions focused on four major areas:

- Impact on the individual;
- Impact on the interviewee's organisation/association;
- Impact on society;
- Sustainability of the training received.

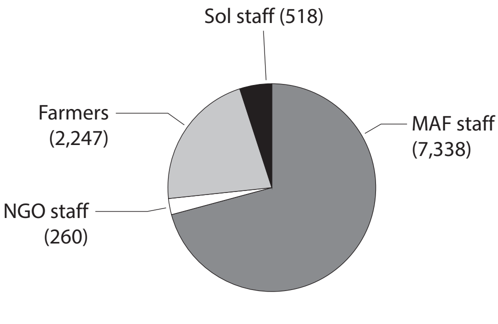

Figure 2. Number of SoL training oportunites offered to various target groups, 2006–15 (n = 10,363).

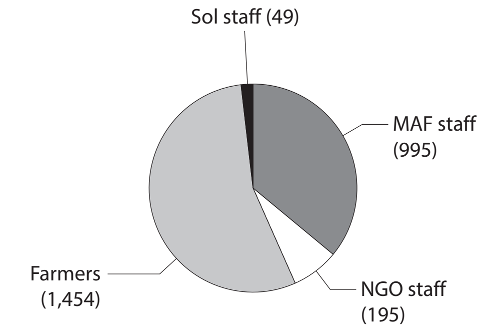

Figure 3. Numbers of unique individuals in each target group who participated in one or more SoL training events, 2006–15 (n=2,653).

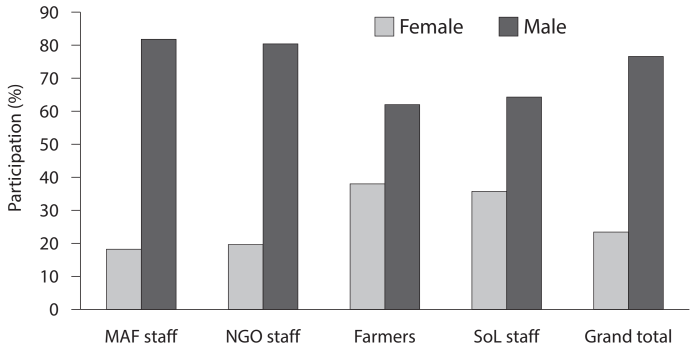

Figure 4. Male and female participation (%) in SoL training events by target group, 2006–15.

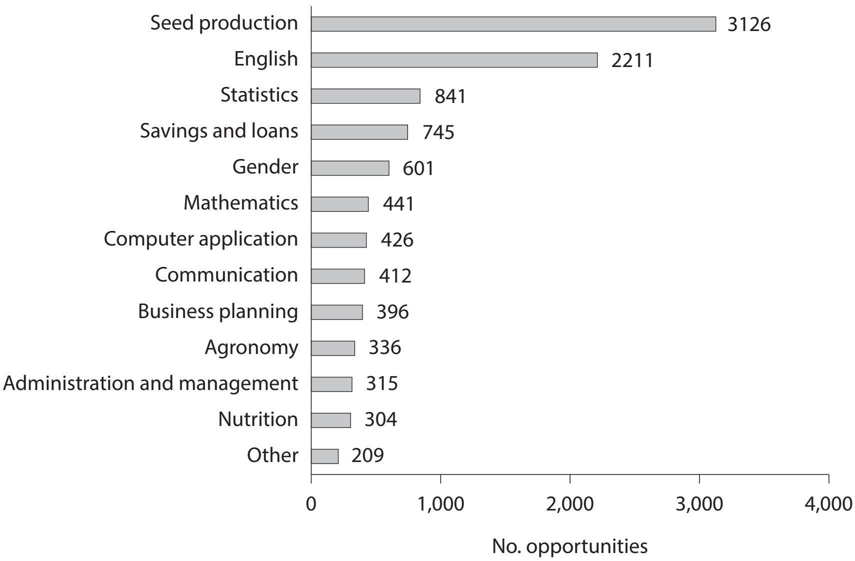

Figure 5. Training opportunities provided in various subject areas, 2006–15 (n = 10,363). 'Other' includes: soils, social science, information technology, and survey data collection and analysis.

Impact on individuals

Based on interview responses there was universal agreement among MAF staff and other professionals that SoL training had had a positive impact on them as individuals. Improved skills and competence were cited most often and benefits mentioned included a better understanding of agricultural research, higher motivation, better problem solving and more confidence in carrying out job-related tasks and in dealing with farmers. English training was greatly appreciated as it was felt to be a valuable asset in dealing with foreign colleagues and allowed access to international information. It opened opportunities for participation in international study tours and education. Collaborating farmer seed producers indicated that their knowledge and skills had improved particularly in regards to seed production and their abilities to manage associations and savings and loans operations.

