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Holistic Agriculture, Food and Nutrition Interventions for Timor-Leste

A cost-benefit analysis of prioritized interventions

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Holistic Agriculture, Food and Nutrition Interventions for Timor-Leste

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Foreword

H.E. Mariano "Assanami" Sabino
Vice Prime Minister, Minister Coordinator of Social Affairs
and Minister of Rural Development and Community Habitation

As Timor-Leste advances toward the Second World Summit on Social Development in Doha in 2025, we find ourselves at a defining moment. The challenges of Hunger and Malnutrition remain deeply intertwined with poverty, vulnerability, and fragile systems. However, as this study shows, these challenges also present us with an opportunity for bold, transformative action.

This Return on Investment analysis demonstrates that targeted investments in food security and nutrition deliver powerful economic and social returns. Every dollar invested in the recommended package of interventions yields an estimated return of $3.50, with total net benefits of nearly $770 million over the next decade. These are not abstract numbers, they represent more food on the table, healthier children, stronger farming families, and a more resilient Timor-Leste.

The interventions identified are not isolated measures. They are a holistic package that strengthens agriculture, boosts production, enhances nutrition, and builds human capital. From expanding research and development and improving seed systems to rice fortification, nutrition services, and school meals, these actions are mutually reinforcing and system wide. Together, they can reduce child mortality by 15%, cut stunting by 12%, and lift tens of thousands of families out of food insecurity.

This study reaffirms what our Government has long recognized, nutrition-sensitive social protection is not only a humanitarian imperative, it is an investment in resilience, human capital, and national development. Initiatives such as *Bolsa da Mãe Kondisionál SANUTRIO* (Saúde Nutrisaun Inan Oan) and the Home-Grown School Meals programme are practical examples of how Timor-Leste is linking social protection, food security, and inclusive growth. By sourcing food locally and connecting farmers to schools and markets, we are strengthening rural livelihoods and building national ownership.

As Vice Prime Minister, I am proud that this report has been developed in close partnership with the World Food Programme, underlining our shared commitment to evidence-based policy making. Its findings provide a strong foundation to scale up interventions, mobilise resources, and align national and international investments with our long-term strategies, including the National Strategy for Social Protection (2021-2030) and the National Multisectoral Nutrition Action Plan (2024-2030).

The message is clear, to achieve our national vision and the Sustainable Development Goals, primarily SDG 2 (Zero Hunger) and SDG 1 (No Poverty), we must act decisively and collectively. This study gives us the evidence and the roadmap to do so.

Let us seize this moment, working hand in hand with our partners, to transform nutrition and social protection into engines of peace, stability, and sustainable development for Timor-Leste and beyond.

Mariano Assanami Sabino
Vice Prime Minister, Minister Coordinator of Social Affairs
and Minister of Rural Development and Community Habitation

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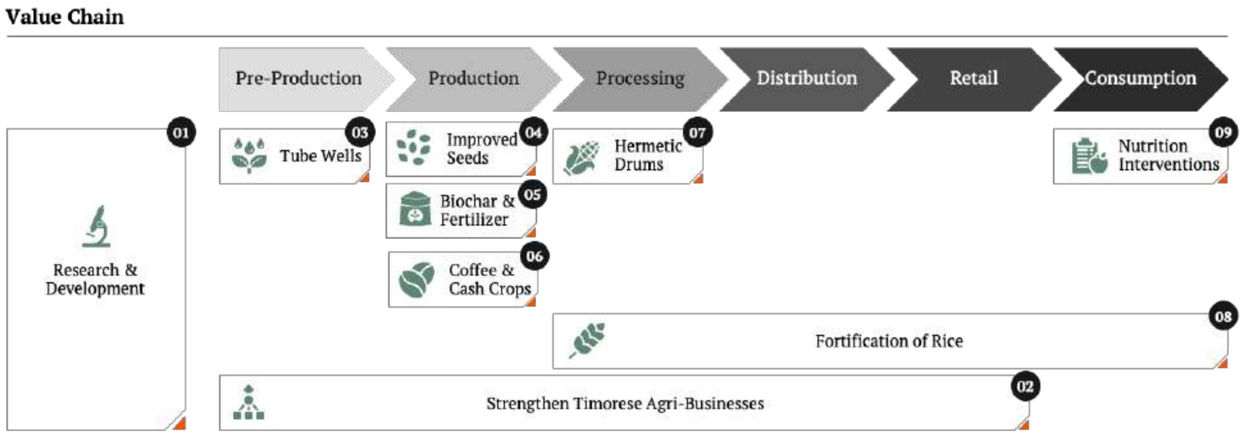
Executive Summary

Based on consultations with 100+ stakeholders, a structured process to identify **high ROI interventions**, and detailed economic evaluation, this report recommends that the government of Timor-Leste scale up **nine interventions to substantially improve food security, nutrition and farmer incomes**. The interventions are designed to be implemented **as a holistic package**, touching multiple parts of the agri-food-nutrition chain, **boosting overall system capacity and delivering synergistic benefits**.

The intervention package consists of the following investments:

1. Double spending on foundational **agricultural research and development**
2. **Strengthen Timorese agri-businesses** to supply inputs, credit information and market linkages
3. Supplement existing irrigation systems with **solar pump tube wells in rice growing areas**
4. Expand the budget for **improved seeds**
5. Incentivize the use of **biochar** and provide a **temporary subsidy for biochar + inorganic fertilizer**
6. Expand farmer-sensitive **coffee rehabilitation and intercropping** with high value spices such as vanilla, clove and pepper
7. Deliver **hermetic drums** for maize storage
8. Expand **rice fortification** for children in schools and the general population
9. Scale up selected community- and facility-based **nutrition specific interventions**

Figure E1: Recommended Interventions Mapped to the Agri-Food-Nutrition Value Chain

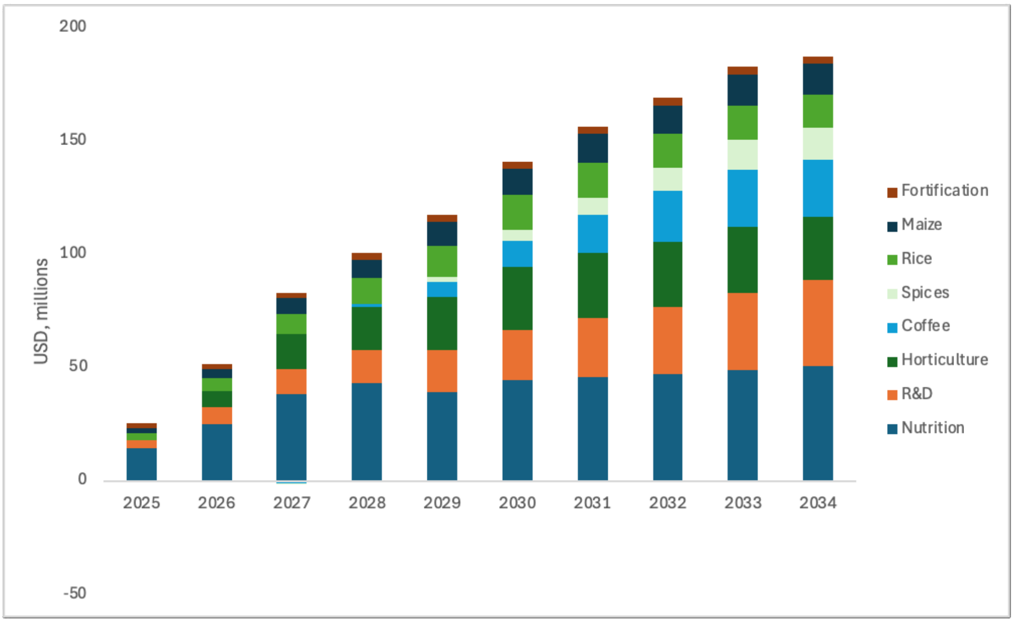


The interventions are expected to deliver a range of benefits by 2034:

- **Increase rice yields** by as much as 60% to ~4.0 metric tonnes (MT) per hectare (ha), raising paddy production to 125,000 MT annually
- **Increase effective maize production** by ~60% to 103,000 MT delivered via a combination of yield improvements (35% yield increase to 2.4 MT / ha) and a 37% reduction in post-harvest losses.
- **Increase horticulture production** by ~60% supporting greater availability of nutritious foods
- **Double the amount of coffee** and substantially increase the amount of vanilla, pepper and cloves produced in the country stimulating key cash crops for export
- **Deliver $133 million annually in increased farm profits** to 190,000 farming families
- **Deliver $14 million in increased revenues** to Timorese agri-businesses
- **Decrease the prevalence of food insecurity** from 42% to 29%
- **Reduce child mortality** by 15% and **reduce stunting** by 12%

Over a period of 10 years, the expected net present value of the benefits is $1,081 million in production ($796 million) and health benefits ($285 million). The interventions require an investment of $429 million over 10 years (or $312 million in net present value terms with a 7% discount rate), which includes the direct cost of the interventions plus a 12.5% contingency. **Compared to the costs, the intervention yields substantial net benefits of $770 million and a benefit-cost ratio of 3.5, meaning that every $1 invested yields $3.5 in benefits for farmers and society.**

Figure E2: Expected annual benefits of the intervention package



"We do not rise to the level of our goals, we fall to the level of our systems"

- James Clear, Author

Introduction

Timor-Leste is a country of great ambition. The Strategic Development Plan 2011-2030 lays out a series of goals focusing on national wealth, human capital, social and economic participation, infrastructure, livelihoods and economic production. Since independence, substantial progress has been made on all these goals. However, one element has faced particular challenges: *"Timor-Leste will be a prosperous society with adequate food... for all people"*.

It is no secret that Timor-Leste experiences high levels of food insecurity and malnutrition. Food insecurity stands at 42% nationally, 47% of children are stunted and 26% of women of reproductive age are anemic (WFP, 2024, Nomura et al. 2023). Despite strong ambition to address this challenge, reflected not only in the Strategic Development plan but also policies such as the 2020 Consolidated National Action Plan for Nutrition and Food Security, the National Multisectoral Nutrition Action Plan to Combat Stunting (PANKOS) for 2024-2030 and the formation of working groups including the Inter-Ministerial Council for Food Security, Food Sovereignty, and Nutrition (KONSSANTIL) and Unidade de Missão de Combate ao Stunting (UNMICS), Timor-Leste has been unable to ensure adequate food for all people.

Why has this happened? Much has been written on the factors that drive Timorese food insecurity and malnutrition: limited investment in agriculture, high susceptibility to variable rainfall and natural disasters, low labor force participation, low agricultural productivity and commercialization potential, poor connective infrastructure, limited dietary diversity and more (Fanzo and Bonis-Profumo, 2019). These factors reflect one key underlying challenge: **a weak and unintegrated agri-food-nutrition system**. Because the system is exactly that, *a system*, individual and isolated efforts to address food insecurity and malnutrition, may make some progress, but they will be ultimately constrained by the weakest parts of the chain. Providing irrigation may enable higher yields and a second harvest, but if there is limited extension support or market to sell excess produce, farmers will not take advantage of the increased water availability (Young, 2014). Informing mothers about best practices for complementary feeding will yield little improvement, if households are unable to access nutritious food (Bhutta et al. 2013). Giving farmers machinery, such as tractors, may reduce the need for on-farm labor in the short-run, but if there is no way to procure spare parts or maintenance services, the tractors may quickly fall into disrepair (Fanzo and Bonis-Profumo, 2019).

Our examination of the evidence indicates that Timor-Leste's food insecurity challenge is not so much about a lack of goals, good ideas or ambition. Rather it has arisen due to an inadequate attention to the interconnectedness of different elements of the agri-food-nutrition system. To paraphrase James Clear, Timorese agriculture does not rise to the level of its goals, it falls to the level of its system. And while there are examples of success within the system, the overall system is weak.

Against this backdrop, this report recommends a package of nine investments across all elements of the agri-food-nutrition system from upstream research and development to a suite of improved cultivation practices, and beyond the harvest, an expansion of highly effective nutrition services. **A key principle that undergirds this recommendation is that the investments must be made simultaneously and holistically to boost the overall capability of the system and yield the greatest returns. They will be less effective if only one or some of the interventions are implemented in isolation**. Importantly, the recommendations are predicated on the expansion of the budget available for agriculture and nutrition, and do not imply that existing and planned activities of the government should be curtailed.

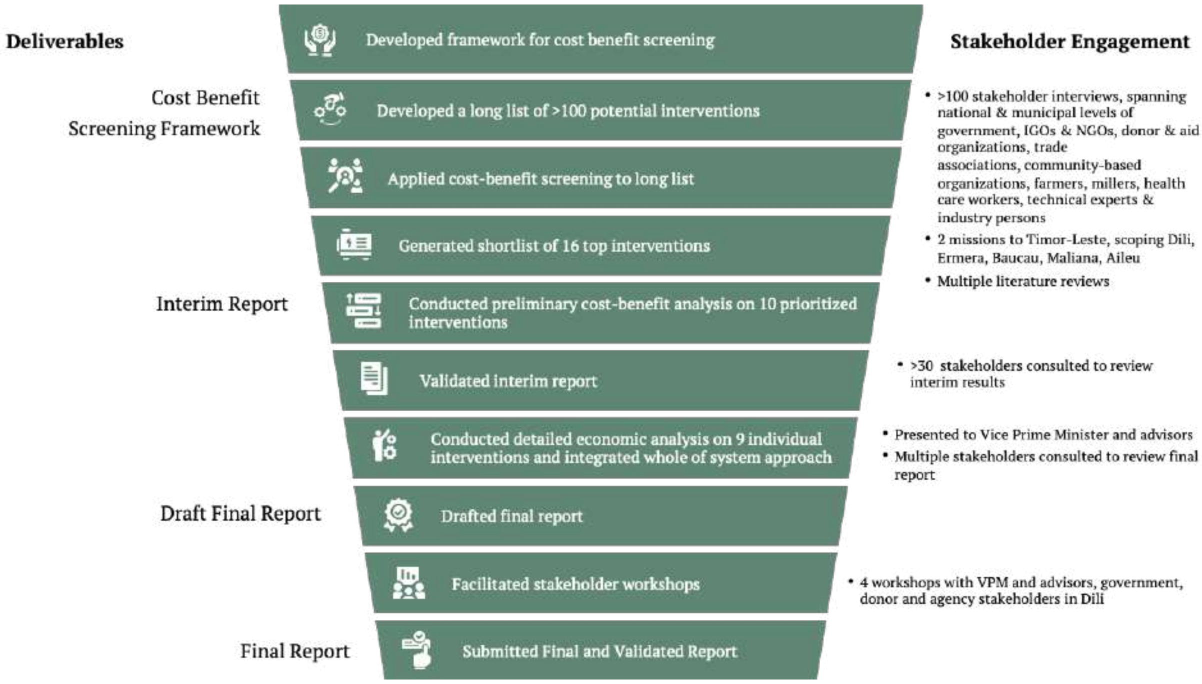
Yet our recommendations are also informed by a clear-eyed understanding of the limited fiscal space and institutional capacity to deliver complex, costly programs. Our entire process has been geared towards identifying interventions that deliver a high return-on-investment (ROI), large net benefits or both. We have conducted detailed economic evaluation of each investment, individually and collectively as a package, searching for interventions that yield high returns at lowest cost, and importantly discarding interventions that do not represent good value-for-money. We have aimed to use limited resources to greatest effect. Moreover, we have aimed to recommend interventions that require relatively simple technologies and tested institutional structures, with evidence of successful deployment in Timor-Leste or similar resource constrained environments.

We arrived at the recommendation following a structured, pre-defined process that the team has adopted previously in other low-and-middle-income countries (see Figure 1 plus Annex Section 11 for a description of our prioritization process). Our mixed methods research process aims to use a combination of qualitative insights and quantitative modeling to uncover effective and high ROI investments. Importantly, we did not have a predetermined set of interventions in mind at the outset of the project. Instead, we allowed the potent mixture of stakeholder input and academic evidence to reveal the best ideas. The process began with participatory consultations of more than 100 stakeholders across all levels of the system, from heads of government departments and senior executive advisors, to farmers, food processors and millers, frontline community health workers and more. We asked stakeholders about the challenges of agriculture, food insecurity and nutrition, gaining insights into their lived experience working and existing within the constraints of the system. We also asked for potential solutions to the challenges, which we supplemented with a review of literature, policy documents and national plans. The long list of solutions were then filtered down using criteria related to the size of the problem, potential efficacy of solutions and their policy salience. These findings were documented in our interim report which we disseminated for further review.

We were left with nine interventions for benefit-cost analysis. For each intervention we identified unit costs and impacts from a variety of sources including program plans and scientific reports. We developed a multi-year, multi-crop model of Timor Leste agriculture, and identified the baseline coverage of each intervention. We then modelled the impacts of scaling up these interventions to plausible levels, including modelling synergies and interdependencies between the interventions. Throughout this process there was ongoing validation by advisors and key engaged stakeholders. The model provides us with incremental costs, incremental benefits and a raft of summary outcomes. We then conducted supplementary modelling to identify food security impacts and farmer gross margins.

We produced a draft report, which was subject to further review and validation by senior stakeholders including the Vice Prime Minister and advisors, technical staff within the government, UN agencies and the donor community at several workshops in Dili in December 2024. This report was finalized after the validation process.

Figure 1: Mettalytics Research and Consultation Process



The Recommendation

Our recommendation is a package of nine investments and supportive policy coherence, covering the breadth of the agri-food-nutrition system. They are summarized below:

Enabling environment

1. **Double spending on foundational agricultural research and development -** The intervention consists of two parts: 1) a 100% increase in the budget for research and development (R&D) activities. 2) Overseas postgraduate training for 100 agricultural scientists over 10 years. The extra R&D budget would be spent on strengthening the basic infrastructure of existing centers and facilities (e.g. computers, hardware and software, land, equipment), expanding the number of centers and facilities, increasing human resources for agricultural research and development, training existing researchers in agronomy and farm economics, knowledge transfer via international research collaborations and demonstration activities. A separate budget is included for post-graduate training to build the capacity and scale of the scientific cadre in Timor-Leste.

2. **Strengthen Timorese agri-businesses to provide inputs, credit, information and market linkages** - The intervention calls for a suite of incentives and policy coherence to increase private sector presence in the agricultural sector, particularly in the provision of input supply, credit, information and market linkages. This involves i) a commitment by government to deliver subsidies to farmers through the private sector via vouchers for use in private sector stores ii) providing quarterly training and information materials to the private sector on good agricultural practices iii) providing a limited loan guarantee for goods that can be purchased with credit in private sector stores iv) supporting the stocking of goods on consignment v) hiring international management talent to provide handholding support and develop market linkages where required.
3. **Supplement existing irrigation systems with tube wells powered by solar pumps in rice growing areas** - The intervention requires the construction of tube wells powered by solar pumps in rice growing areas where irrigation schemes already exist. Tube wells supply supplementary irrigation water to farmers by accessing aquifers that underlie paddy land, enabling higher yields and additional harvest seasons when weir-based diversion irrigation lacks sufficient water (Young, 2014). Tubewells are used widely in other contexts in Africa and Asia, and is a cheaper alternative to supply water to land than *de novo* construction of irrigation schemes (Young, 2014). Hydrological modeling suggests that up to 30% of existing irrigated land in Timor Leste has sufficient groundwater for tube well irrigation to be viable (Wallace et al. 2011).

Cultivation

4. **Expand the budget for improved seeds** - The development of improved seeds and the infrastructure for their propagation and continued innovation under the 16-year Seeds of Life program is one of the agricultural success stories of Timor Leste's short history. Yet there is still room for expansion, given that an estimated 40% of rice and maize farmers do not use improved varieties (Ministry of Agriculture and Fisheries, 2020). The intervention calls for increased budget to double commercial seed development plus technical support for community seed producers to propagate the increased supply of seed within the country.
5. **Incentivize the use of biochar (an organic fertilizer made from agricultural waste) and provide a temporary subsidy for biochar + inorganic fertilizer -** The intervention has two elements: i) developing a system to produce and deploy biochar - a valuable waste product from rice husk that has been shown to double yields of horticulture in Timor-Leste (TL Compendium 2021) and ii) a temporary subsidy for biochar and inorganic fertilizer, delivered by the provision of vouchers for use in private sector stores. Biochar development requires a simple brick pit

and chimney where biomass is burned, and the intervention would provide free construction of these pits at 300 small rice millers and 5 large rice millers across the country. A system to incentivize production would be developed, similar to the system already in place for improved seeds. Training on proper use of the pits along with ongoing monitoring and mentoring support are also part of the intervention. It is our understanding that the government is, at the time of writing, conducting investigations of the impact of biochar at scale. The other primary component of the intervention is a temporary subsidy for biochar and inorganic fertilizer. Besides supporting farmers in the use of yield and income enhancing input, the subsidy would also form part of the Timorese agri-business strengthening initiative (see intervention 2 above). The value of the subsidy and its temporary nature would be clearly communicated at the outset, giving farmers and the private sector time to plan for its eventual phase out.

6. **Expand farmer-sensitive coffee rehabilitation and intercropping with high value spices such as vanilla, clove and pepper -** the intervention calls for an expansion of coffee rehabilitation (tree-stumping) with key characteristics that support uptake and successful rehabilitation: i) incremental rehabilitation of coffee trees to mitigate income loss during the rehabilitation period ii) strong and ongoing extension support, mentoring and monitoring iii) intercropping with high value spices to help bridge the temporary loss of income, and increase farm income in the long run.

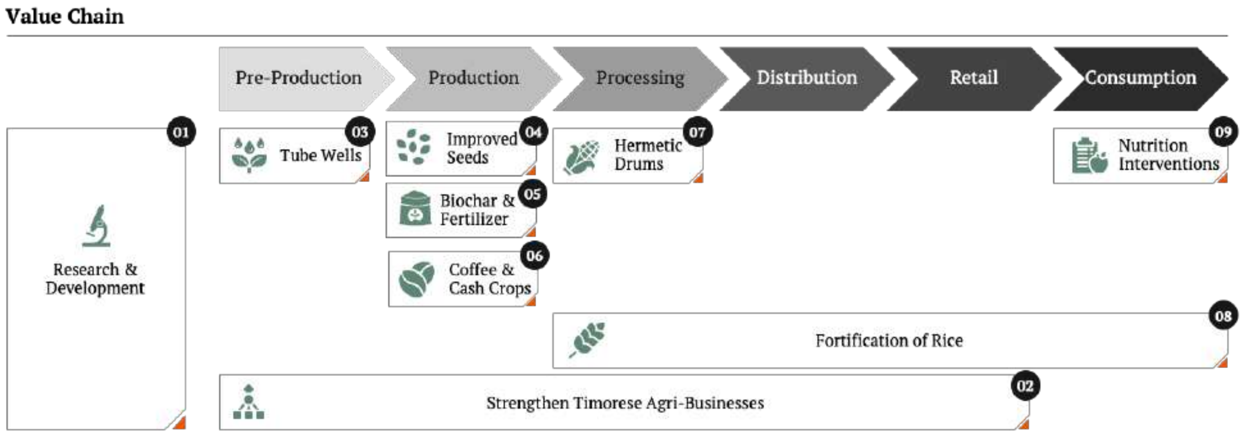
Post-harvest food security and nutrition

7. **Deliver hermetic drums for maize storage** - the intervention is the expansion of the use of hermetic drums for storage of maize and is based on the successful implementation of the IFAD-supported program, Timor-Leste Maize Storage Project (TLMSP I). The storage is a 200kg drum that seals in maize, protecting it from pests, fungus and the elements. The drums would be subsidized and purchasable by eligible farmers from the private sector. The drums have been shown to substantially reduce post-harvest losses in maize, from 30% to 1%, improve food security and enhance childhood nutrition outcomes (IFAD 2019).
8. **Expand rice fortification for children in schools and the general population** - the intervention is the fortification of rice with a series of micronutrients including iron, folate and B vitamins, during the milling process. The intervention is based on an expansion of an existing WFP program that has run over the last year, where rice is being fortified in three large mills in Bobonaro, Liquica and Baucau. There is excess capacity at these mills to fortify more rice, and it is expected that a portion of the increased rice production enabled by the other interventions (e.g. improved seeds, fertilizer, tubewells), will be directed to these existing sites plus

a fourth site in Manufahi. The intervention will prioritize supplying school children via the school meals program, with the remaining fortified rice available for sale to the general public.

9. **Scale up selected community- and facility-based nutrition specific interventions** - the intervention is increased funding to adequately provide nine nutrition specific interventions to 80% coverage. These interventions cover a high ROI subset of the country's nutrition plan, focusing on infant and young child feeding practices, micronutrient supplementation, treatment for diarrhea with zinc and oral rehydration solution, deworming and treatment for severe acute malnutrition. The interventions would be delivered by the primary health care system.

Figure 2: Suite of Interventions across the Agri-Food-Nutrition Value Chain



The intervention package is designed to be integrated and implemented together, simultaneously addressing key constraints within the agri-food-nutrition system and generating interconnected benefits (Figure 2). Importantly, all interventions are supported by government policy. What differentiates this recommendation however, is the requirement for them to be integrated together to unlock additional value.

The three enabling environment investments provide the foundation for the three cultivation interventions. Timorese agri-business strengthening is particularly important in this regard, as limited availability of inputs, extension support, credit and market linkages have been consistently cited as challenges to agricultural production (Fanzo and Bonis-Profumo, 2019). Based on a review of the evidence of successful projects in Timor-Leste (see Annex Intervention 2), we are confident that the private sector has an important role to play in supporting the government to bridge these gaps, as exemplified by initiatives like *Loja Agrikultura*. Moreover, this would support the government's long-standing aim of commercializing the agricultural sector. Many of the other investments rely upon a reasonably well-functioning input supply system that can deliver the relevant inputs (seeds, fertilizers, hermetic drums) while ensuring they are used appropriately by farmers. The second upstream investment, tube wells, addresses uneven rainfall - another key constraint within Timorese agriculture. More consistent and predictable water availability reduces the risk inherent in agricultural enterprise, increasing farmer incentives to invest resources and labor in rice production. Lastly, agricultural R&D - consistently one of the highest returning interventions in agriculture (Rosegrant et al. 2023; Alston, Pardey and Rao, 2022) ensures all efforts are conducted against a background of continuous innovation and improvement, setting up the system for long-term success.

The cultivation investments address two of the major constraints for staple crops: inorganic fertilizer and seeds. Application of these inputs has been shown to deliver substantially increased yields within the country (ACIAR, 2016; TL Compendium 2021), with combined inputs delivering synergistic benefits (TOMAK, 2016). Importantly, the application of simultaneous interventions delivers a step-jump increase in the returns to agricultural effort, increasing the likelihood that the gross margins adequately cover the opportunity cost of labor to justify farmer investment in staple crop production. The intervention for coffee and spices aims to boost the efficiency of Timor's major cash crops, the few agricultural commodities with export potential, while simultaneously raising incomes within the country's most food insecure regions (WFP, 2024).

The preceding interventions increase the production of rice, maize and coffee, which in turn directly influences the scale of benefits in the remaining interventions: biochar production, rice fortification, hermetic storage and nutrition programs. Biochar requires rice husk, coffee residues or coconut husk as an input into the pyrolysis process. Under current production amounts, there is only sufficient husk and residue to deliver biochar to 1,627 ha of vegetable production (17% of horticulture area) and a full biochar rollout would deliver an extra $21 million in horticulture value annually. However, with increased rice and coffee production enabled via upstream and cultivation investments, biochar potential increases to 2,706 ha (28% of horticulture area) and our proposed biochar rollout would deliver an extra $32 million in horticulture value annually. Similarly, rice fortification is limited by the availability of domestic rice production, with more rice grown enabling more essential micronutrients to be delivered to the population. Importantly, neither biochar nor fortification are possible with imported rice.[1] Hermetic storage is one of the most inexpensive methods to increase 'effective production' of maize. Interventions to increase maize output and hermetic storage are more beneficial in tandem than with either intervention alone (Young, 2016). Lastly,

[1] While it is possible to import fortified rice, it would not be calibrated to the specific nutrition needs of the Timorese population.

complementary feeding promotion, a potential intervention to combat stunting, is only effective in food secure populations (Bhutta et al. 2013, Dewey et al. 2021). At full roll out, the investments are expected to decrease the prevalence of food insecurity from 42% to 29%, improving the efficiency of complementary feeding promotion activities.

To reiterate, while each intervention could deliver some benefits if provided in isolation, **greater gains are possible when all interventions are deployed at the same time**. Our economic analysis accounts for the interdependencies of the individual investments. The intervention package is designed to address multiple constraints within the agro-food-nutrition system while remaining cost-effective.

Government Investment Required to Implement the Recommendation

Our analysis assumes a gradual scale up of all interventions from baseline levels to a higher and realistic coverage level over 10 years. Baseline levels of coverage are drawn from various reports, such as the 2019 Agricultural Census with many currently at zero or low coverage levels. Final coverage levels range from 28%-90% of hectares under cultivation depending on intervention and crop. These are determined based on evidence of coverage in similar programs in Timor Leste or comparator geographies, or by production constraints for biochar and fortification (see Table 1).

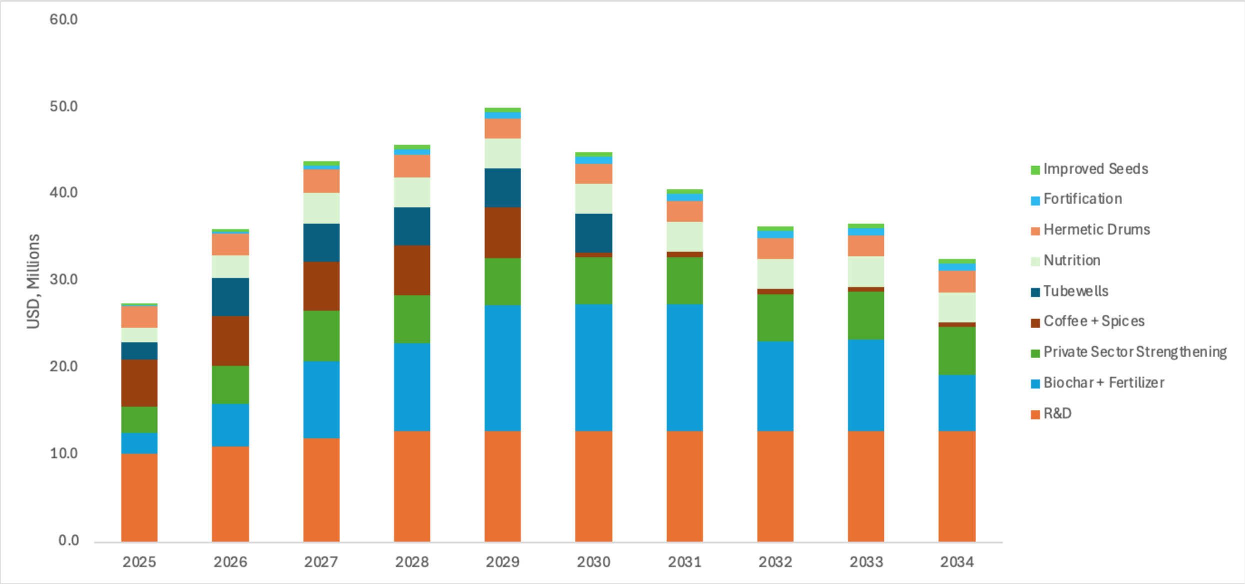
Table 1: Baseline and 10-year coverage level of interventions

Intervention	Baseline coverage	Coverage after 10 years
Agricultural research and development	$8.34m per year (govt and donors) Source: OECD creditor reporting system, Young (2016), Budget documents of Government of Timor-Leste	$16.68m per year (govt and donors) in research + $3.0m for PhD scholarships excluding contingency Source: Assumption based on peak of R&D funding during Seeds of Life project
Private sector strengthening	No coordinated government program to support private sector	Coherent policy and dedicated program to support private sector
Tubewells	3% of cultivated area Source: Agricultural Census 2019	30% of rice area Source: Wallace et al. 2011
Improved seeds	60% of rice and maize cultivated area uses improved seed Source: Agricultural Census 2019	90% of rice and maize cultivated area uses improved seed Source: Assumption reflecting near universal uptake of high yielding sweet potato cultivar
Biochar and fertilizer	Minimal use of biochar in horticulture Source: Assumption 19% use of inorganic fertilizer for rice, 6% for maize Source: Agricultural Census 2019	Biochar: 28% of horticulture area, (coverage constrained by production of rice, coconut and coffee husk/residue) Fertilizer: 60% use of 100kg / ha fertilizer on maize and rice areas (with subsidy) Source: Chirwa and Dorward (2013)
Coffee rehabilitation and intercropping with spices	Exact data on the number of hectares rehabilitated is unknown, but we assess sufficient scope to substantially increase rehabilitation efforts. Source: (MDF, 2021, 2022) Spices: Conflicting statistics but overall scale of spices is limited	Coffee: 30,000 ha (50% of total area) increase in area rehabilitated Source: National Strategic Development Plan 2011-2030 Spices: Thousands of coffee farmers intercrop small areas of land with spices leading to each spice increasing area under cultivation by 300ha (1% of coffee farm land)
Hermetic storage drums	42,000 drums in circulation Source: IFAD, 2019	352,000 drums in circulation (60% coverage of maize production) Source: Assumption based on success of original IFAD drum project

Rice fortification	8,640 tonnes of paddy fortified, excess capacity available for fortification at millers Source: WFP	28,200 tonnes of paddy fortified (Coverage constrained by lesser of excess milling capacity or increased production of rice directed to large millers)
Nutrition interventions	10-78% of target population, varies by intervention Source: Qureshy et al. (2024)	80% of target population Source: Qureshy et al. (2024) and based on intervention with current highest coverage

The interventions require an investment of $429 million over 10 years, which includes the direct cost of the interventions plus a 12.5% contingency to account for unexpected costs such as higher than projected demand for subsidized inputs (See Annex for specific intervention cost assumptions). Investment starts initially at $27.8 million in year 1, peaking at $53.9 million in year 5 before tapering down to $37.3 million by year 10. While this is a substantial sum, the peak expenditure in year 5, would require only a 2.5% increase in the current government budget. Of note is the substantial cost for agriculture R&D which consistently sits at $12.8m in additional funding per year. Historically, 85%-99% of agricultural R&D in Timor Leste has been funded by donors (see Annex Intervention 1). If donors continued to fund R&D at these levels then the financial burden on the government for the program would be reduced by roughly 25%.

Figure 3: Additional budget required for the interventions including 12.5% contingency



Source: Analysis by the authors

Benefits of the Interventions

By the end of the investment period, the interventions are expected to:

- Increase rice yields by as much as 60% to ~4.0 metric tonnes (MT) per hectare (ha), increase paddy production to 125,000 MT annually and substantially decrease the need for rice imports
- Increase effective maize production by ~60% to 103,000 MT delivered via a combination of yield improvements (35% yield increase to 2.4 MT / ha) and a 37% reduction in post-harvest losses.
- Increase horticulture production by ~60% supporting greater availability of nutritious foods
- Double the amount of coffee and substantially increase the amount of vanilla, pepper and cloves produced in the country stimulating key cash crops for export
- Deliver $133 million annually in increased farm profits to 190,000 farming families
- Deliver $14 million in increased revenues to Timorese agri-businesses
- Decrease the prevalence of food insecurity from 42 percentage points (pp) to 29 pp of the population (13pp or 30% reduction; See Annex Section 10 for detail).
- Reduce child mortality by 15% and stunting by 12%

These outcomes are based on various interdependent impacts of the interventions. The annex provides methodological details on the various interventions, with the main assumptions summarized in the table below.

Table 2: Main Impact Assumptions of the Interventions

Intervention	Impact	Source
Agricultural research and development	Increase in agricultural production value by 6% in the short run, 20% in the long run	Wang et al. (2023)
Private sector strengthening	No direct benefit, enables other interventions	N/A
Tubewells	When coupled with fertilizer and improved seed, rice yield increases from 2.45 to 3.99 MT/ha; 0.66ha increase in cropped area per 1ha of irrigation	Young (2014)
Improved seeds	Rice: 24% increase in yield Maize: 34% increase in yield	ACIAR (2016)
Biochar and fertilizer	Biochar on vegetables: 110% for five years Biochar plus on vegetables: 93% in year 1; 47% in year 2 Fertilizer on rice: 28% for one year Fertilizer on maize: 30% for one year	Williams (2023, 2024)
Coffee rehabilitation and intercropping with spices	200% increase in coffee yield 300ha increase in area under vanilla, clove and pepper	MDF (2019)
Hermetic storage drums	Reduction in maize post-harvest losses from 30% to 1%	IFAD (2019)
Rice fortification	Increases learning by 0.45 sd test score improvements for children with anemia; no effect for non-anemic children Increases adult productivity by 1.5% to 4.3% for those with anemia; no effect for non-anemic adults	Chong et al. (2015) Qureshy et al., (2023)
Nutrition interventions	Reduces child mortality by 15%, stunting by 12%	Lives Saved Tool

Figure 3: Food Security Reduction from Interventions

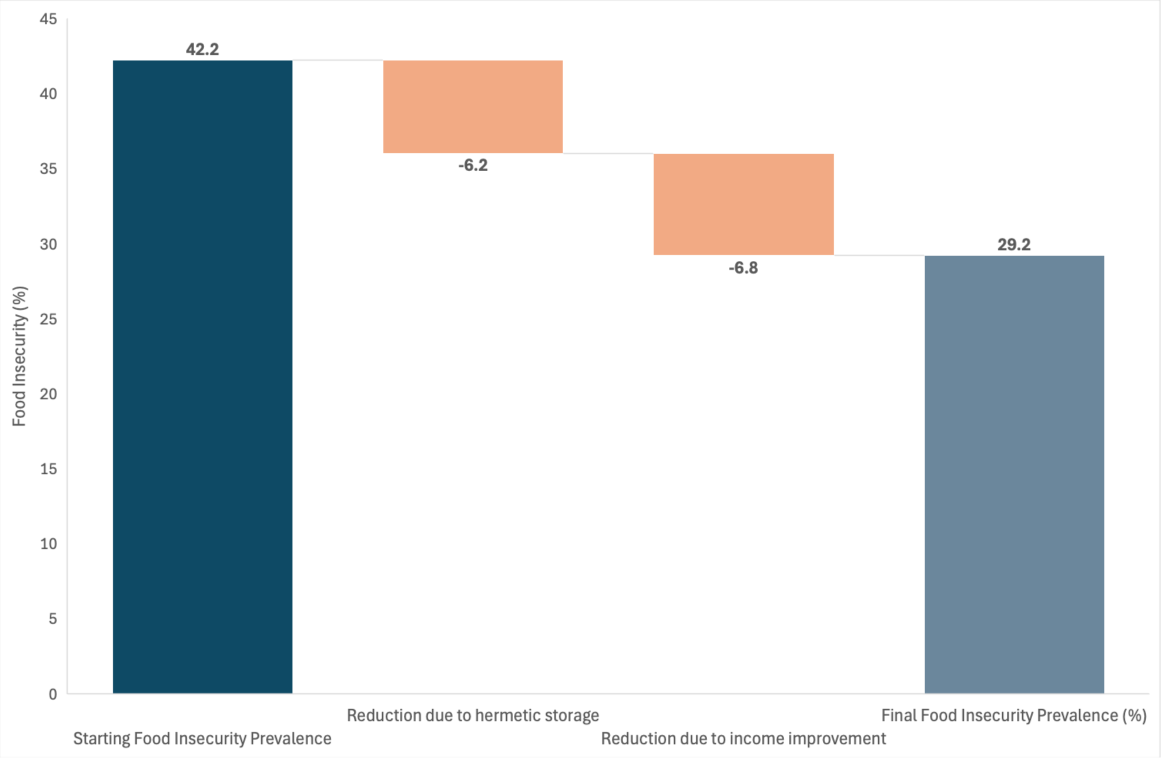
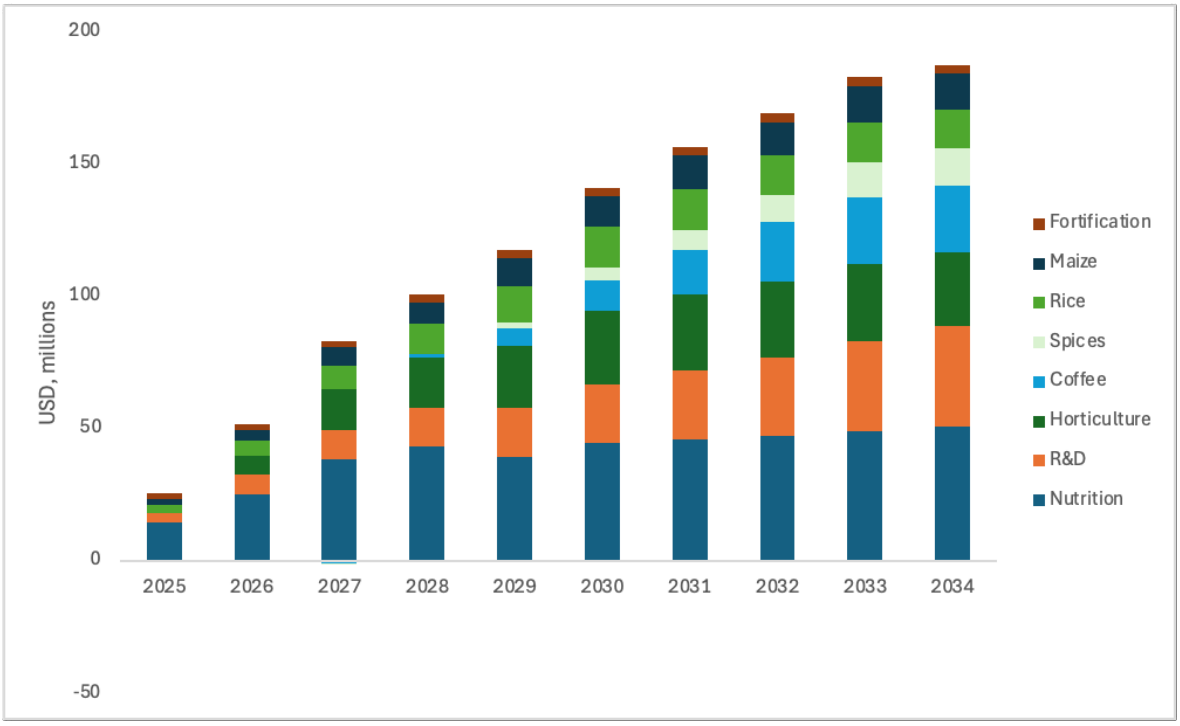


Figure 4: Intervention Benefits over the first 10 years



Overall the economic modeling indicates that benefits start at $25 million in year 1, rising steadily to $117 million by year 5 and $187 million by the end of the 10 year period. Note that certain investments such as the drums, R&D and tubewells will continue to deliver benefits after year 10 but are not depicted in Figure 4. Since the interventions have interdependent effects on production, we report benefits by commodity type rather than intervention, with the exception of nutrition and fortification which have primarily health benefits. R&D is a special case since it generates benefits for all commodities, not just rice, maize, coffee and spices. Therefore the benefit of that particular intervention can be interpreted as the general benefit delivered to the entire agricultural system.

Success Factors

In this section we describe some of the factors that increase the likelihood that this package of interventions will be successfully deployed in Timor-Leste.

1. *Holistic system-wide approach* - Our emphasis on a *holistic system-wide* approach is based on examples of successful past and ongoing programs which have addressed multiple parts of the system simultaneously for improved outcomes:

- *Seeds of Life program* - a collaboration between the government of Timor Leste and the Australian government - which developed both new seed varieties *and* a system to propagate and deliver the seeds via commercial providers (Kunwar et al. 2016), leading to relatively high adoption of improved seed (ACIAR, 2016).

- TOMAK's Phase I which provided a combination of inputs, training and market linkages to substantially increase farm yields (e.g. red rice by 84%) and household income by 200% (TOMAK, 2023).
- Cooperativa Cafe Timor (CCT) which delivers multi-faceted assistance to coffee farmers simultaneously addressing rehabilitation, intercropping, quality controls and market linkages.
- *The Project for Increasing Farmers Households Income Through Strengthening Domestic Rice Production in Timor Leste*, jointly implemented by the (then) Ministry of Agriculture, Ministry of Commerce, Industry and Environment and JICA in Maliana. The project delivered a combination of support on cultivation practices and irrigation management while assisting the government to procure from farmers under various national schemes such as Cesta Basica. The project led to an increase in yield from 2.5 tonnes / ha to ~5.0 tonnes / ha, while increasing land under cultivation by 53% (JICA, 2023). Importantly, the project experienced market linkage failures in the earlier part of the implementation which did not motivate farmers to increase production. By the end of the project, the market linkage failures were (partially) corrected leading to higher output and demonstrating the importance of a system-wide approach.
- WFP's rice fortification and school meals program which not only delivers fortified foods to school children but also procures locally available ingredients from the surrounding area

2. Maximizing use of simple technologies - Where possible, the interventions have adopted simple technologies. For example, biochar production requires a straightforward brick structure to hold the rice husk and a chimney. The materials to make the structure are readily available and it requires little training to operate. Maintenance requirements are small and the biochar can be stored inexpensively in a building or outdoors under cover. Similarly, the hermetic drums deployed in the 2011 IFAD project are simple to use and require limited maintenance. While tubewells represent a more complex technology, the relatively high degree of access to basic water services (80% in rural areas, JMP, 2022) suggests widespread deployment of wells, pumps and associated infrastructure. Moreover, our choice of tubewells, as opposed to larger irrigation systems, is predicated on both cost and simplicity advantages of the former over the latter. Lastly, while there have been some challenges with rice fortification machines in the past, at least four machines are currently being operated by large millers across the country under the guidance of WFP.

3. Availability of markets - one key constraint in Timor Leste is the availability of markets to sell excess produce. While a full market analysis is beyond the scope of this report, we assessed trade and other market statistics to determine if there was in principle sufficient demand to meet increased production. The proposed interventions will increase production of rice and maize to 125,000 tonnes and 102,000 tonnes respectively by year 10. These are substantial but well within the amounts imported by Timor Leste in recent years, suggesting that there is sufficient demand to absorb the excess production. For example in 2023, Timor Leste imported 135,000 tonnes of milled rice, equivalent to approximately 270,000 tonnes of paddy (COMTRADE, 2023). In the same year, maize imports totalled 142,000 tonnes (COMTRADE, 2023). Moreover, there is likely room to use excess maize production as livestock feed to support growing demand for meat (de Sousa, 2024; Fordyce, 2023, Williams, 2024).

Horticulture is a relatively fast growing market in Timor-Leste, driven by increased demand of the rapidly expanding and more affluent population in Dili. Demand for vegetables is expected to grow by 40% over the next five years (Statista, 2023), sufficient to absorb excess production from the application of biochar.

Lastly, we assess that there is sufficient international demand for additional coffee and spice production under the intervention package. While the new production would be substantial compared to current production in Timor-Leste, these amounts would be miniscule relative to global demand for coffee, vanilla, pepper and cloves. For example, coffee tree rehabilitation is expected to increase coffee production by 11,000 tonnes green bean equivalent at its peak, small compared to global consumption of 10 million tonnes (International Coffee Organization, 2023). There is ample demand within the global market to absorb Timorese production, a fact supported by stakeholders during consultations.

4. Supports higher farm income above reservation wage

Another constraint that contributes to low staple crop production is that farming does not often provide sufficient return to labor (Young 2014, Fanzo and Bonis-Profumo, 2019, Rezza and Pakpahan 2023). This has led to declining area under cultivation since 2008, albeit with a modest uptick in recent years (Rezza and Pakpahan 2023, FAOSTAT, 2023). An often cited reservation wage is $5/day which is the rural wage rate available to farmers (TOMAK, 2016; Young 2014, Fanzo and Bonis-Profumo, 2019). The returns to labor days should exceed this threshold for rice and maize farming to become more attractive to farmers.

Using previous gross margins analyses (TOMAK 2016; Soares et al. 2023), and costing assumptions in our economic model, we estimate the financial returns to labor for rice and maize with our intervention package, including a fertilizer subsidy. Our results suggest that the return to labor for rice is $7.48 per day, while for maize it is $7.46 per day, both approximately 50% larger than the reservation wage of $5 per day.

Table 3: Gross margins for rice and maize from the intervention package

	Rice	Maize
Cost per ha	474	134
Revenue per ha	1596	843
Gross Margin	1,122	709
Labor days per ha	150	95
Return to Labor ($/day)	$7.48	$7.46

Returns to labor could improve with other investments such as threshers, tractors and the adoption of conservation agriculture (TOMAK, 2016). Growing red rice, instead of white rice as assumed throughout this report, could also increase returns by perhaps 50% (Williams, 2024). Nothing in this report precludes adoption of these innovations by farmers should it make sense for their individual circumstances. Indeed, it is possible that private input suppliers - enabled by the private sector strengthening intervention - would make farmers aware of these opportunities, and assist them with necessary inputs to realize these gains.

5. Sufficient margin for the private sector

Lastly, we examined whether the private sector would be able to generate sufficient margins under the envisaged intervention package. After five years there would be at least two main sources of revenue available to input suppliers: subsidized fertilizer and hermetic drums. Under our model these two items alone would generate revenues of approximately $14 million nationwide. Assuming a markup on wholesale prices of 20% this would deliver net revenues of $2.8 million. We estimate staff costs of $1.25 million plus utilities and other administrative expenses requiring $250,000. Therefore the profit margin available for the private sector is $1.3 million nationwide from these two inputs alone. We assess that around 50 medium-sized stores could be supported around the country, equating to $25,000 in profit per store per year, a sizable return for an enterprise. Retailing additional inputs such as seeds, machines, herbicides, pesticides and equipment would expand available profit.

Conclusion and The Way Forward

Overall, the results of the economic modeling indicate substantial net benefits from the package of interventions over 10 years. Total net benefits are $769.5 million with production benefits totalling $510.3 million and health benefits of $259.2 million. The overall BCR of the package is 3.5, with health representing a higher ROI at 10.9. Production BCRs are 2.8. While this is a smaller ROI than health, this represents a large (predominantly financial) return on farming enterprise activities.

Table 4: Summary of benefits, costs, BCR and net benefit by production interventions, health interventions and all interventions

	Production (USD, millions)	Health (USD, millions)	Total (USD, millions)
Benefits	795.7	285.3	1,081.1
Costs	285.5	26.1	311.6
BCR	2.8	10.9	3.5
Net Benefit	510.3	259.2	769.5

Source: analysis by the authors. Figures in millions of 2023 USD, assuming a 7% discount rate. The *Health* column represents benefits and costs from fortification and nutrition interventions, while the *Production* column represents costs and benefits from all other interventions.

While this analysis is comprehensive and informed by substantial stakeholder consultation and iterative reviews, it is not without limitations. High-return-on-investment (ROI) interventions may have been inadvertently omitted, particularly those with less robust documentation or lower visibility during consultations. The economic modeling relies on assumptions and parameters derived from the best available evidence, with a deliberate preference for evidence specific to Timor-Leste wherever feasible. However, data quality presented a challenge, with some parameters relying on limited studies or extrapolations from comparable contexts. Moreover, while the interventions were assessed holistically, their implementation and effectiveness may be influenced by contextual factors such as unforeseen policy changes, climatic variability, or shifts in local and global markets that were beyond the scope of this analysis. Despite these limitations, the recommendations are underpinned by a robust consultative process, substantial empirical evidence and a careful study of programs that have worked, or not worked in Timor-Leste.