Impact on organisations/associations

These individual benefits were reflected in interviewees' opinions concerning the positive effects of training on organisational or association performance. Many professionals highlighted that training had helped them to form more productive relationships with peers and colleagues, and that it resulted in better communication and more authority in dealing with farmers while running training activities or organising on-farm demonstrations. Attendance at SoL-sponsored conferences, workshops and meetings was perceived as an extremely valuable networking mechanism resulting in improved collaboration and less duplication of effort. Senior management was particularly appreciative of these types of opportunities and felt that collaborative planning with other directors resulted in tremendous improvements in annual district-level work plans. Farmers indicated that the technical and management skills acquired through SoL training had resulted in increased efficiency in their seed production operations, and that the savings and loans plus training associated with it improved their livelihoods. Training on financial management also assisted many commercial seed producers (CSPs). They maintained that they were increasingly able to independently manage their operations, collaboratively plan for the future, and resolve problems arising in their groups.

Societal impacts

Interviewees also felt that the application of their increased skills and competencies was having a number of positive impacts on national agricultural development and food security. Professional alumni cited their role introducing new production techniques to farmers, such as promoting conservation agriculture and improved seed storage practices. Success in these activities was largely attributed to more effective farmer field days and better communication with farmers. The release of 12 official varieties was seen as a major accomplishment in which they felt themselves to be key players.

Collaborating farmers were overwhelmingly adopting SoL varieties and production practices (row seeding, weeding timing, irrigation) in their production plots and were pleased both with the improved yields of their crops and the quality of the produce. Farmers in the community were showing increasing interest in learning more about their techniques. Their savings and loans operations were seen as central to future financial success and as a way to infuse much needed capital into their groups and the community at large.

Sustainability issues

Responses to questions about the ability of alumni to continue to apply their skills and knowledge in the future revealed varying degrees of concern. Almost all professionals interviewed had serious reservations about the capacity of the government to support those staff involved in managing the national seed system. Most were concerned that finance will be a problem, both in terms of absolute amount as well as in timeliness of budget allocations. There was also fear that skill levels would deteriorate over time as there was general consensus that MAF's commitment to training and professional development of staff was doubtful.

Collaborating farmers, on the other hand, were generally optimistic about the future and committed to maintaining their group activities. Most were confident that their seed operations would continue to provide revenue and that MAF would continue to contract seed production. Some were actively exploring other customers including farmers in the community, NGOs and development projects. The savings and loans operations are obviously valuable income-generating mechanisms and most associations proudly revealed their positive balances, ranging from $1,200 to $6,000, and being used by members to improve their livelihoods. It appears that strong, well-managed CSPs have considerable potential to survive and thrive.

Summary and conclusions

A close look at SoL indicates that a focused long-term capacity building effort coupled with simple appropriate technology can make a difference in Timor-Leste. Interviews with SoL training alumni, both professionals and farmers, indicated that they had benefitted personally, that they had been able to apply their knowledge and skills to improve their organisations/associations, and they felt that society was benefiting from their expertise. Professionals acknowledged that they had gained important skills in agricultural research and outreach. Most farmer alumni felt that they had acquired the skills to allow them to profitably maintain and even grow their associations.

All the evidence collected indicates that training and educational opportunities being provided by SoL and other DPs will have a positive impact on agricultural development in Timor-Leste at least in the short and medium term. Long-term impact is, however, less certain. Without further capacity building in the national agricultural education system, progress on achieving and maintaining food security in the long term may be jeopardised. Taking the long-term view, there is clearly a need to strengthen Timor-Leste's AET system to ensure a sustainable supply of capable individuals in national institutions.

The Government of Timor-Leste is clearly committed to strengthening the country's educational system—including primary, secondary, higher, recurrent and technical and vocational (GoTL 2011)—and DPs can play a key role in helping the country achieve this goal. One way would be for them to support and cultivate stronger linkages with national formal and non-formal educational institutions, with the goal of building a 'pipeline' of newly trained staff to replace those retiring or moving to other positions outside MAF. Development projects could also do much to address some of the more serious constraints of these institutions (curriculum quality, text and reference availability, facilities, lab and practical opportunities). Training opportunities provided by DPs should explicitly be made available to staff of faculties of agriculture and other agricultural instructors who are directly responsible for preparing the next generations of agricultural scientists, technicians and administrators. It is not difficult to appreciate the potential benefits of investing in the education of a teacher who will train hundreds of students over their professional lifetime.

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