Should the government decide to proceed with the investment package, the next step is to develop an implementation plan with input from relevant government directorates and stakeholders. Existing working groups, government processes and key policy windows should be leveraged to the greatest extent possible to implement parts of the package without requiring new decrees or legislation. For example, increasing the budget for improved seeds could be accomplished within existing government processes.

As stated above, the interventions should be delivered together to maximize benefits. Acknowledging that deploying all interventions simultaneously and immediately across the entire country is infeasible, we suggest a pilot where all interventions are rolled out in **one municipality first**, with robust monitoring and evaluation frameworks to determine what works and what requires adjustments. The learnings from the pilot would then inform subsequent implementation which would continue to occur at a pace of one or several municipalities at a time. In each municipality, the overall program would need to be tweaked to reflect nuances of the region such as the mix of key crops, the existing coverage of interventions, the terrain and population density. Importantly, this municipal level approach supports decentralization efforts by the government.

The government might want to consider establishing a dedicated program office to implement the package, with secondment into the program from staff from the government, similar to what was done for the Seeds of Life Program. A program structure for these interventions should incorporate key success factors from the the Seeds of Life program such as:

- Deep integration with the government, where many staff positions were filled by seconded government employees.
- High caliber and stable leadership team drawing from the global market to ensure a wide search for the best candidates.
- An open policy for data and document sharing.
- Intensive collaboration with a wide range of stakeholders and development partners.
- Significant flexibility, allowing for adjustments to the scope and scale of activities to take advantage of emerging opportunities and address implementation challenges.

Lastly, besides a continuous monitoring, learning and evaluation process of planned interventions, which is a staple of all programs, the government should conduct periodic strategic assessments where program interventions are re-evaluated to ensure high returns, and to consider bringing in new interventions into the program. For example, due to resource constraints, the team were unable to examine several promising interventions that might potentially deliver high ROIs. These include improving land tenure security through a titling program, in-line chlorination filters to improve the quality of water at existing water sources and improved feeding and husbandry practices for pig farming. Additional interventions to improve protein are also likely to be important for a country living with a substantial degree of stunting. If economic analysis demonstrates that these have high BCRs, they could be incorporated into the program after the rollout has started.

If successful, this program would have a significant impact on food security, nutrition and production in Timor Leste. It would do so by raising the level of the system, delivering substantial benefits that will renew the foundation for a prosperous society with adequate food for all her people.

ANNEX: Methodology

0. General methods

The economic modeling component of this study is an ex-ante analysis from 2025 to 2034 for most interventions, with extension out beyond this period for certain investments with long lived benefits (agricultural R&D, hermetic drums). All interventions are assumed to scale up to certain achievable levels from baseline coverage rates. Baseline coverage rates for each intervention were drawn from various sources, documented in individual methods sections for each intervention. Coverage rates of certain interventions (drums, fortification, biochar) are dependent upon production from other interventions. A summary of baseline and intervention coverage levels is presented in Table 1 in the main part of the report.

Baseline agricultural production data were drawn from FAOSTAT for the main commodities of rice and maize. A horticulture basket was developed covering cabbage, tomato, cucumber and 'other' vegetables. We assume that the baseline would remain at 2022 levels for output, yield and area under harvest. This is done for parsimony and to ensure our results are based on assumptions of the intervention effects, and not assumptions about the baseline pathway of agriculture in Timor Leste.

Constant baseline values for selected commodities assessed in this report (2025-2034)

	Area under harvest (hectares)	Output (tonnes)	Yield (tonnes / ha)
Rice	30,912	76,000	2.46
Maize	48,753	87,000	1.78
Horticulture	9,381	30,761	3.28

For interventions that affect yield, we model these as multiplicative yield improvements based on percentage effects documented in the literature. For example, fertilizer delivers a 28% increase in yield, while tubewells deliver a 30% increase in yield (see Table 2). The impact for unit increase in coverage is therefore defined as *Impact = Baseline yield * (1+30%) * (1+28%)*.

More formally:

$$Benefit_{t,j} = Baseline\ yield_j * \prod_{a=1}^{n} [(C_{tn} - B_{tn}) * (1 + x_{j,n}) * price_j\ per\ tonne * hectares_{jt}$$

Where t denotes the time period, j denotes commodity, n denotes interventions, C represents intervention coverage and B denotes baseline coverage as percentage of hectares covered, while x is the intervention effect on yield measured as a percentage, from intervention n on commodity j. Baseline yield is the yield for commodity j, while hectares is the number of hectares under cultivation. For maize and horticulture this is simply the baseline values since no interventions increase area under cultivation. For rice, tubewells increase area under production according to the formula:

$$Hectares_t = Baseline\ hectares * [1 + (C_t - B_t) * k]$$

Where hectares under cultivation are a function of baseline hectares, coverage of tubewells over baseline as a % of area $(C_t - B_t)$ and the cropping intensity effect k, which is set at 66% following Young (2014). I.e. placing tubewells on 1ha of land leads to 1.66ha of effective cropped land due an increase in cropping intensity.

Classification of costs and benefits follows the recommendation in Pannell et al. (2024), where the resources under constraint (government or donor costs) are included in the cost denominator while farmer costs are netted off from the numerator as net benefits. The BCR is then interpreted as the net benefits to farmers (production benefits) and the public (health interventions) per $ of government cost. Net benefits are unaffected by the classification of costs as either in the denominator or denominator.

Lastly, the discount rate is set at 7%, or twice the short term per capita growth rate following Robinson et al. (2019).

Intervention 1: Agricultural Research and Development

Introduction

Agricultural research and development (R&D) - if expanded and funded consistently over time - can partially address many of Timor Leste's food security and nutrition challenges. Research and development is a priority of the Timorese government, being explicitly mentioned as a key investment in Timor Leste's Strategic Development Plan 2011-2030, along with the establishment of a Timor-Leste Research and Development Institute (Government of Timor-Leste, 2011). Currently, there is sufficient government funding ($1.3 million) for three research centers and two stations nationwide. These stations are undertaking ten concurrent research projects, focusing on maize, paddy, horticulture and fertilizer, according to discussions with the Director of Agricultural R&D. This does not include other crops, livestock, forestry, coffee, fisheries and there is ample room for expansion. The opportunity costs tied to this under investment are too significant to ignore.

Agricultural research has been and continues to be a bedrock intervention to drive improved food security and nutrition outcomes across the world. The delivery of improved seed varieties, agricultural techniques and more nutritious foods via research has been shown to increase farm output (Alston, Pardey and Rao, 2022), improve population health (von der Goltz *et al.*, 2020) and drive economic growth (Gollin, Hansen and Wingender, 2021). A recent study indicates that extra investment in agricultural R&D for global and national research institutions would deliver $33 for every $1 invested (Rosegrant *et al.*, 2023), consistent with previously documented high returns to innovation (Alston, Pardey and Rao, 2022). In the case of Timor Leste, particularly given the wide variety of micro-climates and unique geographical challenges, the need for agricultural R&D to contextualize modern agricultural practices and techniques to the local environment, and innovate to respond to Timor Leste's unique agricultural challenges, becomes more relevant and pressing. Simultaneously, the ND-GAIN Index ranks Timor Leste's vulnerability to climate change as 139 overall out of 184 countries, with its Food Vulnerability ranking as 184 out of 189 countries. This further highlights the need for the nation to develop an agricultural R&D culture which is capable of increasing agricultural resilience and responding to growing disaster and extreme-weather risk profiles.

Intervention Specification

The intervention consists of two parts: 1) a 100% increase in the budget for research and development activities. 2) Overseas postgraduate training for 100 agricultural scientists over 10 years. The expanded budget could be used on a number of activities as noted by the Director of Agriculture and Research and other policy documents:

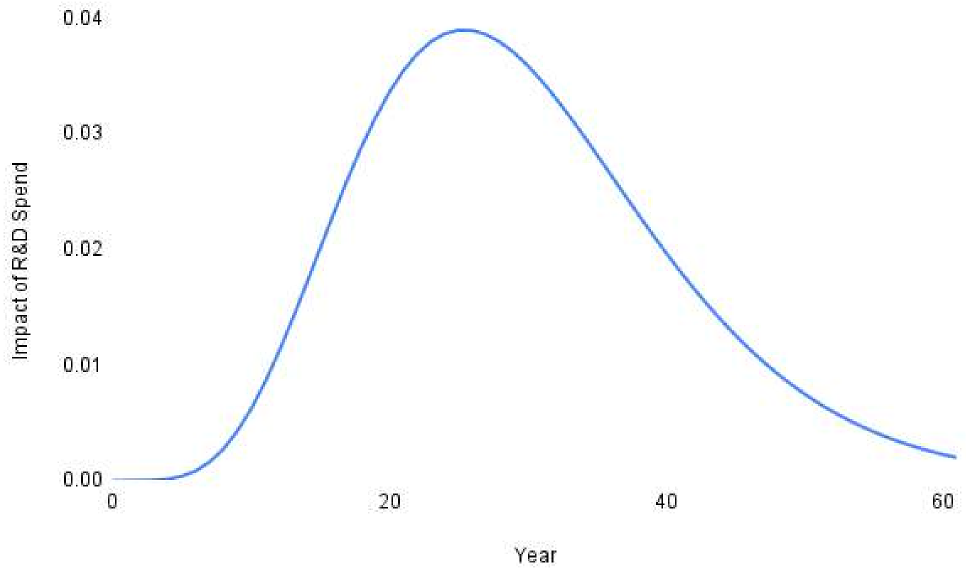
- As a fundamental first step, developing a national research agenda which would form the basis of future activities, while also embedding more localized ownership of agricultural research and development aspirations.
- Research on phyto-sanitary requirements as part of Timor Leste's WTO accession
- Research on the use of formalin in meat consumed in Timor Leste
- Expanding soil health research for all municipalities beyond the ones currently budgeted for (Bobonaro, Baucau, Manufahi, Manatuto)
- Research on developing more climate resistant seed varieties
- A dedicated laboratory to study plant diseases
- Fisheries, livestock and forestry which are currently not part of government research activities
- Coffee, as noted in the National Coffee Sector Development Plan 2019-2030 (Ministry of Agriculture and Fisheries, 2019)
- Ongoing development activities that translate foundational research technologies into implementable products

The extra R&D budget would be spent on strengthening the basic infrastructure of existing centers and facilities (e.g. computers, hardware and software, land, equipment), expanding the number of centers and facilities, increasing human resources for agricultural research and development, training existing researchers in agronomy and farm economics, knowledge transfer via international research collaborations and demonstration activities. A separate budget is included for post-graduate training to build the capacity and scale of the scientific cadre in Timor Leste.

Model Specification

The methodology for assessing costs and benefits of increased agricultural R&D spending draws from the approach documented in Wang et al. (2023), which builds upon Alston et al. (2011) among other studies. In an ex-ante specification, the exact research activities are not specified. Rather it is the totality of spending on R&D that drives outcomes. Specifically, spending on agricultural R&D in a given year influences the stock of knowledge in the future via an assumed pathway of knowledge creation that describes both how long and how much into the future R&D converts to knowledge across time. Alston et al. (2023) canvasses an array of knowledge creation pathways, identifying a long-tailed (i.e 50 years or more) gamma distribution that best matches empirical evidence and the authors' priors on how research works in practice within agriculture. Following the aforementioned studies we also assume a 50-plus-year gamma distribution for Timor Leste, with parameters $\lambda = 0.8$ and $\delta = 0.85$. The implication of this distribution is that spending today on agricultural R&D generates almost no increase in the stock of knowledge for the first 10 years, but then rises rapidly, reaching a peak at year 25. The value of that spending continues for another 25-35 years but with diminishing impact over time (see Figure A1.1). The primary implication of this specification is that Agricultural R&D requires patience and a long-term horizon.

Figure A1.1 Impact of R&D spend at time 0 on future stock of knowledge over the next 60 years.



It is important to note that the distribution essentially spreads out the impact of spending today across a long time horizon with the 'lag weights', providing a time series of when and how much of the spending is converted to knowledge with normalization such that R&D does not convert into knowledge by more than 100% over the pathway. For example, in the above graph, the lag weight at 25 years (i.e. the peak) is 4%, which means that spending 100 units in year 0 on R&D, increases the stock of knowledge in year 25 by 4 units. The equation for generating the 'lag weights' is given by Alston et al. (2011) as:

$$b_k = \frac{(k-g+1)^{(\delta/1-\delta)}\lambda^{(k-g)}}{\sum_{k=0}^{L_R} \quad [(k-g+1)^{(\delta/1-\delta)}\lambda^{(k-g)}]}$$

for $L_R \geq k \geq g$ otherwise b_k= 0

Where k = the lag year, g = gestation period of the number of years before spending spending begins converting into knowledge, λ and δ are parameters that describe the gamma distribution and L_R is the terminal year. In our model g = 1, and L_R = 50.

With a specified form of the lag weights, a time series of R&D spending R_{t-k} on the stock of knowledge, K_t is given by Wang et al (2023):

$$K_t = \sum_{k=0}^{\infty} \quad b_k R_{t-k}$$

Lastly, the benefits from R&D in a given year, B_t , rely on i) the change in the stock of knowledge from the previous year, ii) the elasticity of productivity growth with respect to the stock of knowledge, β and iii) the value of agricultural production V_t. As implied by Wang et al (2023):

$$B_t = \beta * \frac{\Delta K_t}{K_t} * V_t$$

In our primary specification, β = 0.28, following Wang et al. (2023) and V_{2023} is drawn from FAOSTAT and equals $704 million in 2023 after inflation adjustments to 2023 USD. In the model specification that considers Ag R&D as a stand-alone intervention V_t = $V_{t-1} + B_{t-1}$ (i.e. the only source of marginal value creation in agriculture is the impact of previous agricultural R&D spending). In the model that incorporates multiple interventions agricultural production value increases commensurate with the impacts of other interventions and previous agricultural R&D spending.

Baseline and Intervention Specifications

In the case of Timor-Leste, the first effective year of the model is 2000, the start of the Seeds of Life project. We assume that all knowledge was destroyed in 1999 such that $K_{1999} = 0$. Knowledge was generated through spending on agricultural R&D by development partners (e.g. Seeds of Life from 2000 to 2016) and by the Ministry of Agriculture (and variants) from 2001 to 2023. Data on spending by foreign development partners on agricultural research and development was sourced from the OECD Creditor Reporting System, specifically activity codes 31182: agricultural research and 31120: agricultural development. Data on spending by the government of Timor Leste was sourced from the Seeds of Life economic evaluation (Young, 2016) for the period 2000 to 2016, and
from budget reports of the Government of Timor Leste for the period 2017 to 2023.

Historical data of R&D spending (all figures in 2023 USD), as depicted in Figure A1.2 below shows a steady rise in spending until 2013 followed by a general decline then plateauing of spending around the range $8-$9 million (with the exception of 2017 which corresponded to above average development activities by various partners). In the graph, we highlight the proportion of spending undertaken by the Seeds of Life project, drawn from Young (2016). Seeds of Life contributes a substantial proportion of total agricultural R&D expenditure, particularly during phases 2 and 3 of that project (2007 to 2016). Notably the share of government contribution in total agricultural R&D spending has increased steadily over this time period.

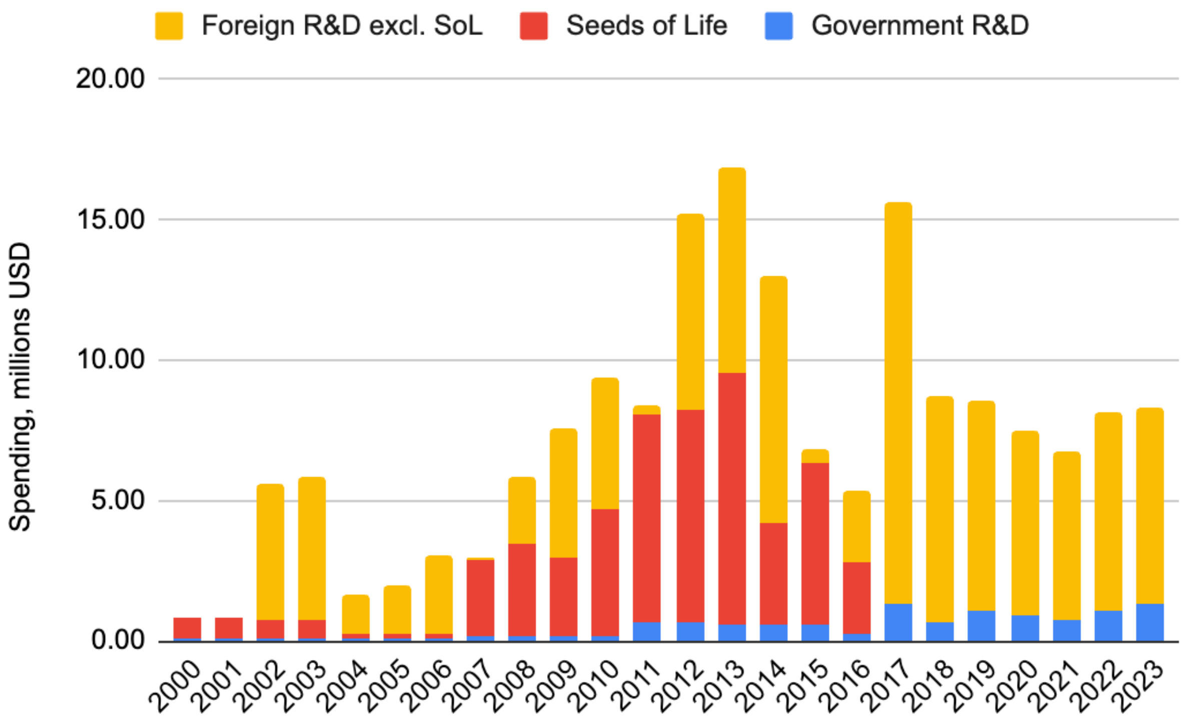
In the baseline specification we assume no increase in R&D spending from 2025 onwards .i.e. The level of spending remains constant at $8.34 million. In the intervention specification we assume a doubling of R&D spending to $16.68 million, large by current standards but approximately the same amount spent during Seeds of Life Phase 3 in 2012 and 2013. In the short run and given historical experience, it is likely all of the increase in spending will be incurred by foreign donors, though the benefit-cost calculations are not sensitive to how increased R&D activity is financed.

Moreover, we include an additional cost to train 100 more research scientists at international PhD programs over 10 years, approximately doubling the existing cadre of scientists estimated at around 50 within MALLF and 50 at the University of Timor Leste.

This would allow Timor Leste to continue the higher level of research activity in the medium term with sufficient, skilled capacity.

We assume that the cost of training is $75,000 per year - $40,000 for tuition, $20,000 for (partial) living stipend and $10,000 for ancillary expenses - for four years per student. These figures represent the approximate existing fees and scholarships for postgraduate education in Australia. Living expenses may be higher than the $20,000 stipend and we assume they are somewhat ameliorated by students working overseas at higher wages than they would otherwise be able to achieve in Timor Leste. To remain conservative, the costs of the additional R&D are assumed to contribute to the stock of knowledge and higher agricultural value, while the costs of training are not.

Figure A1.2: Historical spending on Agricultural Research (all figures in 2023 USD)



Sources: Young (2016), budget documents of government and OECD Creditor Reporting System

Figure A1.3 depicts how the stock of knowledge varies under the baseline and intervention scenario. In the baseline specification, the stock of knowledge continues to rise but then plateaus in the 2040s as the knowledge generated during Seeds of Life and earlier projects become less relevant and R&D spending in the intervening years has failed to bridge the obsolescence gap. In contrast, the stock of knowledge continues to increase steadily in the intervention scenario. Of note is that the gap between the two scenarios is relatively narrow and only widens around 2035, reflecting the long term implications of agricultural R&D.

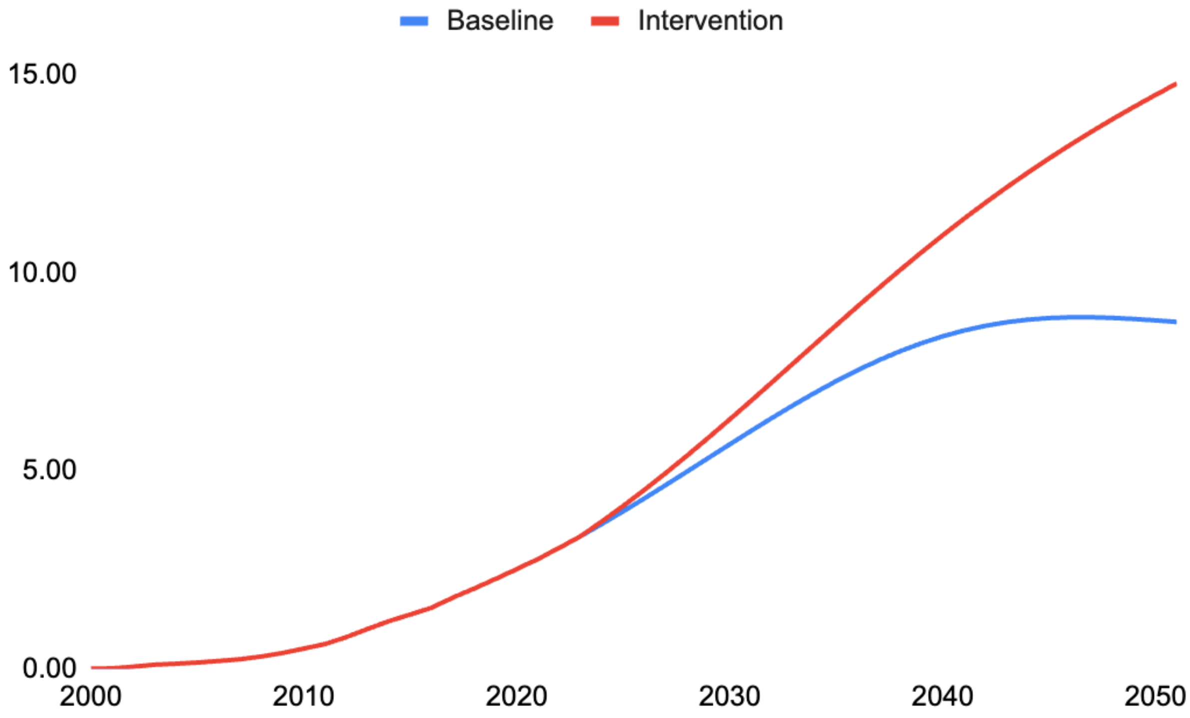


Figure A1.3: Stock of knowledge under intervention and baseline scenarios (indexed such that 2000 = 0.1).

Costs and Benefits Used in the Integrated Model

The results indicate that under the intervention scenario the incremental costs of the intervention start at $9.8 million, rising to $11.3 million by 2027 as the sum of increased R&D spending ($8.3 million) and the annual cost of training ($3.0 million). From 2037 onwards, after all 100 graduates have finished their studies the ongoing cost is $8.3 million. The NPV of costs at a 7% discount rate is $120.3 million from 2025 to 2052.

Incremental benefits, reported as the incremental percentage improvements on baseline agricultural value, start at 0.52%, rising to 5.28% by year 10. By the end of the period (2052) the incremental production gain from previous R&D efforts is 21.0%.

Agricultural R&D intervention differs from the others given the long lag time for benefits. In the integrated model, we use the initial % gains applying them as yield improvements on rice and maize (see General methods for approach to multiplicative benefits). However, the integrated model stops at year 10 reflecting our brief to deliver medium term recommendations.

To ensure a full picture of the net benefits we show the benefits and costs of agricultural R&D if sustained investment is provided over the long run (Table A1.1). The NPV of benefits is $560 million from 2024 to 2051. Overall, the BCR of agricultural R&D is 4.5 when considered as a standalone intervention. Alternative specifications yield BCRs in the range of 3.7-5.6.

Table A1.1. Costs and benefits of agricultural R&D in the long-run

Specification	NPV Costs (USD millions)	NPV Benefits (USD millions)	BCR
Main specification ($\lambda = 0.8, \delta = 0.85$, β=0.28, $r = 7\%$)	123.8	560.1	4.5
Alternative specification 1 ($\lambda = 0.7, \delta = 0.9$, $\beta = 0.28, r = 7\%$)	123.8	463.5	3.7
Alternative specification 2 ($\lambda = 0.8, \delta = 0.85$, $\beta = 0.28, r = 5\%$)	150.1	772.5	5.1
Alternative specification 3 ($\lambda = 0.8, \delta = 0.85$, β=0.33, $r = 7\%$)	123.8	694.0	5.6

The intervention assumes relatively long lag structure typically associated with more foundational research. However, adaptive research and development which utilizes known technology from other contexts will have shorter lead times. For example, the IFAD project which deployed hermetic storage drums in 2011 used a known technology to great effect. In this regard, the BCR estimated in this report is almost certainly on the conservative side. Either way, this analysis shows that sustained investment in R&D pays off substantially in the long run.

Intervention 2: Strengthen Timorese agribusinesses to supply inputs, credit, information and market linkages

Introduction

This intervention aims to enhance the private sector's role in the agricultural industry by implementing a range of incentives and ensuring policy coherence. The focus is on improving the provision of input supply, information, and market linkages.

This intervention is based on the following foundational parameters:

I. The private sector is essential for the long-term success of any intervention.
II. Policy coherence is required to increase private sector presence
III. Free or subsidized inputs when delivered by the government crowd out the private sector, hampering the provision of inputs in the long-run..
IV. Farmers are more invested and responsible when they have a financial stake.
V. The private sector is ideally positioned to provide agricultural inputs, information, training and credit to farmers.
VI. Market linkages are best initiated by the private sector

There are multiple examples from Timor-Leste and other contexts that highlight the essential role of the private sector in ensuring the long-term success of any agricultural intervention. Perhaps one of the best functioning examples of this in Timorese agriculture is the use of private commercial and community seed production groups to propagate improved seed throughout the country - a substantially more efficient and cost-effective approach than centralized production by the government (Kunwar et al. 2016). USAID's Avansa Agrikultura Project in Timor-Leste focused on long-term sustainability through strengthening the private sector and local partners that provide services to rural farmers. Over the course of the 5 year program (2015 - 2020), the input supply sector saw significant growth, with annual sales nearly tripling from $200,000 to over $770,000. Over the same period, household incomes in the targeted areas increased 944% and there was a 90% decline in moderate and severe hunger levels (USAID 2020).

Amongst other things, policy coherence is crucial for encouraging participation in the private sector. For example, in 2018, a TOMAK report noted that input supply provision had greatly improved compared to the situation only a few years prior, with substantial availability of fertilizer, chemicals and quality seed at more affordable prices (TOMAK, 2022). Part of this success was driven by government policy of reducing complex regulations that stifled imports of inputs (TOMAK 2022).

Interventions that provide inputs to farmers at no cost often yield limited benefits, particularly when the market conditions are not supportive. This is especially true in cases where there is a lack of adequate budget, technical expertise, extension support and market incentives. Timor-Leste's tractorization campaign exemplifies this issue, where the absence of necessary support structures, such as budget and technical expertise, meant that the tractors were not used to full effect (MAF 2018). In Myanmar, fertilizer use amongst farmers remained low despite subsidies due to the lack of adequate commodity prices and market incentives (Warr 2000).

When farmers contribute financially to the inputs, it creates a sense of ownership and responsibility, leading to the proper use of the inputs. This was a key factor in the success of IFAD's maize storage drum project, where farmers contributed $10 and received a voucher for the rest of the cost. This co-payment made farmers feel more accountable, and misuse was minimal, with only about 6% of participants not using the drums for maize storage (IFAD 2016). In contrast, previous national programs that provided storage solutions for free did not work well because the lack of investment led to underutilization.

The private sector is ideally positioned to provide agricultural inputs, information, training and credit to farmers. Commercial vendors are motivated to support their customers effectively to promote further business. For instance, the Loja Agi Agrikultura store in Dili offers free training and online technical support via WhatsApp (TOMAK 2018). Rice millers we interviewed in Maliana and Baucau noted that they provide advice and credit to their customers (farmers), with the miller in Maliana also growing a demonstration plot to provide visual evidence of successful high-yielding cultivation practices.

Regarding market linkages, CCT management have been responsible for connecting Timorese coffee farmers to Starbucks (Market Development Facility, 2023) and growing the nascent export market for spices. Moreover, private collectors link farmers to markets in Dili and other larger centers.

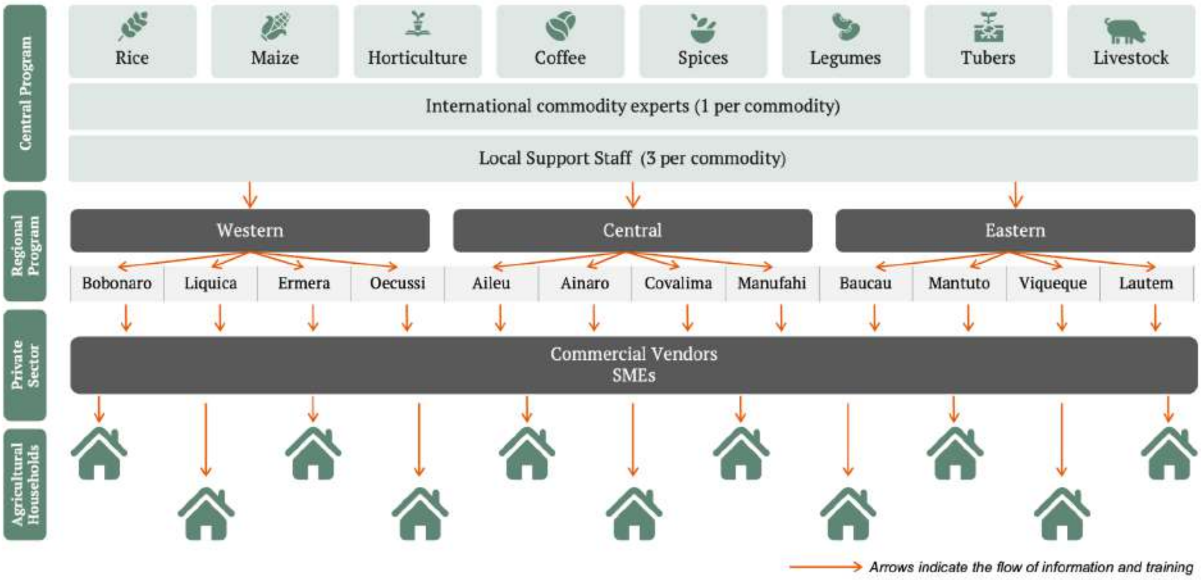
Intervention Specification:
The intervention calls for a more formal program that standardizes and supports the private sector to expand these practices, enabled by policy coherence that ensures the private sector is not crowded out, and is temporarily supported by consumer subsidies to mitigate start-up costs and reduce market entry risk. In the long run, and in a competitive market, the private sector is incentivized to provide high quality products, supported with accurate and useful guidance on appropriate use of inputs and farming practices, and where possible market linkages.

To support private sector growth, there are several commitments required from the government.

I. a commitment by government to not procuring and supplying any agricultural inputs for free, instead delivering any subsidies to consumers through the private sector e.g. via vouchers for use in private sector stores,
II. providing quarterly training and information materials to the private sector on good agricultural practices
III. providing a limited loan guarantee for goods that can be purchased with credit in private sector stores
IV. supporting the stocking of goods on consignment
V. Hiring local and international management talent to provide handholding support and develop market linkages where required

The structure of this intervention is based around key lessons and success factors drawn from the Seeds of Life Program (2016), TOMAK (2018) and CCT (current).

Figure A2.1: Structure of Private Sector Strengthening



Model Specification

Strengthening the private sector is a unique intervention as it incurs various costs but does not directly generate benefits on its own. Instead, it supports and enhances other initiatives that generate benefits. The costs associated with this model include wages, training costs, costs to guarantee loans and consulting to support policy coherence.

i. Staffing

Building on the successful models of CCT and SOL, the proposed structure includes local and international commodity-specific experts to optimize performance and generate market linkages. These experts will focus on key commodities such as rice, maize, horticulture, coffee, and spices, as well as other primary commodities like tubers, legumes, and livestock that were not the main focus of this analysis.

Regional offices support municipalities, provide training to vendors, and offer general cross-component support. This coordinated approach is based on the SOL program structure, which has a proven track record in Timor-Leste.

Parameter	**Metric**	**Value**	**Source:**
International Commodity Experts	#	8	Mettalytics Analysis
Average Wage including benefits pp.	$	350,000	Mettalytics Analysis

Annual Wage for International Staff	**$**	**2,800,000**	
Central staff per commodity	#	3	Mettalytics Analysis
Total Central Staff	#	24	Mettalytics Analysis
Average Wage pp.	$	$2,976	ILO, 2021
Annual Wages for Local Central Staff	**$**	**$71,424**	
Number of Regional Offices	**#**	3	SOL, 2016
Staff per office	**#**	4	Mettalytics Analysis
Regional Staff	**#**	12	Mettalytics Analysis
Average Wage pp	**$**	$2,976	ILO, 2021
Annual Wage for Local Regional Staff	**$**	**$35,712**	
Total Wages		**$2,907,136**	

ii. Training

This intervention involves training the private sector to enable them to support consumers with best practice agricultural information and technical advice. Training will be developed centrally, closely following Good Agricultural Practices guidelines already developed by the government, and delivered through regional offices. The model follows the train-the-trainer model reported by TOMAK, which successfully trained 45 trainers and 1,200 farmers (TOMAK 2018).

TOMAK's analysis of the input supply market identified high-quality printed materials with photos and local guidelines as a key requirement to support vendors and customers in store. Therefore, we have included a provision for printed materials per shop in this intervention.

The cost assumptions are as follows:

Parameter	**Metric**	**Value**	**Source:**
Number of Vendors per Municipality	#	4	Mettalytics Analysis
Number of Vendors per Region	#	12	Mettalytics Analysis
Number of Vendors (national)	#	12	Mettalytics Analysis
Number of farming households delivered per region	#	141,141	Agricultural Census 2019
Number of households per shop		2940	Mettalytics Analysis
Cost per Training - Developing contents & training material - Delivering training to regions - Disseminating trainings to stores	$	38,000	TOMAK 2018 / Mettalytics Analysis
Printed material per shop per year	$	100	TOMAK 2018 / Mettalytics Analysis
Total annual training expense	**$**	**513,600**	

Iii. Guarantee Loan

Government-guaranteed loans are crucial for supporting private sector growth and innovation, especially in underdeveloped and underserved markets like LDCs (Garbacz 2021). These guarantees mitigate the risks associated with lending, encouraging financial institutions to extend credit to businesses that might otherwise be deemed too risky. By increasing access to financing, private enterprises can invest in new technologies, expand their operations, and improve productivity.

In Timor-Leste, credit is already being provided by the private sector, including farmer groups, entrepreneurial rice millers, and wholesale stores. This intervention includes a government guarantee of loans to further encourage financing and incentivize the private sector to provide credit for agricultural inputs. The model is based on the following parameters:

Parameter	Metric	Value
Average access to credit per household	$	$50
Credit potential per store	$	`$150,000
Assumed loan default	%	20%
Cost to guarantee loans across the country	$	1,440,000

Mettalytics Analysis.

Iv. Technical Assistance for Policy Coherence :

Policy coherence is a critical component of this intervention and a complex task. To address this, we have allocated a budget for technical assistance to conduct a detailed policy review, identifying harmful policies that hinder the agri input supply sector, offering evidence-based alternative policies, and helping the government to implement new policies. The budget for this effort is $5 million over three years.

V. Set up costs

The setup of this intervention requires certain costs, including expenses for building and equipment for central and regional staff. These costs have been estimated as follows:

Parameter	**Metric**	**Value**	**Source:**
Central Office			
Building	$	$30,000	DFAT 2018
Equipment	$	$15,000	Mettalytics Assumption
Central Office & Equip	$	$45,000	
Regional Offices & Equip (per region)	$	$31,000	Mettalytics Assumptions
Total Set-Up costs (one-off)	$	$139,500	

Results

This intervention is a cost-only model and will be balanced against the benefits in the integrated model. The standalone costs for the 10-year intervention are summarized below:

Table A2.1: Costs in Strengthening the Private Sector ($ Millions)

	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Set up costs										
Central Office	0.0									
Regional Office	0.1									
Total Set Up costs	**0.1**									
Wages	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
Training	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Loan Guarantee	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Policy coherence	1.7	1.7	1.7							
Total costs	**6.7**	**6.5**	**6.5**	**4.9**	**4.9**	**4.9**	**4.9**	**4.9**	**4.9**	**4.9**

Note: these results do not include 12.5% contingency.

Intervention 3: Tube Wells to Supplement Irrigation

Introduction:

Irrigation has been a long-standing priority for the Government of Timor-Leste. Between 2003 and 2014 over $80 million was invested in restoring and rehabilitating irrigation assets. In 2014, a master plan was developed to restore and rehabilitate a further nine of the nation's major irrigation schemes, as well as to construct additional dams and schemes. The MAP Strategic Plan allocates approximately $590 million for investment in the irrigation sector from 2014 to 2021 (World Bank, 2018).

A review of the irrigation sector conducted by Philip Young in 2014 identified potential issues with the current irrigation strategy. According to Young, Timor-Leste's current strategy of rehabilitating ex-transmigration irrigation schemes followed by constructing dams and new schemes, has not and will not generate high returns on investment.

Firstly, the economic feasibility of rehabilitating damaged and non-functional irrigation schemes is questionable due to the substantial investment required. Construction costs in Timor-Leste are significantly higher than international standards. Additionally, the low returns, driven by low yields and cropping intensities, have resulted in most of the reviewed schemes producing negative Internal Rates of Return (IRRs).

Secondly, irrigation - specifically the weir-based diversion approaches used in Timor-Leste have been unable to significantly increase staple crop production. Despite substantial investments in irrigation infrastructure over the past 20 years, rice production has shown minimal growth. The strategy's heavy emphasis on physical infrastructure (hardware) without also providing farmer support services (software) is likely to lead to limited benefits. Without adequate support services, provision of inputs and the development of rice markets, the irrigation strategy will not produce enough rice to justify the significant investments in physical infrastructure.

Young recommends a hybrid strategy for irrigation that incorporates supplementing the physical infrastructure with software packages, such as farmers support services and market development, as well as additional infrastructure, tube-wells small pumps (TWSPs) to optimize the water accessibility irrigation schemes.

Supplementing irrigation with Tube Well Small Pumps (TWSPs)
TWSPs supply supplementary irrigation water to farmers by accessing aquifers that underlie paddy land. This irrigation strategy is used widely in other contexts in Africa and Asia, and is considered a cheaper alternative to supply water to irrigated land (Young 2014).

In the context of Timor-Leste, the use of TWSPs could significantly increase rice and maize yields. Variable rainfall and seasonal conditions mean that for many rice growing areas, irrigation alone may not provide sufficient water to fully support the rice crop through to harvest. The implementation of Tube Well System Pumps (TWSPs) could ensure the rice plants receive adequate water, mitigating the risk of low yields due to insufficient irrigation. In regions with an abundant supply of irrigated water, such as Mailiana, the use of TWSPs can support a second or third rice crop season or the growth of additional vegetable crops.

Intervention Specification
The proposed intervention does not intend to change the existing roadmap for irrigation investment, but to enhance current and future irrigation schemes with the addition of tube-well system pumps (TWSPs).

Our analysis considered the impact of tube wells on both rice and maize production. While tube wells have the potential to increase yields and production for both crops, the high capital cost makes the economic case unviable as a standalone intervention. However, in the integrated model, tube wells make economic sense for rice crops. This is because they contribute to additional benefits such as biochar production for horticulture and fortified rice for school programs and public consumption. For maize, on the other hand, without similar flow-on benefits, the economic case is not viable and has been excluded from our recommendation.

Model Specification
Evaluating this intervention is simply measuring the incremental value from the increased rice yields over the incremental costs of the hardware and maintenance of the TWSPs. The simple methodology is outlined below.

i. Determine the baseline area for irrigation

To ensure sufficient water supply, TWSPs must be used in conjunction with existing irrigation systems (Young, 2024) and as such the first step is to determine the total area of irrigated land in Timor-Leste. This analysis assumes the baseline of irrigated land as of 2015, plus the addition of schemes rehabilitated up to 2023.

According to the World Bank report (2020), the area of additional irrigated land from rehabilitated schemes completed between 2013 and 2023 is approximately 12,900 hectares. There have been no major new dams or schemes constructed since 2013.

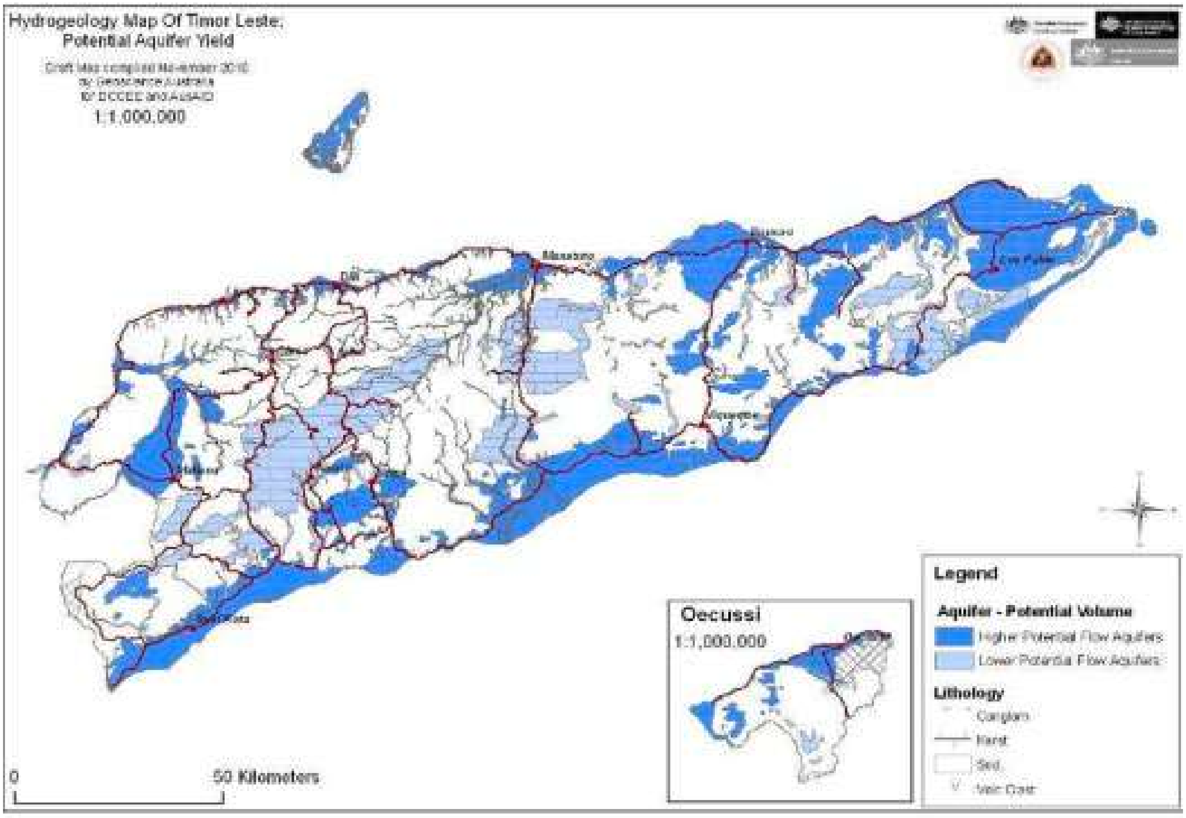
Table A3.1: Baseline Irrigation Area

Metric	Area	Source
2015 Area (inc Beibui)	46,000 ha	MAF
Additional area from rehabilitated schemes	12,900 ha	World Bank
Additional area from new dams	-	World Bank
2024 Area Baseline	59,200 ha	

Ii. Identify area with high aquifer potential

A hydrogeological map for Timor-Leste shows the topographical view of potential for aquifers. This map has been used, in conjunction with the map of irrigation schemes and crop production by region to generate a high level assessment for the area potential for supplementation with TWSPs.

Figure A3.1: Hydrogeology of Timor-Leste.



Source: Wallace, L., Sundaram, B., Brodie, R.S., Dawson, S. and Furness, L. (2011) *Hydrogeology of Timor-Leste*. Geoscience Australia, Record 2011

Figure A3.1: Planned Irrigation Schemes in Timor-Leste

Source: Philip Young 2014

It has been conservatively estimated that 40% of irrigated land for rice has high aquifer potential. Further assessment will be required in the implementation planning, including drill tests to determine the viability of groundwater sources.

iii. Calculate incremental yield on existing and cropping intensity

As outlined in the general methodology section of this report, the following formulas have been used to calculate the increased yield and increased cropping intensity:

$$Benefit_{t,j} = Baseline\ yield_j * \prod_{a=1}^{n} [(C_{tn} - B_{tn}) * (1 + x_{j,n}) * price_j\ per\ tonne * hectares_{jt}$$

The yield improvement is based on the most likely scenario from Young's analysis (2014), where rice production increased from 3.0 t/ha to 4.5 t/ha, representing a 50% yield increase due to the combined effects of tube wells and software packages. The benefits from the 'software' are accounted for in other interventions, so to avoid double counting in our analysis, we have conservatively assumed a 30% increase in yield.

$$Hectares_t = Baseline\ hectares * [1 + (C_t - B_t) * k]$$

Where hectares under cultivation are a function of baseline hectares, coverage of tubewells over baseline as a % of area $(C_t - B_t)$ and the cropping intensity effect k, which is set at 66% following Young (2014). I.e. placing tubewells on 1ha of land leads to 1.66ha of effective cropped land due an increase in cropping intensity.

iv. Determine cost of TWSPs

The cost of TWSP / ha in 2013 was $2000. With inflation, the 2024 price per hectare is $2,527 (Young 2024). The assumed annual maintenance cost of 20% of capital investment.

v. Calculate net impact

Net Benefits to Farmer	-	Costs to Government / Donor
Incremental value of increased rice crop		Cost of TWSP infrastructure + Ongoing maintenance cost

Table A3.2: Results of standalone Tube Wells intervention

		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Irrigation baseline coverage	%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Irrigation intervention coverage (max 30%)	%	5%	10%	15%	20%	25%	30%	30%	30%	30%	30%
Incremental Costs to Government	$m	1.7	3.9	3.9	3.9	3.9	3.9	0.0	0.0	0.0	0.0
Irrigation intervention yield increase	%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%
Irrigation expansion of rice area	% change	66%	66%	66%	66%	66%	66%	66%	66%	66%	66%

Note: these results do not include 12.5% contingency.

Intervention 4: Improved Seeds

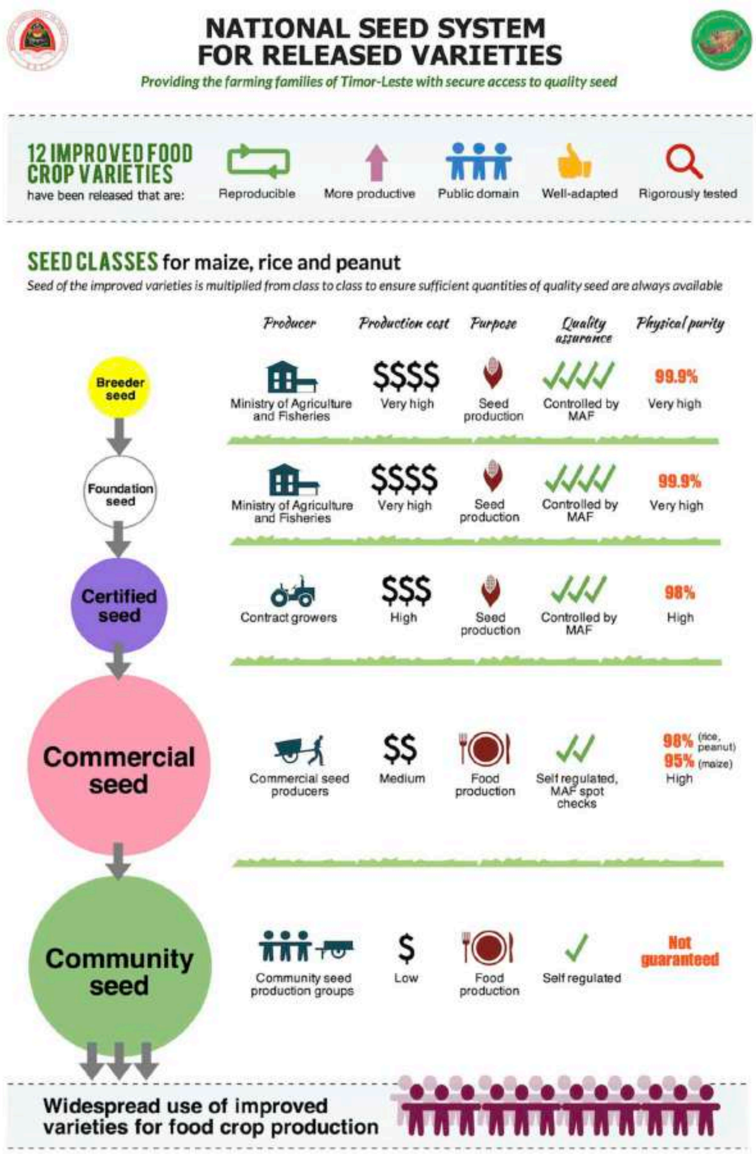
Introduction

Yields of Timorese crops, including staple crops, horticulture and cash crops, are amongst the lowest in the world. Timor-Leste's rice yield is estimated to be 2.46 tonnes per ha compared to the global average of 4.76 tonnes per ha (FAOSTAT, Our World in Data 2021). National corn yield is 1.78 tonnes per ha compared to global average of 5.75 tonnes per ha (FAOSTAT, ICAR 2020).

Productivity has been found to be especially low in cases where traditional seed varieties are used (WB 2023). Continued dependence on conventional and low-yield seeds results in decreased germination and emergence rates, diminished viability, low resistance to environmental conditions, and low crop growth rate. High-quality, high-yielding seeds are imperative for establishing productive crops and increasing the availability of food and income for farming households.

Improving seed quality for local agriculture is a clear priority for the Government of Timor-Leste. The Ministry of Agriculture in conjunction with the Seeds of Life programme (2000 to 2016) supported the extensive research and development to introduce and disseminate improved seed varieties for well adapted crops. Now improved seed technology exists for Timor-Leste's major staples food crops, with significant yield advantages over the traditional local cultivar (ACIAR 2016). The program established a decentralized national seed system, depicted in Figure A4.1

Figure A4.1: The National Seed System



Source: Seeds of Life (2016)

In the national seed system, commercial seed producers (CSPs) use Ministry of Agriculture, Livestock, Forestry and Fisheries (MALFF) certified seed to produce quantities of commercial seed under strict guidelines and MALFF supervision. Community seed production groups (CSPG) produce community seed for their own and neighbors to use. Each year the government, through MALFF, allocates a budget to procure commercial seed from CSPs at $1.50/kg and distribute to community seed groups.

Farmer surveys reporting on the adoption of improved seed varieties in Timor-Leste produce mixed results. The end-of-program survey conducted by Seeds of Life (2016) indicated that 48% of households interviewed were growing one or more of the improved varieties. In the 2019 Agricultural Census only 20% of farming households reported using high-yielding and local seed varieties, with 1% of farmers using certified government sourced seeds. A more recent report by USAID stated 58% of farmers received seed aid through direct seed distribution from the government between 2014 and 2023, however, only 25% of farmers received or obtained seed of new varieties of crops from GoTL (Martins 2023). As a conservative baseline, we have adopted the high-end range, assuming 60% of farmers already use improved seeds, so as not to overstate the potential benefits.

Based on feedback from interviews with Anaprofiko and MAF, there may be two constraining factors limiting the opportunity to expand the use of improved seed to the remaining ~40% of farmers who are still relying on traditional cultivar. Firstly, insufficient and inconsistent government budgets for commercial seed, limiting the distribution of improved seed to community groups and propagation to the farmers'. Secondly, there may be insufficient extension and financial support for community seed groups, hindering the ability for these groups to (i) form and (ii) effectively grow and propagate the improved varieties.

Intervention Specification

The intervention is to increase use of improved seed for rice and maize by

I. Increasing the annual government budget for commercial seeds
II. Providing additional extension and financial support for community seed production groups.

Building on the foundational experience of the Seeds of Life program, the intervention is structured around the following foundational assumptions:

- Improved seed varieties can be reused over a period of years without significant (5% or less) diminishment to the improvement of yield and the budget can be based around a multi-year model for seeds renewal
- The use of improved varieties increases self-provisioning and boosts the informal seeds system, organically propagating the use of improved varieties beyond the government budget for commercial seeds. This delivers additional value without adding directly to government expenditure.
- There is widespread willingness amongst the farming community to adopt improved varieties. While it is assumed that demand for seeds is not a constraint, appropriate extension support is required to support community seed production groups to disseminate seeds to the broader farming community
- Community groups in Timor-Leste require hand-holding and ongoing financial support to form and continue to operate

The model has been developed for Timorese' primary staple crops, rice and maize. Although detailed modeling has not been specifically conducted for other crops in this report, the assumption is the BCR for other crops would be of a similar range to rice and maize.

Model Specification

The methodology for evaluating this intervention involves a comparison of the incremental benefits and costs associated with the increased use of improved seeds relative to a baseline with no change to the existing seed mix.

The use of improved seeds delivers yield improvements over traditional cultivar which is measured based on the market value of the crop. The direct costs to implement this initiative includes the government provision of commercial seed as well as the extension support required for dissemination and financial support for community groups.

As the distribution of commercial seeds grows, so does the supply and demand for improved varieties at the community level. This propagation of improved seed on the informal market generates additional incremental value. While there is still a cost for the seeds on the informal market, this is incurred by the farmer. As discussed in the general methods section, the cost is therefore deducted from the benefit (in the numerator) rather than adding to the direct government cost for the initiative (in the denominator).

The net benefits are calculated as:

Net Benefits to Farmer	-	Costs to Government / Donor
A.Incremental value of improved seed - B. Incremental cost of improved community seed		D. Incremental Cost of Commercial Seed + E. Incremental costs to disseminate + F. Incremental cost to support community seed producers

Table A4.1: Parameters for Seeds Analysis

General Parameters

Metric	Unit	Rice	Maize	Source
General Parameters				
Market price of Crop	$ / kg	$0.40	$0.35	Williams, R. 2024
Cost of Commercial Seed (formal & Informal	$ / kg	$1.50	$1.50	Williams, R. 2024
Seeds required per ha	kg / ha	40	30	Williams, R. 2024

Cost Parameters

Baseline:				
Budget for Commercial Seed (% of total national seed requirement)	*%*	*5%*	*5%*	
Use of Improved Seed	*%*	*60%*	*60%*	*SOL, 2016*
Use of Traditional Seed	*%*	*40%*	*40%*	*SOL, 206*
Scenario				
Budget for Commercial Seed (% of total national seed requirement)	*%*	*10%*	*10%*	*Mettalytics Scenario*
Use of Improved Seed	*%*	*100%*	*100%*	*Mettalytics Scenario*
Extension Support				
Dissemination	*$ / ha*	*1.70*	*1.70*	*Calculation[2]*
Support Community Groups	*$/ha*	*14.0*	*14.0*	*Calculation[2]*

Benefit Parameters

Yield				
Baseline Yield	*t / ha*	*2.46*	*1.78*	*FAOSTAT 2022*
Improvement on Traditional Seed	*%*	*24%*	*50%*	*ACIAR 2016*
Yield of Traditional Seed[3]	*t / ha*	*2.15*	*1.48*	*Mettalytics Analysis*
Yield of Improved Seed[3,4]	*t / ha*	*2.66*	*1.99*	*Mettalytics Analysis*
Yield Increment of Improved Seed	*t / ha*	*0.54*	*0.55*	*Mettalytics Analysis*
Decline per year of use	*%*	*0%*	*5%*	*Williams, R. 2024*

1. The cost for certified seed is verified at $1.50 per kg. It is assumed that the cost of seed on the informal market is the same.

2. Cost to disseminate seed and support community groups are estimated on a per hectare basis, founded on data from Seeds of Life Final Report (2016) and TOMAK's Agricultural Input Supply Strengthening (2018)

3. Yield of traditional and improved seed is calculated as a weighted average based on baseline yield and baseline seed mix. 4.. Improved varieties generate the same incremental yields, regardless of the source of the seed (ie certified vs. non certified)

Baseline Specifications

In 2024, year 0, the yield for rice is 2.46 t/ha and maize is 1.78 t/ha. Production is 76,000t and 87,000t of crop respectively (FAOSTAT). This is based on the assumption of the baseline seed mix, with 60% of the population using improved seed and 40% using traditional cultivar. Assuming no intervention, the yield and production is assumed to remain at current levels for the next 10 year period.

Scenario Specifications

In the scenario analysis, the government budget for commercial seed has grown from 5% of total seed requirement to 10% of total seed requirement for both rice and maize. The assumed outcome is 90% of community adoption of improved seed. The rate of propagation assumed in the scenario is relatively conservative, at 10x the volume of commercial seeds, compared to 9x in the base case.

Results

The result of increasing the use of improved seeds is an increase in the yield and production of rice and maize. Incremental value has been calculated based on the market price for each crop.

The model is based on the assumption that farmers are purchasing additional seed to receive the improved varieties. However in the baseline, farmers may already be purchasing seed from community producers and receive traditional cultivar or a mix of traditional and improved. As such this analysis may be understating the net benefit for the farmer.

Table A4.2: Results of seeds intervention: maize

		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Baseline Coverage	%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%
Intervention Coverage	%	70%	80%	90%	90%	90%	90%	90%	90%	90%	90%
Cost to Government	$m	0.08	0.17	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Incremental Yield (%)	%	34%	34%	34%	34%	34%	34%	34%	34%	34%	34%

Note: these results do not include 12.5% contingency.

Table A4.2: Results of seeds intervention: rice

		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Baseline Coverage	%	60%	60%	60%	60%	60%	60%	60%	60%	60%	60%
Intervention Coverage	%	70%	80%	90%	90%	90%	90%	90%	90%	90%	90%
Cost to Government	$m	0.06	0.13	0.20	0.21	0.23	0.25	0.25	0.25	0.25	0.25
Incremental Yield (%)	%	24%	24%	24%	24%	24%	24%	24%	24%	24%	24%

Note: these results do not include 12.5% contingency.

Intervention 5: Fertilizer as soil amendment

Introduction

Crop yields in Timor-Leste rank among the lowest in Southeast Asia and are notably low in global comparisons (TL Compendium 2021). The low yields observed in the country can be attributed to the prevalent poor soil conditions. Over 80% of the soil exhibits low levels of Olsen P, deficient organic carbon content, and a significant portion also demonstrates low soil pH (TL Compendium 2021). These factors collectively hinder crop growth and ultimately affect the overall yield, which directly contributes to food insecurity in Timor-Leste.

The use of fertilizers in Timor-Leste is limited. According to the Agricultural Census, only 6% of households use fertilizer (organic and inorganic) and pesticides. This is due to a combination of factors. Firstly, fertilizer is not always accessible specifically in rural areas. Secondly, fertilizer is expensive and, given the seasonal cash flow of agriculture, farmers typically cannot afford to pay for fertilizer at the beginning of a new crop season. Finally, there is a general cultural aversion to the use of fertilizers due to the negative perceptions of chemical inputs in Timorese soils. As an alternative, farmers typically rely on shifting and burning before planting to boost yields, which leads to significant degradation of soil and hindering longer term crop yields (FAO 2021).

The improvement of soil and nutrient availability through soil is crucial in promoting crop growth and obtaining high current and future productivity in Timor-Leste. This is a clear priority for the Timorese government and agricultural development to address food security is referred to multiple times in the Strategic Development Plan 2011-2030.

Two approaches have been considered for this intervention
5.1 The use of biochar as fertilizer for horticulture
5.2 Expand the use of inorganic fertilizer for rice production

5.1 Biochar and biochar plus as fertilizer for horticulture

Intervention Specification

Biochar is a method that harnesses the power of waste to enhance soil quality. By converting waste products into a valuable soil amendment, biochar not only neutralizes acidic soils but also increases the availability of essential nutrients for crops to thrive. (TL Compendium 2021). This intervention is the production and dissemination of biochar as fertilizer for horticulture crops, focusing initially on rice-husk biochar, with the potential to expand to other forms including coffee and coconut husk biochar.

The intervention is underpinned the following foundational assumptions:

- **Biochar is an effective soil amendment in Timor-Leste and generates high economic returns on horticulture crops.** When used on its own, rice-husk biochar has been found to produce increased yields across almost all crops in Timorese soil (TL Compendium 2021). Rice-husk biochar has been found to generate higher economic returns on horticulture compared to other crops, primarily a function of the dose required to produce yield benefits. Most research to date has focused on rice-husk biochar, and similar results have been established with coffee husk. Coconut husk biochar has not yet been tested but is assumed to generate similar returns.

- **The process of making biochar has low barriers and requires minimal technical capacity.** Biochar production requires an inexpensive pyrolysis chimney and occurs through a simple process of burning biomass. Access to volumes of suitable biomass, such as rice, coffee or coconut husk, is the primary barrier for production at scale. This intervention would target rice millers, coffee growers or larger farmers as viable producers.

- **Fortifying biochar with small amounts of inorganic fertilizer to create Biochar Plus significantly increases its effectiveness and reduces the required dose. Yet due to additional capital requirements, opportunities for viable production of biochar plus is constrained.** To make it more effective, biochar can be mixed with small amounts of urea and superphosphate, to create Biochar Plus. The synergistic effect of this combination significantly increases yields and reduces the required dose of Biochar or chemical fertilizers used in isolation (ACIAR 2023)**.** Specific machinery is required to grind down chemical additives into ash form that can be combined with the biochar. This additional capital investment, estimated at $2000, would be limited for millers and farmers that can produce biochar at scale. Given the decentralized nature of Timorese agriculture production, few rice millers or coffee growers meet the scale required for this additional process, and the viable supply of biochar plus is limited.

- **Overall, there is a limit to biochar production and in the long run it would not be sufficient to fertilize all Timorese crops.** Biochar production is constrained by the availability of suitable biomass. Coupled with the relatively high required dose, it is not a viable solution to sustainably fertilize all Timorese crops. As such, this intervention is purely focused on biochar as fertilizer for horticulture crops

Model Specification

The methodology for evaluation involves a comparison of the incremental benefits and costs associated with the use of biochar as fertilizer for horticulture relative to the baseline of the current use. Biochar as fertilizer improves yields on horticulture crops, increasing production which is measured as value based on the farmgate price of the crop. Production of biochar and biochar plus generates a cost per kilogram, accounting for energy, labor and chemical inputs (for biochar plus). Given the current economics, the cost of biochar will need to be subsidized or farmer credit provided to incentivise use. The government expenditure would also include the capital investment to install the equipment required for the production and for the initial training required to incubate the process.

The net benefits are calculated as:

Benefit to Farmer	-	Costs to Government
Incremental value of horticulture crop less non-subsidized component of biochar and biochar plus		Subsidized cost to produce biochar and biochar plus + Capital cost of biochar equipment and installation

Baseline Specifications

In 2024, year 0, the cultivated area for horticulture is 9,400 ha (FAOSTAT). With a yield of 6.7 t/ha (TL Compendium), production is estimated at 63,000 t per annum. It is assumed that there is currently limited biochar used as fertilizer for horticulture. Without intervention, the yield and production is assumed to remain at current levels for the next 10 year period.

Scenario Specifications - Rice Husk Biochar

In the scenario analysis, large millers produce biochar plus and small millers produce straight biochar. The yield of biochar from rice paddy is ~9%. The annual production of 2,808 and 1,404 of biochar plus and biochar respectively. The parameters underpinning the model for rice-husk biochar are outlined in the table below:

Table A5.1: Parameters for Rice Husk Biochar

Baseline Parameters

Biochar yield to Rice Paddy	%	9%	
Market price of horticulture	$/kg	0.86	FAOSTAT.2021

Production		Biochar Plus	Biochar	Source
Number of millers		5[1]	300[2]	TBC
Volume milled per miller p/a	t	6,240	52	WFP, 2024
Total volume milled p/a	t	31,200	15,600	
Biochar Production (supply)	t	2,808	1,404	
Chemical Inputs				
Urea (N)	%	2%	-	TL Compendium
Superphosphate (P)	%	1%	-	TL Compendium
Urea (N)	t	56	-	
Superphosphate (P)	t	28	-	

1. "Large" millers viable for biochar plus production mill between 8-32 tonnes of rice per day. There are currently only 5 in Timor-Leste (TBC).
2. There is 1 small miller per 100 ha of rice, assumed to mill at a capacity of ~ 1 tonne of rice per week (Williams, R, 2024)

Production Cost		Biochar Plus	Biochar	
Dose Required	t/ha	1	20	Williams, R. 2024
Area covered by supply	ha	2,808	70	
Cost (price)	$ / kg	0.8	0.5	Williams, R. 2024

Yield Improvement		Biochar Plus	Biochar	
Baseline Yield	t/ha	6.7	6.4	Williams, R 2024
Yield Improvement	%	93%	110%	TL Compendium
Incremental yield	t/ha	5.0	5.9	
Year of benefit	#	1.5[1]	5	Williams,, R 2023

1. Biochar plus produces yield benefits of 100% in year 1 and 50% in year 2
2. Biochar (solo) yields benefits for 5+ years following initial application

Capital Costs:		Biochar Plus	Biochar	
Chimney	$	200	200	Williams, R. 2024
Grinder	$	2,000	0	Williams, R. 2024

Total Equipment Cost	**$**	**2,200**	**200**	
Annual Training per site	$	50	30	
Training Cost per annum	$	250	9,000	
Lifespan	years	8	8	Williams, R. 2024

Examining the return for the farmer, if the farmer was out-of-pocket for the biochar the net return per hectare in year 1 would be $4.6 for biochar plus and -$3.7 for biochar straight. As such, a government subsidy or credit system is recommended to incentivise use of straight biochar to ameliorate losses in the short run. The approach to subsidization is considered more comprehensively in the main section of this report.

Table A5.2: Return to Farmer

Return to Farmer per Ha		Plus	Straight
Cost	$ / ha	0.8	10
Year 1			
Return	$ / ha	5.4	6.3
Net Return	$ / ha	4.6	(3.7)
Year 5			
Return	$ / ha	8.0	31.7
Net Return	$ / ha	7.2	21.7

Scenario Specifications - Rice, Coconut & Coffee Husk Biochar

In the scenario that biochar production was extended to coffee and coconut, there would be potential to cover a great scope of horticulture crop. Assuming 60% of the current production of rice, coffee and coconut, was used to produce biochar and biochar plus, there would be a supply to fertilize 1,627 HA, 17% of horticulture crops, in Timor-Leste. This does not consider the incremental production that will result from increased rice and coffee production from the other system intervention.

Table A5.3: Biochar Yield to Crop

Yield of Biochar	%
Rice (Paddy)	9%
Coconut (whole)	25%
Coffee (whole)	20%

Table A5.4: Biochar production as a standalone intervention

	Rice		Coconut	Coffee	
	Biochar Plus	Biochar	**Biochar**	Biochar Plus	Biochar
Number of Millers / Farmers	5	300	500	5	200
Biochar production	864	1,080	4,711	431	861
Potential Area Covered	**864**	**54**	**236**	**431**	**43**

Table A5.5: Potential Scope of Biochar and Biochar Plus for Horticulture a standalone intervention

Total Horticulture Area (ha)	9,381
Area covered by biochar supply	1,628
% covered	17%

In this scenario, applying the same yield benefits and cost assumptions as rice husk biochar. The summary results are depicted in the table below.

Table A5.6: Coverage and costs of biochar intervention

		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Baseline Coverage	**%**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Intervention Coverage	**%**	0%	19%	21%	22%	24%	26%	27%	28%	29%	29%
Cost to Government	**$m**	0.3	1.8	2.6	2.6	3.5	3.5	3.5	2.6	2.9	1.8

Note: these results do not include 12.5% contingency. These results may differ from the integrated model.

The benefits of biochar are realized over several years. A single application of standard biochar results in a 110% yield increase for five years, while biochar plus delivers a 93% yield increase in the first year and 47% in the second year, as shown in the table below.

	Year 1	Year 2	Year 3	Year 4	Year 5
Biochar: 20 t / ha	110%	110%	110%	110%	110%
Biochar Plus: 1 t / ha	93%	47%	0%	0%	0%

Table 5.7: Yield benefits of a single application of biochar and biochar plus

5.2 Expand the use of inorganic fertilizer for rice & maize production

Intervention specifications

Significant yield improvements have been found on Timorese rice production with the small conservative application rates of inorganic fertilizers. Specifically, small volumes of urea and superphosphate have been found to generate yield improvements of 5:1, returning 5 kg of rice per kg of fertilizer (Williams 2024). The Timorese agri-environment currently severely underuses chemical fertilizer and is forgoing the opportunity to reduce per kg production costs, increase yields and profitability.

This intervention is increasing the use of inorganic fertilizers for rice and maize crops. This intervention is based on the foundational assumptions

- Inorganic fertilizers can be imported into Timor-Leste at the required volumes, provided there is either a government or private procurer.
- As with most inputs, there is a year on year dependency for the continued use of fertilizer. However despite some misconception, no decline in future years has been found as a result of the use of the input.

- Microdosing, or using a small amount of inorganic fertilizer, is an effective way to increase yields and considered an appropriate initial approach to help assimilate farmers to the use of inorganic fertilizer
- Over time, there may be an opportunity to increase the dose, as farmers and farming culture adapt to the use of inorganic inputs.

Model Specification

The methodology for evaluating this intervention involves a comparison of the incremental benefits and costs associated with the expanded use of inorganic fertilizer for rice and maize crop, relative to the baseline current use of fertilizer.

Benefit to Farmer	-	Costs to Government / Donor
Incremental return on rice + Incremental return on maize - Non-subsidized cost component of fertilizer		Subsidized cost component of fertilizer

The following parameters have been adopted in the benefit cost analysis:

Table A5.7: Parameters for Inorganic Fertilizer

Metric	*Unit*	*Value*	*Source*
Market price of rice	*$ / kg*	*$0.40*	*Williams, R. 2024*
Cost of Fertilizer	*$ / kg*	*$2.50*	*Williams, R. 2024, TOMAK*[1]
Rice:			
Cultivated Area	*ha*	*30,900*	*FAOSTAT*
Baseline Fertilizer use for Rice	*%*	*19%*	*Agriculture Census, 2019*
Baseline Yield	*t / ha*	*2.46*	*FAOSTAT 2022*
Maize			
Cultivated Area	*ha*	*48,753*	*FAOSTAT*
Baseline Fertilizer use for Maize	*%*	*6%*	*Agriculture Census, 2019*
Baseline Yield	*t / ha*	*1.78*	*FAOSTAT 2022*

1. The price of fertilizer in Maliana is $1.50 per kg (Williams 2024). The national market price of $2.50 / kg incorporates a cost for transportation of the fertilizer around the country (TOMAK 2018).

Baseline Specifications

In 2024, year 0, the estimated use of fertilizer for rice crop is 19% and 6% for maize crop (Agricultural Census, 2019). Without intervention, the use of fertilizer and resulting yield and production is assumed to remain at current levels for the next 10 year period.

Scenario Specifications

Two scenarios have been considered for the application of inorganic fertilizer.

1. ***Microdosing:*** The application of small appropriate amounts of fertilizer to minimize risk of overuse, and
2. ***Larger Dosage:*** Applications of larger amounts of fertilizer to maximize domestic rice production

The primary scenario is microdosing, introducing small appropriate amounts of fertilizer to improve yields while minimizing costs and environmental impacts and assimilating farmers who are not used to such practices.and the risk of over-fertilization. Microdosing is assumed to be an appropriate entry point with the option for scalability with demonstrated results and cultural acceptance. Based on research applied on rice in Timorese soils, the appropriate microdose would be 50kg of Urea and 50kg of Potassium Sulphate.

In the second scenario, larger applications of fertilizer are applied to maximize yields and increase production, with the intention to achieve rice self-sufficiency. For white rice in Timor-Leste, 100kg of Urea and 100kg of Potassium Sulphate has been found to be an appropriate larger dose, significantly increasing yields without leading to the risks of overuse.

Return to Farmer:

On a per hectare basis, the cost and returns for the farmer are considered.

Table A5.8: Net Returns for Rice Farmers

		Scenario 1	Scenario 2
Dose		50 kg U 50kg SP 36	100kg U 100kg SP 36
Yield Increase	%	23%	52%
Cost per ha	$	$150	$300
Return per ha	$	$270	$600
Net return per ha	$	$120	$300

The microdosing approach has been recommended as the most suitable method for Timor-Leste (Williams 2024). Studies on Timorese soil have demonstrated promising results with small amounts of fertilizer. For instance, applying 100 kg of fertilizer to white rice increased yields by 28%, from 2.7 to 3.4 tons per hectare (Williams 2024). On-farm trials have also shown that small doses of phosphorus (P) and nitrogen (N) can boost maize yields by up to 30% (TOMAK 2016). The effects of microdosing fertilizer on rice and maize are summarized in the tables below:

Table A5.9: Results of inorganic fertilizer intervention

Rice		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Baseline Coverage	**%**	19%	19%	19%	19%	19%	19%	19%	19%	19%	19%
Fertilizer subsidy	**%**	40%	40%	60%	60%	80%	80%	80%	60%	60%	40%
Intervention Coverage	**%**	30%	40%	50%	60%	60%	60%	60%	60%	60%	60%
Cost to Government	**$m**	0.38	0.55	1.58	1.99	3.51	3.63	3.63	2.17	2.17	1.07
Yield Increase		28%	28%	28%	28%	28%	28%	28%	28%	28%	28%

Maize		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Baseline Coverage	**%**	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
Fertilizer subsidy	**%**	40%	40%	60%	60%	80%	80%	80%	60%	60%	40%
Intervention Coverage	**%**	30%	40%	50%	60%	60%	60%	60%	60%	60%	60%
Cost to Government	**$m**	1.5	2.0	3.7	4.4	5.9	5.9	5.9	4.4	4.4	2.9
Yield Increase		30%	30%	30%	30%	30%	30%	30%	30%	30%	30%

Note: these results do not include 12.5% contingency.

Intervention 6: Expand farmer-sensitive coffee rehabilitation and intercropping of high value crops

Introduction

The coffee sector holds significant potential for enhancing food security and nutrition in Timor-Leste. Coffee is the country's largest non-oil export, with earnings between $14 and $28 million from 2017 to 2021 (Market Development Facility, 2023), indicating a strong international market presence for Timorese coffee. Stakeholder discussions within the coffee value chain reveal an unmet demand for Timorese coffee. Globally, coffee demand has doubled in the past 30 years and is expected to double again by 2050, suggesting a robust market for increased coffee production in Timor-Leste.

However, coffee farmers in Timor-Leste remain among the most vulnerable and food-insecure households. In Ermera, the primary coffee-producing municipality, 61% of households experienced moderate to severe food insecurity in 2023 (WFP, 2024). In 2014, about 50% of coffee-producing households were below the poverty line. Doubling coffee income could reduce poverty among these households to 28%, highlighting coffee's potential to alleviate poverty and improve food security and nutrition (Ministry of Agriculture and Fisheries, 2019).

Opportunity to Boost Coffee Yields through Rehabilitation

A significant portion of the coffee trees in Timor-Leste are beyond their productive years. The lack of replanting and proper pruning has led to some of the lowest coffee yields globally, with an average of 182 kg/ha compared to the global average of 2,000 kg/ha (Market Development Facility 2021). Consequently, the income of coffee-growing households remains very low.

The opportunity to address these low yields is in the regular Rehabilitation and Renovation (R&R) of coffee trees. Rehabilitation involves pruning and stumping existing trees, while renovation entails removing old trees and replacing them with new plantings. Although R&R can significantly boost productivity by up to 300% in the medium term, it may reduce production for 2-4 years initially (Market Development Facility 2021). As demonstrated in Timor-Leste in the current efforts of rehabilitation, any such intervention to encourage farmers to undertake this requires financial compensation and hand-holding in the form of training and extension support.

Rehabilitation and restoration of plantations represents a sizable opportunity for coffee farmers. The rehabilitation of 1ha of coffee plantation could boost farmers income from coffee by 200%, from $450 per year to an expected $1,360 per year.

Opportunity for Spice Production and Intercropping

Global demand for spices is increasing due to the growing popularity of ethnic cuisine, healthy foods, and the rise in convenience and ready-to-eat dishes that rely on spices and herbs for flavor. Global spice consumption is growing at an annual rate of 2% to 5%, with the market expected to exceed USD 20 billion by 2024 (TOMAK 2018, Fortune Business Insights 2024).

Common spices grown in Timor-Leste include cinnamon, cloves, galangal, ginger, pepper, turmeric, and more recently, vanilla. These spices are generally cultivated in the same areas as coffee and are often intercropped with coffee plantations.

The export market access provided by coffee traders like CCT has made spice production viable in Timor-Leste. Expanding the production and export of high-value spices presents a significant opportunity. Spices offer higher returns than many other crops. For example, the farmgate price of clove in Timor-Leste is $7.50/kg (TOMAK 2018), while vanilla prices ranged from $7 to $57 per kg between 2015 and 2018. Despite price variability and a downward trend in international spice prices (TOMAK 2018), these crops still fetch substantially higher prices compared to horticulture, which averages $0.86/kg in Timor-Leste (Williams 2024).

TOMAK's 2018 Analysis of the Spices Supply Chain identified three viable cash crops that should be prioritized to supplement coffee growth:

- Clove: High prices and a ready market in Indonesia's kretek cigarette industry and the food ingredient market.
- Black Pepper: Despite recent price declines, returns on investment remain high compared to other crops, and prices are expected to recover due to the cyclical nature of spice markets.
- Vanilla: Maintains high prices and strong global demand.

Intercropping these crops within coffee plantations is both environmentally and economically sustainable for Timorese farmers. This practice reduces livelihood risks by diversifying income sources and extending harvest opportunities throughout the year. The labor demands for these spices align well with coffee farming; for instance, vanilla is harvested before the coffee season, while pepper and clove are harvested afterward.

Additionally, spice production complements agroforestry systems, which are well-suited to Timor-Leste's topography.

By planting each of these crops in just 1% of their cultivated area (approximately 100 sqm for each crop per coffee farm), farmers could earn an additional $545 net profit per year. This represents a significant opportunity for vulnerable coffee farmers who currently earn $450 per year from coffee on average.

Intervention specifications
This intervention involves the expansion of 'farmer sensitive' coffee rehabilitation and intercropping with high value crops. The term 'farmer sensitive' entails several key success factors to ensure that rehabilitation is initiated by farmers, benefits are sustained, and other avenues for income generation are supported. Without accounting for all four factors below, the benefits are likely to be dramatically reduced. The factors include:

1. **Rehabilitation is conducted incrementally rather than all at once.** One clear and consistent finding from farmers and stakeholders is that rehabilitation needs to be conducted incrementally with 10-25% of trees stumped per year, rather than all at once. While the expected net present value of rehabilitation is positive for farmers, they are unable to wear several years of significantly reduced income. Moreover, the perceived risks associated with rehabilitation timelines act as a significant deterrent to undertaking the activity. However these perceived risks can be mitigated substantially when incremental models are used. Market Development Facility (2019) recommends the use of a 'two-stem' management system for simplicity.
2. **Trust in extension support may be more important than direct monetary compensation when deciding to initiate rehabilitation.** Discussions with stakeholders suggest the current *one off* compensation of $340 per ha is insufficient *by itself* to encourage many farmers to undertake the process. This is understandable, given that the estimated revenue from one hectare of coffee is approximately $450 *per year*, and that rehabilitation requires several years before the trees bear fruit again. Our discussions highlighted the importance of **trust in extension support** when deciding to initiate rehabilitation efforts. Stakeholders noted that this referred to both trust that they would be *supported during rehabilitation* and ongoing maintenance of trees, and that *the outcomes* (i.e. increased yield) would actually materialize. For example, a coffee farmer we interviewed in Ermera stated that his main motivation for joining the Asian Development Bank's CALIP program was based on advice from the government

extension worker. The same farmer stated he was provided with no other incentives.

3. **Guidance, seedlings, and equipment for intercropping are provided to bridge temporary income loss and diversify income streams over the long term**. Several farms and cooperatives have supported farmers in intercropping on coffee farms to bolster incomes during the rehabilitation process and beyond. This support includes guidance on pollinating, growing, and harvesting various crops, as well as the provision of seedlings, tools, and equipment (e.g., secateurs, tarpaulins). This approach addresses temporary income loss while stumped trees are regrowing and boosts and diversifies income across commodities and time, providing both income and insurance benefits in the long run. The optimal choice of crops will vary depending on the farm's altitude and the farmer's time horizon. According to the review conducted by TOMAK, the recommended crops for intercropping are clove, black pepper, and vanilla. Each of these crops has specific planting and harvesting requirements, especially vanilla, necessitating hands-on support to help farmers get started.
4. **Ongoing training and support are essential to reap benefits from rehabilitation and intercropping.** Rehabilitation is not a one-off activity. As the tree grows back, effort is required to sustain the improved yield. Market Development Facility (2019) notes three key maintenance activities that are required: i) pruning water shoots ii) cutting the top of the central branches (apical meristem) and iii) pruning unproductive lateral branches. Ideally (organic) fertilizer or mulch should also be applied at appropriate times. Given that many coffee farmers currently practice few cultivation techniques, maintenance represents a new set of activities that require support from agricultural extension workers to motivate, undertake, and sustain. If the practices are not implemented, then tree yields deteriorate to baseline levels after several years, generating close to zero net benefits. Intercropping activities would also require extension support especially in cases where farmers are implementing new crops. For example, vanilla requires a host tree to grow, as well as specific pruning and pollination techniques, activities which extension workers are best placed to provide guidance.

The expansion of farmer sensitive coffee rehabilitation

Model specifications

The methodology for evaluating this intervention involves a comparison of the incremental benefits and costs associated with the expanded rehabilitation of coffee plantations relative to the baseline program.

Net Benefit to Farmer	/	Costs to Government / Donor
Incremental Value on Coffee - Maintenance + Incremental Value on spices - Cost to cultivate (seeds / labor)		Cost of Rehabilitation + Incentives + Training + Extension support + Structures required to propagate growth (spices)

The expansion of farmer sensitive coffee rehabilitation

The intervention calls for an incremental 30,000 hectares of coffee plantation for rehabilitation. The following parameters have been adopted in the benefit cost analysis:

Table A6.1 General parameters for coffee rehabilitation

General Parameters	*Unit*	*Value*	*Source*
Coffee Production	kg[1]	10,765,000	National Coffee Sector Development Plan
Hectares of Coffee Production	ha	59,278	National Coffee Sector Development Plan
Yield per hectare	kg[1]/ ha	182	National Coffee Sector Development Plan[2]
Price per kg GBE	USD	2.5	ACT
Number of coffee hectares for rehabilitation	ha	30,000	Strategic Development Plan 2011-2030[3]
Average farm size	ha	1	National Coffee Sector Development Plan[4]

1. Kg of Green Bean Equivalent
2. Calculation from National Coffee Sector Development Plan
3. Estimate from strategic development plan
4. Conservative estimate based on National Coffee Sector Development Plan (62% household grow less than a ha, 95% grow less than 5 ha)

The rehabilitation program offers a significant 300% improvement in coffee yield after four years. However, there is a two-year period with no yield, leading to a delay in realizing these benefits. The benefit parameters are summarized in the table below:

Table A6.2 Benefit parameters for coffee rehabilitation

Benefit Parameters	***Unit***	***Value***	***Source***
Improvement in yield from stumping	%	300%	Estimates[1]
Time to hit maximum new yield	years	4	Stakeholder interviews
Growback period with no yield	years	2	

1. Estimate based on TechnoServe's Ethiopia study; National Development Plan 2011-2030 p127; MDF (2021) Rehabilitation of coffee trees in Timor-Leste

Rehabilitation should be staged in tranches over several years to account for the growback period. The model suggests six tranches, with 20% of trees rehabilitated in each tranche.

Table A6.3: Tranches for coffee rehabilitation

Hectares done per year		
1st tranche	20%	6,000
2nd tranche	40%	6,000
3rd tranche	60%	6,000
4th tranche	80%	6,000
5th tranche	100%	6,000
TOTAL		**30,000**

To support the program, farmers will need financial incentives, extension support, and training. The cost assumptions, derived from field research and stakeholder interviews, are outlined below:

Table A6.4: Cost parameters for coffee rehabilitation

Cost Parameters	*Unit*	*Value*	*Source*
Cost of rehabilitation - labor and equipment costs	USD per ha	457	MDF 2021
Cost of incentives	USD per ha	340	
Number of farmers supported per extension worker	farmers	250	Landell Mills[1]
Cost per extension worker	USD per year	3,785	Estimates[2]
Cost of training per farmer	USD per person	10	Nimmi Galearachchi[3]
Time required for maintenance per year	days	14	Nimmi Galearachchi[3]
Reserve price of labor	USD	5	TOMAK, 2016
Training of farmers	USD per ha	10	Nimmi Galearachchi[3]
Agricultural extension worker support	USD per ha	15	Calculation
Maintenance cost per year	USD per ha	70	Calculation

1. Private correspondence with Landell Mills 2024
2. Estimates based on TOMAK, SOL 2016 and ILO 2021
3. Private correspondence with Nimmi 2024

The expansion of intercropping of clove, black pepper and vanilla

This intervention extends the coffee rehabilitation model by working with the same coffee farmers and introducing additional cash crops to diversify revenue streams. The following parameters have been applied to estimate the costs and benefits of this intervention:

Table A6.5: Parameters for Cash Crops for Intercropping

Metric	Unit	Cloves	Pepper	Vanilla
Number of Farmers[1]	*#*	3,000	2,000	1,200
Production[1]	*t*	452	46	21
Yield[3]	*t/ha*	1.40	0.75	1.25
Farmgate Price[1]	*$/kg*	7.5	7.0	32.0

Revenue per Ha	***$/ha***	**10,500**	**5,250**	**40,000**
Cost per HA				
Labour days Planting	*days / ha*	6	15	150
Labour Days harvest	*days / ha*	54	135	300
Total labor days[1]	*days / ha*	*60*	*150*	*450*
Labour cost per day[4]	*$*	11	11	11
Labor cost per ha	*$*	687	1,718	5,155
Cost of seed per kg[5]	*$/kg*	2	2	0
Seed requirement	*kg / ha*	1	1,695	0
Reduction from use of cuttings	%	0%	90%	100%
Cost of seed	*$ /ha*	2	254	0
Cost per ha	***$***	**689**	**1,972**	**5,155**
Net return per ha	*$*	9,811	3,278	34,845
Years until first harvest (post planting)		6	3	3
Increase production of cash crops	*% increase*	200%	200%	200%
Cost to Government				
Cost to build structure to propagate growth		10,000		
Structures required per municipality		1		
Number of municipalities supported		6		
Cost to support incubation of industry in 6 Municipalities[6]		60,000		

1. TOMAK Analysis of Spice Value Chain 2018
2. 2019 Agricultural Census
3. Estimated based on TOMAK Analysis of Spice Value Chain 2018
4. ILO, 2021
5. Estimated based on Seeds of Life and interviews with Anaprofiko
6. Municipalities supported include Bobonaro, Ailue, Ermera, Ainaro, Liquica, Manufahi. To be verified in implementation planning.

Results:

The results of the 10 year intervention are summarized below.

Table A6.6: Results of standalone coffee and cash crops intervention

	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Intervention Coverage Coffee (%)	20%	40%	60%	80%	100%	100%	100%	100%	100%	100%
Intervention coverage Spices (%)	100%	120%	140%	160%	180%	200%	200%	200%	200%	200%
Incremental Cost to to Gov ($m)	4.84	5.11	5.02	5.11	5.21	0.45	0.5	0.5	0.5	0.5
Incremental Net Benefits to Farmers ($m)										
Coffee	0.0	-0.4	-0.8	1.5	6.5	11.5	17.0	22.4	25.1	25.1
Clove	0.0	0.0	0.0	0.0	0.0	0.6	1.2	1.8	2.4	3.0
Black Pepper	0.0	0.0	0.2	0.4	0.6	0.9	1.1	1.1	1.1	1.4
Vanilla	0.0	-0.1	2.1	4.3	6.5	8.8	11.0	11.0	11.0	12.0

Note: these results do not include 12.5% contingency.

Intervention 7: Hermetic Storage for Maize

Introduction

A key issue affecting agriculture production is the loss of yields associated with insufficient postharvest practices. In Timor-Leste postharvest losses are significant, in the estimated range of 20%-50%, which affects the incomes of farming households and national food security (WFP 2019).

Inadequate storage methods contribute to these losses. About 10% of initial rice production and up to 30% of maize is lost due to the traditional storage methods (IFAD 2016). In the case of maize, storage loss is attributable to weevils (17%), rats/mice (5%), mold (3%), and chickens (1%) (IFAD 2016).

Postharvest storage loss has consequences not only on household hunger, but also on market access. Without adequate storage, smallholder farmers face pressure to sell crops immediately after harvest resulting in falling prices right after harvest and peak prices just before the next one. In Timor-Leste in the case of maize, the market price at planting ($1/kg) is much higher than at harvest ($0.35/kg). Households with the right facilities are able to store surplus grain until the next planting time with no losses. This allows them to sell clean grain as seed at planting time capitalizing on the higher price (TL Compendium 2021). As the agricultural system improves, the ability to store grain and smooth market access will become an increasingly important strategy for farmers. With higher yields and better market access, it is expected that both the volume and value of stored grain will increase significantly.

The improvement of postharvest practices is mentioned across national policies and has been recognised as a KONSSANTIL priority area for improved nutrition (WFP 2021). Moreover, interest in post-harvest production techniques was consistently cited among farmer groups (Baucau, Maliana), of which, post-harvest storage is a critical starting point.

Intervention

The intervention is the expansion of the use of hermetic drums for storage of maize and is based on the successful implementation of the IFAD-supported program, Timor-Leste Maize Storage Project (TLMSP I).

TLMSP I delivered 43,000 hermetic drums to 23,000 maize growing households in Timor-Leste between 2011 - 2015. This simple technology proved to be very effective and TLMSP I produced significant benefits in Timor-Leste. Farmers who adopted the drums experienced more than 93% reduction in postharvest storage losses. This resulted in an estimated saving of 80 kg of staple food per target family every year. The food security of target households was substantially improved as a result of the intervention. According to the final impact assessment, the percentage of households experiencing a first hungry season reduced from 95 to 33 per cent, while the percentage of households experiencing a second hungry season dropped from 31 to 6 per cent. Among children under 5 years, acute malnutrition was reduced by 3.2 per cent, chronic malnutrition was reduced by 3.3 per cent, and the rate of underweight children was reduced by 14.1 per cent in the area in which the programme was run (OnePlanet 2020). In addition the drums reduced the risk of contamination and as a result of the intervention, the project area now has the lowest occurrence of mycotoxin in Timor-Leste (IFAD 2019).

With an estimated 102,000 maize growing households there is ample scope to expand the use of hermetic drums. A phase 2 concept for the TLMSP was developed in 2014, which outlined the proposed implementation of an additional 150,000 drums to 50,000 maize growing families. The concept was not implemented at the time due to policy and funding barriers. Yet given the simplicity and success of TLMSP I, the recommendation is to now implement the second phase of this successful maize storage initiative.

The successful implementation is based on the following parameters:

1. **Drums must be provided at a subsidized cost, yet some financial contribution from the farmers is important to encourage adoption and effective use of the drums.** Previous government programmes that supplied free storage drums in Timor-Leste underperformed, mainly because the drums were either mis-used or not used at all by beneficiaries (IFAD 2019). To encourage farmers to value the drums and use them effectively, the farmers must be required to make some financial contribution towards the procurement of the drum, which can be matched by a government subsidy to cover the remaining cost. In the IFAD the beneficiaries paid $10 for the drum which was matched with a voucher to subsidize the

remaining cost of the drum, resulting in 93% adoption and correct use of the hermetic drum (IFAD 2019).

2. **Local manufacturing of the drums will ultimately reduce the cost of the drums and increase access for the improved storage systems.** TLMSPI relied on imported drums from a manufacturer in Indonesia, which were expensive ($60 per drum) and resulted in delays and logistical challenges. The small scale of the Timorese project prevented more efficient and cheaper manufacturers from China and India from bidding for the contract in Timor. On-shore manufacture is deemed feasible in Timor-Leste and expected to be able to produce drums for less ($50 per drum) and be a more efficient approach in stimulating the supply of hermetic drums and enabling access to local farmers. Equity partnership and mentorship would be required to equip timor-leste's evolving private sector in the incubation of this sector.

3. **Support will be required to socialize, promote correct use and maintenance of hermetic drums.** Hermetic drums are relatively low maintenance and easy to use, which is a primary advantage compared to other storage technologies. Despite this, it is assumed that farmers will need some initial training to become equipped with practical skills and knowledge for effective use, maintenance, and additional seed storage techniques.

Model Specification

The methodology for evaluating this intervention involves a comparison of the incremental benefits and costs associated with the expanded use of hermetic storage for maize, relative to the baseline use.

Benefit to Farmer	-	Costs to Government / Donor
A. Maize Loss Avoided - B. Initial Investment in Drum (farmer's share)		C. Initial Investment in Drum (Donor's Share) + D. Overhead costs

The following parameters have been adopted in the benefit cost analysis

Table A7.1: General Parameters for Hermetic Storage

Baseline	Metric	Value	Source:

Cultivated Area	ha	48,753	FAOSTAT
Production	t	87,000	FAOSTAT
Baseline Yield	t/ha	1.8	FAOSTAT
National Maize Households	#	102,350	TLMSP I
Production of Maize per Household	t	0.9	Mettalytics Analysis
Post Harvest Storage Losses (no drum)	%	30%	TLMSP I
Post Harvest Storage Losses (with Drum)	%	1%	TLMSP I
Lifespan of Drum	yrs	20	TLMSP I

The price of maize has been weighted to account for the volume of maize that can be sold at a higher price due to market demand in the "hungry season".

Table A7.2: Price Assumptions for Maize

Price of Maize	Portion	Price	Source
Post Harvest (Feb - Sept)	67%	0.35	William,s R 2024
Hungry Season (October - Jan)	33%	1.00	TLMSP II
Weighted Price of Maize		**0.57**	Mettalytics Analysis

The cost of the drum is assumed to be lower than in Phase 1 of the project due to efficiencies gained in the on-shore manufacture. The total cost of a drum, including overheads, in this scenario is $80, compared to $100 in Phase 1 (TLMSP II).

Table A7.3: Cost Parameters for Hermetic Storage

Cost per Drum			Source:
Drum Cost	$	40	TLMSP II
Overhead (or margin)	$ / drum	40	TLMSP II
Cost per drum		**80**	TLMSP II
Cost to Farmer	$/drum	10	TLMSP I
Cost of Drum to Donor	$/drum	40	TLMSP I
Cost of Overheads to Donor	$/drum	50	TLMSP I

Scenario Specification

The scenario is based on the TLMSP Phase II concept that suggested targeting the remaining maize growing families with 4 drums per household.

Table A7.4: Households in Scope for Hermetic Storage

Metric	Unit	Value
Total Maize Growing Households	#	102,350
Households Covered in TLMS I	#	23,001
Remaining Households	#	79,350
Drums per household	#	4

Source: IFAD 2016

The results could lead to 60% of maize-growing households having storage drums and reduce national post-harvest storage losses by 37% by 2034. In the integrated model, increased maize production generates larger storage needs for a given level of coverage.

Table A7.5: Results of hermetic storage intervention

Maize		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Drum baseline coverage	% of all maize	9.7%	9.7%	9.7%	9.7%	9.7%	9.7%	9.7%	9.7%	9.7%	9.7%
Drum intervention coverage	% of all maize	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%
Cost to Government	$m	2.2	2.2	2.4	2.3	2.1	2.1	2.1	2.1	2.2	2.2
Reduction in Post Harvest Losses	% of total	0%	0%	0%	0%	4%	11%	17%	24%	31%	37%

Note: these results do not include 12.5% contingency.

Intervention 8: Fortification of Rice

Introduction

Anemia remains widespread across Timor-Leste, affecting 17.8% of adults and 46% of children under 5. Anemia not only leads to suboptimal health outcomes but has significant economic consequences due to reduced productivity and increased strain on the healthcare system.

Anemia is defined as low levels of hemoglobin (HB) in the blood, and iron deficiency is the leading cause of anemia amongst adults. Lower hemoglobin (Hb) levels diminish the blood's oxygen-carrying capacity, leading to lethargy, fatigue, poor concentration, and decreased cognitive ability (Kraemer and Zimmerman, 2007). The impact of low Hb in adults is well-documented, resulting in reduced work capacity and productivity.

Fortification of rice with iron and other micronutrients is a low cost, wide-reaching approach that is expected to increase the levels of HB and reduce the burden of iron deficiency anemia.

Fortification has the potential to deliver a high ROI, particularly when implemented in conjunction with existing large mills that serve a substantial share of the population's staple food consumption needs. Fortification occurs before the grain reaches the consumer, during a normal part of food processing activity (i.e. milling). This implies limited marginal costs, except for the premix which is relatively inexpensive per tonne of fortified rice. Importantly, fortification does not change the taste or the texture of the rice and does not require any behavior change on behalf of the consumer.

Fortified Rice and School Feeding

In the last 12 months in Timor-Leste, local fortified rice was introduced to the school feeding program in Manufahi, Bobonaro and Baucau. Given the relative infancy of the program, the evidence in health outcomes for children receiving the fortified product has not yet been observed (WFP). In other contexts, fortification has resulted in significant benefits, ranging from reduced prevalence of nutritional deficiencies, improved health outcomes and productivity benefits for societies and economies (Olsen 2021). Chong et al (2015) studied the impact of iron fortification on school performance and found the average grades of the treated anemic subsample improved over 0.45 standard deviations over the period of a year. Improvement in school performance is directly linked to future earning, and we use an assumption that an increase of 1 standard deviation in test scores drives 20% increase future earnings (Angrist et al. 2023).

Supply of fortified rice in Timor-Leste

Rice mills are the natural site for fortification, yet the volume of rice processed in the majority of millers is too small to warrant investment in fortification. A fortification machine has the capacity to fortify up to 32 tonnes of rice per day, and many of the small millers are working at a capacity of 1 tonne per day. This poses a challenge to the viable expansion of this intervention in this context.

There are currently three known fortification sites, located at large millers in Baucau, Bobonaro and Liquica (WFP). The quantity of rice fortified is limited by the volume of rice milled at each site and each mill is currently working at 25-50% fortification (WFP). Rice mills are the natural site for fortification, yet the volume of rice processed in the majority of millers is too small to warrant investment in fortification. The potential to scale this initiative is challenged by the decentralized nature of the industry. Despite limited opportunity for expansion, a fourth potential site has been identified in Manufahi as a viable opportunity for fortification.

Intervention Specifications

In the current agricultural context, the opportunity for the expansion of fortification is limited by the existing capacity at the mills. However, in the context of an improved agricultural system with dramatic increase in rice yields, the opportunities for fortification expand significantly. While all the interventions recommended in this brief are synergistic, the scalability of fortification in particular is dependent on implementation and result of other interventions. In particular, the use of improved seeds and inorganic fertilizers as soil amendment are expected to increase rice production by 1.8t/ha, 73% increase on current production.

As such, there are three potential scenarios for the expansion of the fortification of rice in Timor-Leste.

1. **Base Scenario:** As a standalone intervention, the recommendation is to establish fortification at the site in Manufahi, and provide the fortified grain firstly to supply school feeding for the area and secondly for household consumption. This has been modeled as the base case intervention for fortification.

2. **Expanded capacity at existing millers:** As rice yields increase with the implementation of interventions including improved seed and the use of fertilizer, the capacity at the existing mills will increase and there will be larger volumes of rice for fortification. This scenario has been modeled, assuming that the existing

mills will be able to pr as the potential is highly likely with the improvements in the agriculture system.

3. **Potential creation of new sites for fortification:** As the volume of rice produced around the country increases there may be the natural creation of additional large millers who become viable producers of fortified rice. This scenario has not been modeled due to limited insight into the potential expansion in different rice growing regions in Timor-Leste.

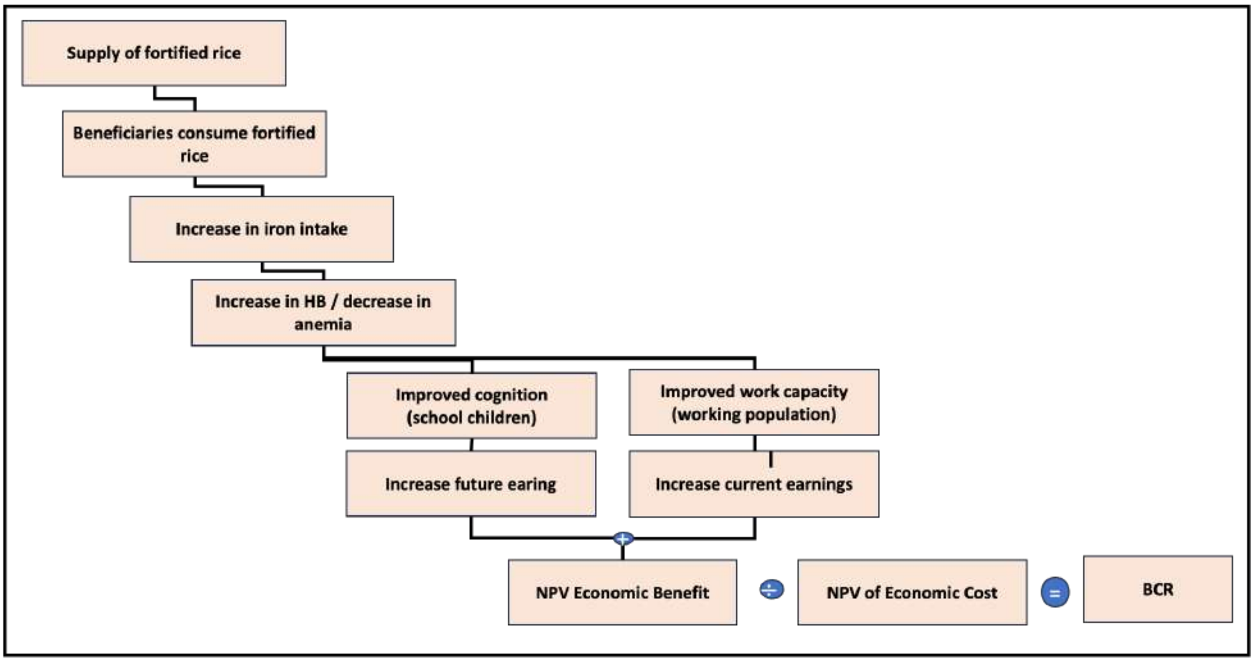
Model Specification

The benefit cost analysis involves a comparison of the incremental benefits and costs associated with additional production and consumption of fortified rice, relative to the baseline production and consumption.

The benefits is driven by

A. **Increase in future productivity:** Improved cognition of anemic school children leading to improved school performance and future earnings
B. **Increase in current productivity:** Increased work capacity of anemic adult workers leading increased current earnings

The costs associated with delivery include capital equipment and maintenance, cost of fortificant (inputs) and costs to deliver the program.



The methodology for assessing the economic benefits of fortified rice draws from the approach documented in Qureshy et al (2023). This model applies a number of parameters to map fortified rice consumption to expected HB response amongst the working age population, in a multistep analysis, which is briefly outlined below.

I. Determining the number beneficiaries

The first step involves determining who will benefit from the fortificant. In the context of Timor-Leste where there is limited supply of fortified rice, policy is required to determine where and how the rice should be distributed across the population

To have a meaningful impact on hemoglobin levels, a minimum dose of fortificant is required. As rice is fortified in specific areas, it is assumed that the fortified rice will supply the population in that area. This concentrated approach will increase the likelihood of success, as well as avoid costly and logistically challenging transport issues.

The supply of fortified rice will firstly provide rice to the school feeding program, covering elementary school children, ages 6-11, with 100g of fortified rice per school day (240 days). The “excess” supply can serve the general public.

The 2022 Population and Housing Census provides the population data by municipality. The number of school children has been extrapolated by applying the age demographic profile from CIA World Factbook.

The working adult population, age 15-64 by gender, has been drawn from the ILO Labour Survey 2021. Rates of anemia have been obtained from the 2016 Timor-Leste Demographic Health Survey

This analysis evaluates the benefits of fortification for individuals who are anemic. Anemia rates were obtained from the 2016 Timor-Leste Demographic and Health Survey, which provides detailed rates for adult men and women by municipality and for children under five by municipality. The anemia rates for children aged 6-11 years are not directly reported in the survey; therefore, they have been estimated based on the available data for adults and children under five.

II. Determining quantity of rice consumed

On average, Timorese individuals consume 115 kg of rice per capita annually, which is approximately 315 grams per day. It is assumed that rice is a staple food consumed daily by all Timorese, meaning that the introduction of fortified rice would not require any changes in their dietary habits.

For both the school feeding program and general public consumption, it is assumed that each beneficiary will receive 100g of fortified rice per day. This aligns with the lower end of quantities provided in successful programs in other regions (Qureshy et al., 2023).

III. Determining additional iron intake, change in HB and duration

The additional daily iron intake per beneficiary is calculated by multiplying the fortificant level in the rice by the daily rice consumption. This analysis adopts a conventional fortification level of 4 mg per 100 g of rice, consistent with global standards and current practices in Timor-Leste (WFP). The program is assumed to run for over 10 years.

Research shows that hemoglobin (Hb) levels respond to iron intake in a diminishing return pattern (Qureshy et al., 2023). Hb levels increase until they normalize, after which the response diminishes and plateaus, with a more pronounced response at lower initial Hb levels. The analysis formula assumes 50% of the total Hb response occurs with the first third of the dose, 30% with the next third, and 20% with the final third.

The Hb response is based on Peña-Rosas et al. (2015)'s meta-analysis of iron fortification of rice, estimating an average Hb increase of 0.393 g/dL for iron fortification alone.

While most research examines higher average daily doses over shorter periods (ie. 15mg/day over 150 days), evidence suggests that a low dose over a longer duration can also predict Hb response (Ekstrom et al., 2002). This analysis conservatively estimates impacts over a year, assuming that recipients receive the fortificant consistently throughout this period to achieve a change in HB.

IV. Determining increase in productivity and learning

This analysis considered two economic outcomes from the change in HB, i) improved cognition in school children and ii) productivity gain in working adults.

i) Improved Cognition

The increase in hemoglobin levels can be associated with enhanced learning outcomes and improved academic performance in school (Chong et al., 2015). It is assumed that cognitive gains are realized only if anemia is prevented. Not all anemia is due to iron deficiency, factors such as the prevalence of worms or disease can also cause anemia. In these cases, fortification may not be effective. A meta-analysis of large-scale fortification programs reported a 34% decline in anemia prevalence (Keats et al., 2019), accounting for anemia cases not related to iron deficiency.

This analysis adopts Chong et al. (2015)'s estimate of a 0.45 standard deviation improvement in academic performance resulting from the reduction of anemia. The cognitive benefits of fortification are assumed to accumulate in school-aged children for each year they receive fortified meals. This improvement is applied to 34% of the anemic student population, who are presumed to experience a reduction in anemia through an iron supplementation program.

ii) Productivity Gains

The analysis assumes that all adult beneficiaries of the fortification program who experience improved hemoglobin (Hb) levels will see enhanced work capacity, leading to increased productivity. Unlike improved learning outcomes, it is assumed that work capacity increases proportionally with Hb levels, rather than only when anemia is averted (Qureshy et al., 2023).

To map the Hb increase to productivity, a linear relationship is assumed across all Hb values, applying an average increase rather than a sharper increase for those with initially lower Hb levels. The model adjusts productivity gains or Hb improvements by gender, maintaining a linear relationship between Hb levels and productivity. Thus, ΔPraqg represents the product of the percentage change in productivity and the change in hemoglobin levels (Qureshy et al., 2023).

Following the established methodologies for estimating productivity gains presented and reviewed by Qureshy et al. (2023), this analysis distinguishes between the impacts on heavy manual and light manual work. For heavy manual labor, such as construction and mining, there is a 16.5% productivity increase associated with increases in hemoglobin (Hb) (Basta et al., 1979). For light manual work, including the service sector and manufacturing, there is an estimated 5% productivity increase (Li et al., 1994; Rajagopal and Vinodkumar, 2000).

The productivity gains are adjusted based on the proportion of the workforce in each sector, which has been estimated from the 2021 Timor-Leste Labour Force Survey. Specifically, the 16.5% increase in heavy manual productivity corresponds to a 1.5 g/dL increase in Hb, and the 5% increase in light manual productivity corresponds to a 1.3 g/dL increase in Hb. Therefore, the productivity gain (ΔPraqg) is calculated as follows:

- Heavy Manual Labour: 0.165/1.5g/dL × ΔHbaqg
- Light Manual Work: 0.05/1.3g/dL × ΔHbaqg.

There is also an increase in productivity in domestic work, which can be applied to the adult population outside the workforce. It is assumed that domestic work corresponds to light manual work, and the same formula is applied (0.05/1.3g/dL × ΔHbaqg).

V. Determining the economic benefit as earning gains

Changes in learning are associated with future earnings. The impact of 1 standard deviation improvement has been reported to lead to an increase in future earnings of 20% (Angrist et al. 2023) up to an average of 36% (Evans and Yuan 2019). The conservative estimate of 20% has been adopted for this analysis.

A child with anemia is therefore assumed to earn 0.45 * 0.2 = 9% less than a non-anemic student for every year the child has anemia. The stream of income for non-anemic children is assumed to reflect GDP per capita, growing at 2% per year, a conservative estimate. The economic benefit is the avoided 9% loss of income and is applied to the number of participating students that have anemia, multiplied by 34% to reflect the probability of the program in reducing anemia, and scaled to account for labor force participation rate in Timor-Leste, approximately 30%. The present value of increased future earnings from cognitive gains is calculated by discounting the earnings stream at an annual rate of 7 percent. This calculation spans the adult working life of the children, from age 15 to 64, covering a period of 50 years.

Changes in adult productivity are associated with current earnings. An economic value is applied by multiplying the productivity gain with the current wage by gender.

For individuals employed in agriculture and industry, it is assumed that productivity gains are equivalent to heavy manual labor for 100% of men and 50% of women. The remaining 50% of women in these sectors are presumed to engage in lighter manual labor.

Although their unpaid work is not included in GDP calculations, domestic workers are assumed to achieve productivity gains similar to those of light manual labor. To account for the welfare value of this productivity gain, which should translate to time savings, a benefit factor of 0.5 is applied to average wages (Whittington and Cook, 2019).

The beneficiaries are assumed to achieve productivity gains for each year over the 10-year program, and their earnings are discounted at 7% to calculate the net present value of the economic gains.

VI. Determining the cost of fortification

The program's costs include a fixed initial expense for equipment and setup, estimated at approximately $45,000 (WFP). Ongoing maintenance is projected to be $1,000 per annum (WFP). The primary variable cost is the imported fortificant input, costing $37 per tonne of fortified rice (WFP).

VII. Calculating benefit cost ratio:

Benefit	/	Costs to Government / Donor	=	BCR
A. NPV of Increase in future productivity (children) + B. NPV of Increase in current productivity (adults)		C. NPV of Capital Cost of Equipment + D. NPV of Maintenance Cost + E. NPV of Cost of Inputs + F. NPV of Cost of Program		BCR

The following national parameters have been applied in the BCR.

Table A8.1 Parameters for Improved Cognition leading to future earnings

Metric	Unit	Value
Total Population	million	1.37
School Feeding: Aged 6-11		
Portion of total population aged 6-11	%	15%
Portion of school children with Anemia	%	26%
Quantity of Fortified Rice Consumed per Day	g / day	100
Level of iron fortificant	mg / day	4
Reduction in Anemia (% of anemic population)	%	34%

Metric	Unit	Value
Academic Performance Improvement	per annum	0.45
Increase in Earnings per SD Improvement	%	20%
Increase in earnings in school children	per annum	9.00%
Average GDP per Capita (2024)	USD	2,389
Annual Growth in GDP	%	2%

Table A8.2 Parameters for improved productivity leading to current earnings

		Men	Women
Population Aged 15-64		403,600	405,800
Anemic (national)		13%	26%
Labour Force Participation		36.89%	24.17%
Domestic Participation		63.11%	75.83%
Heavy Workload		15%	5%
Light Workload		22%	19%
Domestic Workload (Light)		63%	76%
Quantity of Fortified Rice Consumed per Day	g	100	100
Net Increase of HB	g/dL	0.393	0.393
Change in labor (heavy)	%	16.50%	16.5%
Change in labor (light)		5.0%	5.0%
Change in labor (domestic)		5.0%	5.0%
Impact of HB (heavy)		1.5	1.5
Impact of HB (light)		1.3	1.3
Impact of HB (domestic)		1.3	1.3
Change in Productivity (heavy)		4.32%	4.32%
Change in productivity (light)		1.51%	1.51%
Change in Productivity (domestic)		1.51%	1.51%
Average Wage (annual)	USD	3084	2880
Benefit Factor (heavy)		1	1

Benefit Factor (light)		1	1
Benefit Factor (domestic)		0.5	0.5
Potential Benefit per Person (workforce heavy)	USD	133.32	124.50
Potential Benefit Per Person (Workforce Light)	USD	46.62	43.53
Potential Benefit per Person (domestic)	USD	23.31	21.77

The results of fortification are noteworthy. A school child with anemia could earn an additional $4,240 over their lifetime due to the fortification provided through the school feeding program. On average, an adult with anemia could see an annual income increase of $37.90 due to improved productivity.

At the national level, the benefits of the program are substantial, while the costs required to achieve these significant outcomes are relatively minimal.

Table A8.3; Results for Fortification

		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Total costs to government	$ millions	0.15	0.24	0.39	0.52	0.61	0.70	0.71	0.71	0.72	0.74
Benefit	$ millions	2.0	2.3	2.6	2.9	3.0	3.2	3.2	3.3	3.3	3.3

In the integrated model, we assess the potential unmet capacity of the existing mills and the site at Manufahi to be 22,080 tonnes per year. As rice production increases due to the other interventions, we assume 40% reaches these large mills (similar to current share), increasing the availability of fortified rice. Fortified rice is prioritized for school children with the remainder going to the general population.

Intervention 9: Scale Up Selected Community- and Facility-Based Nutrition Specific Interventions

Introduction

At an estimated prevalence of 47% in 2020, Timor Leste has one of the highest rates of child stunting in the world (Nomura et al. 2023). Stunting causes a raft of well known health (Olofin et al. 2013), cognitive (Sudfield et al. 2015), and socio-economic challenges (Hoddinott et al. 2013; McGovern et al. 2017). Estimates have placed the adult productivity loss associated with child stunting at 30% (Gelli et al. 2022). Other malnutrition indicators are poor in Timor Leste. Rates of child wasting are 8% (World Bank, 2024). Micronutrient deficiencies are widespread (see section on rice fortification). These nutrition deficiencies contribute to high rates of child mortality estimated at 51 deaths per 1000 births (World Bank, 2024) and maternal mortality estimated at 129 deaths per 100,000 live births in 2016 (World Bank, 2024).

Nutrition is a priority of the government and WFP. Nutrition appears prominently in the Strategic Development Plan 2011-2030. The Costing of Consolidated National Action Plan for Nutrition and Food Security sets out a series of interventions to meet SDG 2. Despite current challenges, nutrition indicators have improved slowly over time.

The intervention calls for ensuring the health system has sufficient budget to conduct critical nutrition tasks such as infant and young child feeding practice counseling, deworming, vitamin A supplementation, child growth monitoring and maternal nutrition supplementation. During our visits to Timor Leste, nutrition leadership at the Ministry of Health pointed out that a budget for nutrition coordinators - the primary frontline health workers tasked with nutrition interventions - had not been approved, casting uncertainty on the employment and operational status of the nutrition function. This should be rectified as soon as possible.

Moreover, our discussions with the Ministry of Health and frontline workers suggest that the workload on the existing cadre of nutrition coordinators is too large to execute effectively, necessitating the need for additional human resources. For example, a nutrition coordinator we met in Maliana indicated she and four staff had to cover a population of 30,000, substantially lower than requirements to provide adequate coverage for the population, especially children and mothers. Within this population of 30,000 there were 2,970 children requiring visits twice annually, 588 breastfeeding mothers and 647 pregnant women requiring monthly patient interactions. The number of expected patient interactions for this cadre of five staff is therefore around 19,000 or more than 3,700 per health worker per year - substantially more than is physically feasible by any individual. This is likely contributing to less than optimal coverage of nutrition interventions across the country. Lastly, in The Indicative Costing of Timor-Leste's Consolidated National Action Plan for Nutrition and Food Security (Qureshy et al, 2024) consulted a number of reports including several surveys (TLFNS 2020; TLDHS, 2016), National Health Sector Nutrition Strategic Plan (NHSNSP 2022-26) and the General Directorate of Statistics (GDS, MOH and ICF 2018), identifying low levels of coverage for many nutrition specific interventions.

Nutrition specific interventions consistently rate as some of the highest returning interventions in all of global health and development (Larsen, Hoddinott and Razvi, 2023). The 2013 Lancet series on Nutrition established a package of high impact, high returning interventions to address stunting and other forms of undernutrition (Bhutta et al. 2013). These interventions are part of the established guidelines for nutrition coordinators in Timor Leste, but there are insufficient resources to enable full coverage.

Intervention Specification

For this analysis, we assume scale up of some but not all interventions in The Indicative Costing of Timor-Leste's Consolidated National Action Plan for Nutrition and Food Security (Qureshy et al, 2024). Our subset focuses specifically on nine interventions that could be implemented by the healthcare system, as nutrition specific interventions tend to have higher ROIs than nutrition sensitive interventions (Aryeetey et al. 2020). Moreover, within this subset we include interventions with higher returns or stronger evidence of impact. The Indicative Costing (Qureshy) estimates an additional $15.6 million per year in steady state for just nutrition specific interventions, which is substantially higher than current funding of $2 million per year. In contrast, focusing on a high performing subset would only cost an additional $2.9 million per year. Incidentally, during our visit in January 2024, officials at the Nutrition Department of the Ministry of Health suggested that a similar budget increase was required to enable them to fulfill their primary duties.

The nine activities in this high-performing subset are noted below, with figures drawn from Qureshy et al (2024). The package includes social and behavioral change interventions around breastfeeding and complementary food provision, several supplementation interventions for pregnant women and children, and two curative interventions focusing on treatment of diarrheal disease and severe acute malnutrition. Across the package, baseline coverage levels are low (<20%) for five interventions and moderate (20-50%) for three. Only the provision of Vitamin A is reasonably high at 78% coverage. Target coverage levels are set to 80% across interventions uniformly.

Table A9.1: Beneficiaries, current coverage, target coverage and costs of nutriton interventions

Intervention	Number of potential beneficiaries	Current coverage (%)	Target coverage (%)	Unit Costs	Incremental cost per year at target coverage (USD)
Early initiation of breastfeeding promotion	41,078	10%	80%	$15.0	431,319
Exclusive breastfeeding for first 6 months and continued breastfeeding promotion	19,301	10%	80%	$15.0	202,661
Complementary feeding promotion	18,288	10%	80%	$15.0	192,024
IFA supplementation in pregnancy	41,078	32%	80%	$13.8	272,101
Vitamin A (2 rounds per year)	198,394	78%	80%	$1.6	6,349
ORS + Zinc for diarrhea	221,718	50%	80%	$3.1	204,867
Deworming	182,403	50%	80%	$0.7	38,305
Multiple micronutrient supplementation for children	18,288	19%	80%	$7.0	78,090
Ready to use therapeutic food for SAM management	7,880	12%	80%	$266.0	1,425,334
				TOTAL	2,851,050

Source: Adapted from Qureshy et al. (2024).

Costs

Our costing methods draw from the report by Qureshy et al. (2024). For each intervention unit costs were identified via literature search and Timorese budget documents, and then inflated to current USD using GDP deflators. Unit costs are presented in Table A9.1, and a detailed description of each source is contained in Annexure 2 of Qureshy et al. (2024). Our estimates of incremental costs is simply the difference between the target and coverage rate, multiplied by the number of potential beneficiaries and the unit cost.

Impacts

Impacts of the intervention were estimated using the Lives Saved Tool (or LiST), an online platform that allows for modeling of various interventions to address malnutrition, maternal and child mortality. LiST was originally developed in 2003 for the Lancet Nutrition Series, and has undergone updates and iterations as new evidence has emerged and to include more interventions (Walker et al. 2017). It is used extensively in global health modeling (e.g. Wong and Radin, 2017).

The following interventions were included in the LiST simulation:

1. Breastfeeding promotion
2. Provision of appropriate fortified complementary food for food secure population
3. Vitamin A supplementation
4. ORS for treatment of diarrhea
5. Zinc for treatment of diarrhea
6. Treatment for severe acute malnutrition

LiST has specific, unmodifiable intervention categories that do not necessarily map exactly to the interventions in the Consolidated National Action Plan for Nutrition and Food Security. The above six LiST interventions represent the closest interventions to the nine in the package. The first two LiST interventions map to the three promotion activities in Table A9.1. The LiST interventions on Vitamin A supplementation, ORS and zinc treatment for diarrhea and treatment for SAM map exactly to the same interventions in Table A9.1. However, LiST does not include any interventions for IFA supplementation, deworming or multiple micronutrient supplementation for children. These benefits are excluded from the calculations and so the impacts might be considered conservative.

We report two important impacts from the LiST simulation: child mortality and cases of child stunting. The results indicate that scaling up the package of interventions would result in 245 avoided child deaths and 8,588 avoided cases of stunting in steady state.

Child mortality	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Intervention	1,410	1,409	1,408	1,404	1,446	1,400	1,396	1,387	1,378	1,367
Baseline	1,660	1,660	1,659	1,656	1,654	1,646	1,644	1,634	1,624	1,612
Avoided child mortality	251	251	251	251	207	247	248	247	246	245
Stunting										
Intervention	69,266	67,166	65,129	63,038	63,097	62,990	62,808	62,603	61,918	61,286
Baseline	71,597	71,496	71,348	71,144	71,036	70,945	70,786	70,560	70,264	69,874
Avoided stunting	2,331	4,330	6,219	8,106	7,939	7,955	7,978	7,956	8,346	8,588

Source: Estimates by the authors

Benefits

Child mortality benefits are monetized using a value-of-statistical-life (VSL) approach. The VSL of Timor-Leste is estimated using the approach documented in Robinson et al. (2019). The ratio of VSL to income per capita is estimated using the following equation:

$$VSL\ multiplier = \left[\frac{GDP\ per\ capita\ (Timor - Leste)}{GDP\ per\ capita\ (USA)}\right]^{e-1} * 160 = 39$$

where the income elasticity, e = 1.5, and GDP per capita is measured in PPP terms. The multiplier is then used to estimate the VSL of an adult of average age by taking the product of the VSL multiplier and GDP per capita in USD. This gives a value of $93,544 in 2022, the latest year with available GDP per capita data. Following Cropper et al. (2019) future values of (adult) VSL are estimated by:

$$VSL_{t+1} = VSL_t * (1 + g_t)^e$$

Where g is growth in per capita income and is assumed to equal 2%. Lastly, preference studies suggest that mortality risk reductions for children are valued more highly than adults (Robinson et al. 2019; Peasgood et al. 2024). Following the evidence from Redfern et al (2024) we apply a 1.2x multiplier to the VSL for adults to approximate the VSL for children. This implies a value of $112,000 in the first year and rises rapidly with expected income growth.

For avoided stunting benefits we follow previous studies that account for avoided productivity loss in adulthood (Hoddinott et al. 2013; Wong and Radin, 2019).

Specifically, we assume that avoiding stunting leads to a 30% boost to future productivity and income (Aryeetey et al. 2020). This is applied to the stream of GDP per capita, which proxies for income, from ages 15 to 64. The value of avoided stunting is $10.579 in the first year.

Results and Discussion

The BCA formula applied is:

Benefit	/	Costs to Government	=	BCR
A. Child mortality averted * VSL (child) + B. Child stunting averted * productivity benefit per case of avoided stunting		(Target coverage - baseline coverage) * unit cost summed across each intervention		BCR

The results of the analysis indicate a BCR of 13.9. Total benefits are $251 million with costs equal to $18.2 million over a 10 year period at 7% discount rate.

Table

Benefits over a 10 year intervention period, 7% discount rate (millions, USD)	$265.5
Costs over a 10 year intervention period. 7% discount rate (millions, USD)	$19.6
BCR	13.5

10. Food Security Impacts

(The authors thank Bryce Everett for conducting aspects of this analysis)

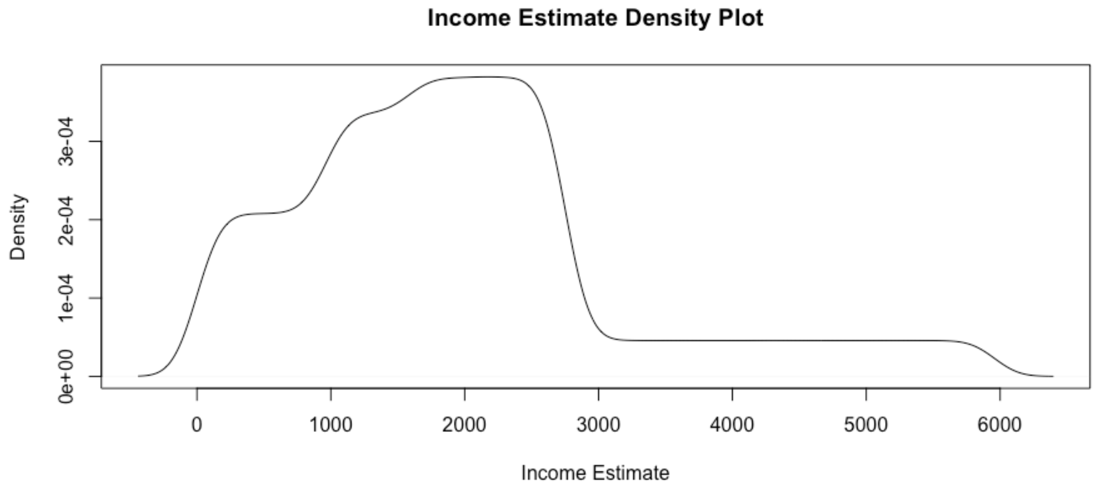
Terminal (i.e year 10) food security impacts are estimated as a function of two complementing factors: i) hermetic storage drums which have been demonstrated to dramatically reduce food insecurity (95% to 35% in the Timor-Leste Maize Storage Improvement, IFAD) and ii) broad income improvements from the production interventions which will increase household's ability to purchase food and mitigate the use of coping strategies.

To assess the impact of these effects on food insecurity, we generated a municipality level understanding of food insecurity, income and agricultural activity by the commodities of interest. Baseline food insecurity data by municipality were sourced from the 2023 food security assessment (WFP 2024). Population, household size and number of households per municipality were sourced from the 2022 Population Census. For each municipality we also obtained coffee, maize, rice, horticulture and total area under harvest from the 2019 Agricultural Census. Summing these figures did not reflect the same country level figures as those reported in FAOSTAT. To ensure consistency with the rest of the analysis, municipal level data on area under harvest was multiplied by a factor of [FAOSTAT total / Agriculture Census total] for each commodity such that total areas under harvest matched total areas from FAOSTAT.

Average baseline household income per municipality was needed to estimate changes in food security though this data was unavailable from the Food Security Assessment, the Population Census or the Agricultural Census. However, The Food Security Assessment included a multitude of metrics related to wealth (i.e. asset ownership, consumption, house and roof material, etc.), which we assumed followed the same distribution as household income. Therefore, an estimate was calculated using average GNI per capita in 2023 ($2,140), and a wealth share distribution detailed in the 2018 UN Vulnerability Profile. Households are generally made up of more than one income earner, so GNI per capita is multiplied by 1.5 ($3,210) to more accurately model household income. The income distribution is split into three groups; bottom 20%, middle 60%, and top 20%. Roughly 41% of wealth in Timor Leste is held by the richest 20% of the population, 50% held by the middle 60%, and approximately 9% held by the poorest 20%.

To predict income, observations are ordered by percentile within the wealth index. Average GNI per capita, multiplied by 1.5, is then multiplied by the number of observations (9,488) in the dataset and dispersed according to percentile in proportion to the share of wealth held by each respective group. This serves to create a reasonable prediction of income for each household based on the wealth index provided by the WFP. Average household income by municipality is calculated by taking the average income of each observation within each municipality and dividing by the number of observations within the respective municipality.

Figure 1: Income Estimate Density Plot



The result generates the following summary statistic measures by municipality.

Municipality	Food Insecurity Prevalence (%)	Estimated HH Income per year, USD	Population	No. of House-holds	Area under Coffee (Ha)	Area under Maize (Ha)	Area under Rice (Ha)	Area under Vegetables (Ha)
Aileu	41.4	2,939	54,324	9,366	2,811	2,556	239	703
Ainaro	47.8	2,480	73,115	12,392	4,399	1,330	82	542
Atauro	49.6	2,871	10,295	2,101	0	0	0	0
Baucau	40.7	2,826	134,878	24,977	245	3,385	5,539	1,105
Bobonaro	47.4	2,663	106,639	20,910	4,077	12,857	4,029	936
Covalima	61.2	2,181	73,933	15,730	595	3,165	2,427	319
Dili	26.5	5,880	324,738	56,972	68	509	8	909
Ermera	60.7	2,526	137,750	25,509	10,771	6,300	712	936
Lautém	47.7	3,421	70,022	13,466	163	3,197	887	291
Liquiça	47.6	2,816	83,658	14,677	2,653	1,451	256	458
Manatuto	43.3	2,978	50,859	8,769	387	609	386	58

Manufahi	38.5	2,669	60,665	11,030	3,374	2,209	206	1,253
SAR-Oecusse	38.1	2,119	60,685	13,192	176	8,576	11,560	1,601
Viqueque	41.5	2,968	80,176	16,703	281	2,609	4,580	268
Timor Leste Total	**42.2**	**2,977**	**1,321,737**	**245,795**	**30,000**	**48,753**	**30,912**	**9,381**

To estimate the impact from the hermetic drums, we first assess average household maize production by municipality. This is done by multiplying the ha under maize by the year 10 yield (2.41 MT / ha) and dividing by the number of households. The Timor-Leste Maize Storage Project food security improvements were based on the use of 1.8 200kg drums per household (42,000 drums across 23,000 households). We therefore assessed that if the average household had access to 400kg of maize under storage, then food insecurity risk would be reduced by 32.6%. Note that this is half the effect documented in the original TLMSP project since that project targeted the most food insecure households who may not be representative of the beneficiaries of a larger rollout. We adopted a 50% effect size for conservatism. For municipalities where households grow less than 400kg of maize on average, we reduced the effect by the proportion of maize grown below the 400kg threshold. Last, we adjusted the impact to account for the fact that by year 10 the coverage of drums under the model is only 60%, essentially multiplying all proportional reductions by 60%.

To estimate the impact of income improvements on food security we used detailed survey data from the WFP's 2023 Food Security Assessment to estimate the relationship between the constructed income index and food insecurity. Food security is classified in increments of 0.25 ranging from 0 to 3, with 3 representing most food secure and 0 denoting least food secure. The creation of a binary food insecurity variable was necessary for later analysis, where all food security class values greater than or equal to 1.5 are considered food insecure and equal to 1. The income estimate variable is log-transformed for inclusion in the model (specified below) allowing for percentage change interpretation rather than single unit change.

To estimate the relationship between income and food security, a logistic regression specification is utilized. The binary food insecurity indicator serves as the dependent variable, with the log-transformed income estimate included as the independent variable. Models with and without controls for head of household age, gender and municipality are estimated, but do not differ notably in resulting interpretation. The coefficient for income is then exponentiated to provide an estimate of the percentage change in income associated with the odds of being classified as food insecure. Both the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) statistics are used for model comparison to prevent overfitting, with BIC imposing a greater penalty for additional model parameters, and a lower value between models indicating a better fit. Absolute value is not as informative in this setting, but rather the difference in values between a set of models is assessed to judge specification fit. Both statistics are lower with controls included, so the full model is chosen to serve as the primary specification.

Logit Model Specification

$$\log\left(\frac{P(\text{Food Insecure}=1)}{P(\text{Food Insecure}=0)}\right) = \beta_0 + \beta_1\text{Income} + \beta_2\text{Age} + \beta_3\text{Gender} + \beta_4\text{Ermera}_1 + \beta_5\text{Atauro}_2 + \cdots + \beta_{16}\text{Dili}_{13}$$

With this approach, the log-transformed income variable indicates the way in which log-odds of being food insecure differ with a proportional change to income. The coefficient for income is calculated at -0.477 ($p < 0.001$), and exponentiating returns a value of 0.621. This translates to an expected decrease in food insecurity likelihood of 37.9% when income is doubled, or approximately **0.38pp reduction in food insecurity prevalence for every 1% increase in income**. The coefficients corresponding with municipality are with respect to the omitted region, Covalima. This municipality has the highest percentage of households facing food insecurity in the country. The coefficient for Dili, the municipality with the least food insecurity, is -1.059 ($p < 0.001$). When exponentiated, this returns a value of 0.347 which can be interpreted as a 65.3% decrease in food insecurity likelihood with respect to households within Covalima. In summary, wealth and income can be intuitively tied to food security, but this analysis strengthens the case for that relationship in the context of developing economies and increased income continues to serve as one of the greatest alleviators to food insecurity.

Variable	(1)	(2)	(3)
Intercept	3.416***	3.225***	3.866***
	(0.191)	(0.209)	(0.227)
Income	-0.478***	-0.476***	-0.477***
	(0.026)	(0.026)	(0.027)
Age		0.005***	0.005***
		(0.001)	(0.001)
Male		-0.091	-0.085
		(0.055)	(0.056)
Ermera			-0.077
			(0.117)
Atauro			-0.464***
			(0.112)
⋮			⋮
Dili			-1.059***
			(0.120)
AIC	12,746.8	12,733.2	12,489.9
BIC	12,761.1	12,761.9	12,611.5

Note: *p < 0.05, **p < 0.01, ***p < 0.001

Lastly, for each municipality we estimated the increase in average household income attributable to the interventions by multiplying the average net benefit to farmer per hectare by the number of hectares in each municipality and then dividing by the number of households. To avoid double counting with any food security benefits from the drums, we ignore income gains from maize. The absolute income gain (excluding maize) is divided by average baseline income to determine the % change in income and then multiplied by the impact from the regression results of 0.38pp to determine the reduction in food insecurity.

The results of the analysis are presented below. Overall food insecurity is expected to reduce from 42pp of the population to 29pp of the population equivalent to a 13pp (or 31%) reduction in food insecurity. At a municipality level, the largest improvements are expected in Oecusse, Ermera, Bobonaro, Manufahi and Alieu.

Table A10.1: Results of Food Security Analysis, Estimates of Year 10 food security prevalence after rollout of interventions

Municipality	Baseline Food Insecurity Prevalence (%)	*Less Food Insecurity Reduction Due to Hermetic Drum Rollout (%)*	*Less Food Insecurity Reduction Due to Income Improvements (%)*	Final Food Insecurity Prevalence (%)
Aileu	41.4	-7.9	-10.5	23.0
Ainaro	47.8	-2.9	-11.1	33.8
Atauro	49.6	na	na	na
Baucau	40.7	-8.0	-4.9	27.8
Bobonaro	47.4	-9.3	-11.5	26.6
Covalima	61.2	-12.0	-5.2	44.0
Dili	26.5	-1.1	-0.6	24.9
Ermera	60.7	-11.9	-13.1	35.7
Lautém	47.7	-9.3	-3.4	35.0
Liquiça	47.6	-4.9	-6.3	36.4
Manatuto	43.3	-3.3	-2.0	37.9
Manufahi	38.5	-4.0	-15.2	19.3
SAR-Oecusse	38.1	-7.5	-20.1	10.5
Viqueque	41.5	-8.1	-4.9	28.5
Timor Leste Total	**42.2**	**-6.2**	**-6.8**	**29.2**

11. Process for Identifying Prioritized Interventions

11.1. Developing a long list of potential interventions

The long list was developed as a product of multiple literature reviews and key informant interviews. The process was designed to be participatory, inclusive, and audience-informed, ensuring that the final findings would be recognized and owned by those who are most likely to define policy and implement recommendations, as well as those in affected communities. As a result of this informant/audience approach to identifying stakeholders, key informants spanned a wAp, throwing the net widely to ensure all plausible interventions were duly considered, and lending a higher likelihood of uptake to the recommendations.

Our consultations initially focused on technical experts and program managers within the World Food Programme, informing our understanding of the contours of the challenges, context, and potential areas of opportunity and further investigation within the arena of food security and nutrition in Timor Leste. Based on these initial conversations, we conducted an initial literature review, ranging from academic articles to food security assessments, while considering literature tied either to Timor Leste specifically, or to globally established best practices and innovations within potential intervention areas.

Mettalytics' first mission to Timor Leste took place in January 2024, during which the team conducted scoping interviews with stakeholders across Dili, Ermera, and Baucau. A second mission took place in March 2024, with interviews conducted in Dili, Bobonaro, Ermera, and Aileu. Beyond these in-country interviews, a number of virtual interviews have also been conducted with technical experts and stakeholders engaged in Timor Leste and/or having technical expertise in key intervention areas. In total, Mettalytics spoke with 101 stakeholders between January and August 2024. Literature reviews were also conducted following the interviews as a source of additional validation and to unpack key inflection points in program design, implementation, and impact.

These efforts resulted in a comprehensive and layered understanding of hidden costs and benefits within Timor Leste's food security and nutrition environments, and revealing key windows of opportunity within policy making and the machinery of government, while pinning over 180 potential interventions to the long list of interventions for consideration (see Annex Section 12).

11.2. Applying cost-benefit screening criteria to the long list

One challenge in prioritization exercises is to credibly and reliably screen a long list of interventions down to a manageable number for analysis without excluding high impact opportunities. To expedite the process, we have used a screening process to narrow down to a short list of interventions for more detailed analysis.

Cost-benefit Screening Criteria

We applied the following criteria to screen interventions in the list:

1. ***The extent of the problem addressed by the intervention (30% weighting)*** – Interventions that address a larger extent of Timor-Leste's food insecurity challenges were preferred over interventions that address a smaller share of the problem. 'Addressable problem size' encompasses the following factors:
    a. the number of individuals impacted
    b. the magnitude of economic cost addressed and,
    c. the extent and depth of food insecurity or undernutrition addressed by the intervention.

   It is important to note that this criterion considers the intervention's impact, not the size of the problem in the abstract. For example, there may be some very large and costly challenges, but if the potential interventions cannot solve them to a meaningful degree they will not be assessed favorably under this criterion.

2. ***The expected ROI of the solution (40% weighting)*** – Interventions that are more likely to deliver larger returns will be favored over interventions that are likely to deliver lower returns. This criterion assesses benefits or impact against costs *in expectation*. To assess this, we have consulted academic literature with a focus on systematic reviews, meta-analyses as well as evaluations conducted specifically in Timor-Leste. We have also held consultations with various stakeholders to hear local views on the cost-effectiveness of interventions. Importantly, this step is not designed as an in-depth assessment of benefits and costs – which would be infeasible. Rather it is an iterative discovery process which at first identifies interventions that are likely to deliver high returns (which are included in the next stage), and interventions that are likely to have limited impact (which are excluded). The interventions in the 'middle-ground' – neither those with high nor low returns – have required more examination during the discovery process to assess whether they should be included in the next stage of analysis.

3. ***Identified priorities of government, local stakeholders, WFP and FAO (30% weighting)*** – interventions that have been favored or will likely be favored by government, local stakeholders, WFP and FAO will be given more weight. This criterion recognizes that it is useful to conduct economic evaluation of 'high profile' interventions – either to confirm their value objectively or give the opportunity to decision-makers to consider evidence to change their position.

At the end of this process we had preliminarily identified 16 interventions for further benefit-cost analysis. Further review and analysis brought these down to 10 interventions, which were then subject to deeper economic evaluation. In the process of conducting the more in-depth economic evaluation, one of the interventions was dropped / merged into another intervention, and other interventions altered slightly based on emerging evidence. The results of that process are presented in this report.

12. List of Considered Interventions

1. Train farmers in climate-resilient planting techniques.
2. Develop community-based crop diversification programs.
3. Promote organic farming practices to reduce dependence on chemical inputs and increase market potential.
4. Introduce integrated pest management (IPM) practices to reduce crop losses.
5. Promote agroforestry systems..
6. Provide technical assistance for cultivating high-value export crops like vanilla and pepper.
7. Pilot a program for regenerating fallow lands for agricultural use.
8. Launch a farmer recognition program for adopting sustainable practices.
9. Promote the use of composting to enhance soil fertility.
10. Double spending on foundational agricultural research and development to enhance productivity and resilience.
11. Create a national seed registry to standardize seed quality.
12. Organize farmer seed fairs to exchange local seed varieties.
13. Partner with research institutions to develop drought-resistant seed varieties.
14. Establish community seed banks.
15. Provide training to farmers on seed saving techniques.
16. Develop a subsidy program for seeds to reduce farmer costs.
17. Introduce seed treatment methods to prevent pest infestations.
18. Map local seed supply chains to identify gaps and opportunities.
19. Expand the budget for improved seeds to ensure wider availability for farmers.
20. Provide tractors and train farmers on the safe use and maintenance of tractors and equipment.
21. Establish cooperative machinery hiring services in rural areas.
22. Develop guidelines for multi-cropping systems tailored to different regions.
23. Encourage the use of biopesticides to reduce environmental damage.
24. Organize workshops on the benefits of intercropping for smallholder farmers.
25. Train farmers to use crop rotation techniques and conservation agriculture to restore soil health.
26. Deliver hermetic drums for maize storage to reduce post-harvest losses.
27. Establish coffee nurseries to provide disease-resistant seedlings to farmers.
28. Organize farmer field schools focused on coffee plant rejuvenation techniques.
29. Develop a traceability system for coffee to improve market access.
30. Provide solar-powered drying equipment for coffee beans to improve quality.
31. Create a certification program for organic and Fair Trade coffee.
32. Train farmers on financial planning to better manage coffee income.
33. Expand farmer-sensitive coffee rehabilitation programs and promote intercropping with high-value spices such as vanilla, clove, and pepper.
34. Train farmers in integrated livestock-crop systems to maximize farm efficiency.
35. Introduce high-yield chicken breeds for egg production.
36. Promote fish farming in small ponds for protein and income generation.
37. Develop a vaccination program for livestock to prevent disease outbreaks.
38. Provide training on sustainable fishing practices for coastal communities.
39. Introduce pig fattening programs to improve rural household incomes and nutrition.
40. Create mobile agricultural training units to reach remote farmers.
41. Develop digital platforms to provide farmers with on-demand agricultural advice.

42. Train extension workers in participatory methods for community engagement.
43. Organize farmer exchange visits to share best practices.
44. Develop training modules on integrating nutrition-sensitive agriculture.
45. Establish rural collection points to aggregate farmer produce for market access.
46. Develop mobile apps for price transparency and market linkages.
47. Train farmers on branding and packaging to add value to products.
48. Organize regional agricultural trade fairs to connect farmers with buyers.
49. Build cold storage facilities in key agricultural regions.
50. Strengthen Timorese agri-businesses to supply inputs, credit information, and market linkages.
51. Install solar-powered irrigation pumps for energy-efficient water access.
52. Train farmers on water-saving irrigation techniques like drip irrigation.
53. Build community-managed rainwater harvesting systems.
54. Update the national irrigation master plan to prioritize investments.
55. Rehabilitate existing irrigation infrastructure with climate-resilient designs.
56. Supplement existing irrigation systems with solar pump tube wells in rice-growing areas.
57. Organize community cooking demonstrations using locally grown nutritious foods.
58. Create a voucher system for pregnant women to access fresh produce.
59. Integrate nutrition education into school curriculums.
60. Train health workers to provide nutrition counseling during home visits.
61. Promote biofortified crops like iron-rich beans and zinc-rich rice.
62. Expand rice fortification for children in schools and the general population.
63. Scale up selected community- and facility-based nutrition-specific interventions to address malnutrition.
64. Expand water chlorination and treatment programs to reduce waterborne diseases.
65. Incentivize the use of biochar as a sustainable soil amendment.
66. Provide a temporary subsidy for combining biochar with inorganic fertilizers to improve soil fertility and crop yields.
67. Develop farmer training on soil conservation practices, such as terracing and cover cropping.
68. Train farmers on agro-climatic forecasting to improve decision-making.
69. Establish community seed reserves for disaster recovery.
70. Develop early warning systems for pests and diseases linked to climate change.
71. Pre-position food stocks for faster access in disasters.
72. Link local schools to producers for school feeding programs.
73. Expand the national school feeding program.
74. Ensure more timely budget allocation for the school feeding program.
75. Expand government procurement of grain for disasters.
76. Conduct risk assessments for climate impacts on agriculture.
77. Provide grants for adopting climate-smart farming technologies.
78. Pilot climate-smart villages combining multiple adaptation strategies.
79. Train farmers on gender-sensitive practices in agriculture.
80. Promote youth involvement in agriculture through training and grants.
81. Organize financial literacy workshops for farmers.
82. Establish farmer cooperatives to strengthen bargaining power.
83. Conduct baseline surveys to monitor the impact of agricultural interventions.
84. Develop national campaigns on the importance of sustainable agriculture.
85. Partner with universities to conduct research on innovative farming practices.
86. Provide microloans to farmers for purchasing inputs and equipment.

87. Build capacity among government officials for agricultural planning.
88. Develop public-private partnerships to scale successful initiatives.
89. Expand digital connectivity to improve access to agricultural information.
90. Improve land tenure security by formalizing land titles and ensuring clear ownership rights for farmers.
91. Enhance credit availability through rural-focused microfinance initiatives and agricultural loan products.
92. Pilot mental health interventions to support the well-being of farmers and their families.
93. Introduction of Farmer Field Schools (FFS) to train farmers on best practices for crop production, pest management, and sustainable agriculture.
94. Promotion of Integrated Pest Management (IPM) to minimize environmental harm and increase crop yields.
95. Development of market infrastructure such as roads and storage facilities to reduce post-harvest losses and improve access to markets.
96. Support for small-scale irrigation projects to enhance water availability for agriculture in rural areas.
97. Expansion of agroforestry programs that combine tree planting with crops and livestock to improve soil fertility and combat erosion.
98. Provision of agricultural credit facilities for smallholders to invest in seeds, fertilizers, and other inputs.
99. Strengthening of agricultural cooperatives to improve collective bargaining, access to markets, and resource sharing among farmers.
100. Promotion of climate-resilient crops such as drought-tolerant and salt-resistant varieties.
101. Enhancement of livestock production through improved breeding programs, veterinary services, and fodder development.
102. Development of fisheries and aquaculture to provide alternative sources of protein and boost livelihoods.
103. Hire more extension workers and capacity building for extension workers to provide farmers with updated knowledge and technology.
104. Expansion of school feeding programs using locally grown produce to support nutrition and local farmers.
105. Promotion of home gardening initiatives to improve household food security and diversify diets.
106. Investment in post-harvest technology such as improved drying, processing, and packaging to add value to agricultural products.
107. Support for women's participation in agriculture through training, credit, and land access to ensure equitable benefits.
108. Development of national seed banks to preserve biodiversity and ensure access to high-quality seeds.
109. Implementation of water harvesting techniques such as rainwater collection and conservation structures for agriculture.
110. Promotion of organic farming practices to improve soil health and produce high-value crops.
111. Public awareness campaigns on nutrition to promote balanced diets and reduce malnutrition rates.
112. Establishment of farmer incentive programs for adopting sustainable and innovative practices.

113. Integration of nutrition education in agricultural training to link production to improved dietary outcomes.
114. Scaling up of agro-processing industries to create jobs and reduce reliance on raw exports.
115. Promotion of renewable energy use in agriculture such as solar-powered irrigation and processing facilities.
116. Development of risk management tools such as crop insurance and early warning systems for climate-related disasters.
117. Promotion of contract farming models to link farmers directly with buyers and secure income.
118. Strengthening food safety standards to improve market access and ensure consumer health.
119. Build six dams around the country to ensure water access
120. Link school feeding programs to local farmers to build markets
121. Tax imported rice
122. Promote red rice as a high value crop
123. Lower barriers to seed certification and registration
124. Consult youth gangs to understand why youth don't want to do farming
125. Promote breastfeeding practices (early initiation, exclusive breastfeeding until six months, and continued breastfeeding up to two years or beyond).
126. Improve complementary feeding practices by promoting healthy diets and dietary diversity for children aged 6–23 months.
127. Provide micronutrient supplementation for vulnerable groups, including pregnant women and young children.
128. Enhance the management of acute malnutrition through community- and facility-based programs.
129. Expand access to improved sanitation and hygiene facilities, especially in rural areas, to reduce exposure to faecal pathogens.
130. Increase access to contraceptives to ensure healthier birth intervals and reduce the risk of maternal and child malnutrition.
131. Strengthen the Bolsa da Mãe program, integrating nutrition-sensitive support for poor households with pregnant and lactating women and children under five.
132. Link social cash transfers with nutrition-sensitive behavior change communication (SBCC) to maximize impact on stunting and dietary diversity.
133. Support universal salt iodization to address iodine deficiency.
134. Fortify rice with essential micronutrients, making fortified rice accessible to all consumers.
135. Enforce the International Code of Marketing of Breast-milk Substitutes (BMS) to support breastfeeding and child nutrition.
136. Enhance school feeding programs as both a social safety net and a nutrition education platform.
137. Provide nutrition education in schools, including food-based education for students, teachers, and administrators.
138. Develop nutrition-sensitive agriculture programs to improve dietary diversity and reduce micronutrient deficiencies.
139. Increase diversification and sustainable intensification of homestead food production, including small livestock.

140. Boost fish production and consumption through sustainable aquaculture practices.
141. Promote the integration of nutrition SBCC with agriculture and food security initiatives to improve health outcomes.
142. Support women and girls' access to agricultural inputs, technologies, and finance, ensuring gender-sensitive nutrition-promoting activities across sectors.
143. Reduce gender-based violence as part of a holistic approach to improving maternal and child nutrition outcomes.
144. Expand access to safe drinking water, focusing on both urban and rural areas.
145. Provide training for farmers on sustainable agricultural practices, including climate-resilient farming techniques.
146. Establish school gardens to demonstrate good nutrition practices and provide fresh produce for school feeding programs.
147. Strengthen capacity for effective multisector coordination at the subnational level to promote convergent approaches in nutrition programming.
148. Develop and enforce food fortification policies, including for salt and rice, to address micronutrient deficiencies.
149. Encourage the use of small and medium enterprises (SMEs) to supply and market nutritious foods.
150. Promote dietary behavior change communication targeting vulnerable populations through community outreach and public campaigns.
151. Increase funding and capacity for data collection and monitoring to measure progress and inform program adjustments.
152. Enhance access to water, sanitation, and hygiene (WASH) facilities in schools to support student health and nutrition.
153. Integrate nutrition and food security priorities into subnational budgets and activities to ensure alignment with national SDG2 goals.
154. Promote mixed farming systems including cereals, legumes, vegetables, and fruits.
155. Introduce drought-tolerant and pest-resistant crops.
156. Improve access to fertilizers and quality seeds.
157. Support irrigation infrastructure to mitigate drought.
158. Promote agroforestry and conservation agriculture.
159. Encourage soil fertility management and erosion control measures.
160. Strengthen animal husbandry and veterinary services.
161. Introduce improved livestock breeds for higher productivity.
162. Implement school feeding programs with locally sourced ingredients.
163. Provide education on nutrition-sensitive agriculture and balanced diets.
164. Fortify staple foods such as rice, maize, and flour to combat malnutrition.
165. Establish mechanisms to distribute food aid during natural disasters or drought periods.
166. Train farmers in climate-resilient practices.
167. Establish early warning systems for extreme weather events.
168. Develop rainwater harvesting systems.
169. Construct small-scale irrigation schemes.
170. Support farmer cooperatives to aggregate produce for market access.
171. Develop cold storage and transportation facilities.
172. Promote off-farm income activities like processing and packaging.
173. Provide microfinance services for small enterprises.
174. Strengthen agricultural extension systems.

175. Provide skill-building programs for youth and women in agriculture.
176. Invest in agricultural research institutions to develop adaptive technologies.
177. Establish farmer field schools for hands-on learning.
178. Address land tenure insecurity to promote investment in farming.
179. Improve governance structures for food and agriculture policies.
180. Encourage private sector investment in agriculture.
181. Facilitate partnerships for technology transfer and innovation.
182. Upgrade rural roads for better market connectivity.
183. Expand electrification in farming communities to support mechanization.
184. Provide storage facilities to reduce food losses.
185. Establish processing units to add value to agricultural products.
186. Promote access to clean drinking water and sanitation facilities.
187. Conduct hygiene awareness campaigns to reduce waterborne diseases.
188. Integrate nutrition and health interventions at the community level.
189. Ensure maternal and child health services are accessible.
190. Assist Timor Leste to fully partake in ASEAN membership.
191. Improve access to finance via loan guarantees.
192. Mandate importation of fortified rice.
193. Enhancements to DisasterAware intervention for improved DRR.
194. Implement the National Seed Policy.
195. Minimum Support Price for maize and rice.
196. Increase the quality of coffee to access more lucrative export markets.
197. Conditional cash transfers for pregnant women, conditional on attending health facilities.
198. Improve road infrastructure.

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