República Democrática de Timor-Leste

TECHNOLOGY NEEDS ASSESSMENT

Barrier Analysis and Enabling Framework Report

ADAPTATION

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Barrier Analysis and Enabling Framework Report

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Foreword

Timor-Leste is a member of Small Island Developing States (SIDS) and the Least Developed Country (LDC) which is very vulnerable to the effects of climate change and has been experiencing the negative impacts of extreme weather events, including intense storms and sea-level rise. The impacts of climate change are already undermining its development. Hence, without addressing the drivers of climate change and providing support for the most vulnerable sectors, these impacts will continue to worsen.

As a party to the UNFCCC, the Government of Timor-Leste is fully committed to developing and implementing measures that make its major development sectors climate-resilient and reduce greenhouse gas emissions from potential sectors. For example, the Nationally Determined Contribution (NDC) listed a number of mitigations and adaptation measures to enable sustainable low-carbon development and to build climate resilience in Timor-Leste. To support the implementation of its NDC and other national strategies, Timor-Leste is currently conducting a Technology Needs Assessment (TNA) to identify priority technology transfer investments and determine which environmentally sound technologies (EST) are the most effective in adapting and mitigating climate change.

The Minister of Tourism and the Environment (MTE) acknowledges that the TNA project is the first thorough national exercise undertaken toward assessing our needs for climate change technology. It was carried out by MTE through National Directorate for Climate Change (NDCC) in collaboration with the United Nations Environment Programme Copenhagen Climate Centre (UNEP-CCC) and the Asian Institute of Technology (AIT) and was funded by the Global Environment Facility (GEF). The Climate Change Working Groups (CCWG), key stakeholders, and local experts were all consulted during the TNA process.

Timor-Leste is proud to have completed the second phase of the TNA, Barrier Analysis and Enabling Framework (BAEF) Report, following the completion of the first phase of TNA, Identification and Prioritisation of Technologies Report. The BAEF Report for Adaptation was completed with the assistance of relevant line ministries, international agencies, non-governmental organizations (NGOs), private sectors, academia, and youth organizations. Through this collaboration, barriers for adoption and deployment of selected technologies in adaptation along with their measures were identified.

I look forward to seeing deployment and diffusion of selected technologies based on analysis, findings, and recommendations from this BAEF report.

Francisco Kalbuadi Lay
Vice-Prime Minister, Coordinating Minister for Economic Affairs,
Minister of Tourism and the Environment

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ACRONYMS

ADA	Austrian Development Cooperation
CA	Conservation agriculture
CR	Crop rotation
BAEF	Barrier analysis and enabling framework
BTL, E.P.	Bee Timor-Leste Empressa Publica
CBNMR	Community-based natural resource management
CRB	Coastal Resilience Building
CTSP	Coral Triangle Support Programme
EC	European Commission
KFF	Klibur Flora and Fauna
LIFT	Local Initiatives for Food-security Transformation
MALFF	Ministry of Agriculture and Fisheries
MCA	Multi-criteria analysis
MPAs	Marine protected areas
MPW	Ministry of Public Works
MSA	Ministry of State Administration
MTE	Ministry of Tourism and Environment
NAP	National Adaptation Plan
NbS	Nature-based solutions
NDC	National Determined Contribution
NETIL	Nova Esperanca Timor-Leste
PERMATIL	Permakultura Timor Lorosa’e
R&D	Research and development
RDTL	República Democrática de Timor-Leste
SALT	Slope agriculture land technology
SLM	Sustainable land management
SSE	Secretary of State for the Environment
TNA	Technology needs assessment
UNTL	Universidade Nacional Timor Lorosa'e

EXECUTIVE SUMMARY

During the first step of Technology Need Assessment (TNA) in Timor-Leste, four technologies in sector 1, **sustainable land management (SLM) in agriculture,** and another set of four technologies in sector 2, **infrastructure and natural methods to prevent erosion,** were identified (see table 1). Pre-liminary target for transfer and diffusion of all technologies in sector 1 by 2028 is 141,141 agricultural households whose livelihood depends on agriculture. In sector 2, the pre-liminary target for technology transfer and diffusion varies from one technology to another. For soil bioengineering and SALT, the target can be 60% of the approximately 70,000 ha of total cultivated land in Timor-Leste. For mangrove plantation technology, the target can be 53% of total mangrove area in Timor-Leste (4,831 Ha). *Tarabandu* can help enhance management of land and coastal resources where these technologies are applied.

Climate Change Adaptation	
Sector 1: Sustainable land management in agriculture: 1. Conservation Agriculture (CA) and Crop Rotation 2. Water Management and Restoration 3. Green Char 4. Composting	**Sector 2: Infrastructure and natural methods to prevent erosion:** 1. Soil bioengineering 2. *Tarabandu* 3. Mangrove plantation 4. Sloping Agriculture Land Technology

Table 1: List of selected technologies for adaptation (Source: GoTL, 2023)

The Barrier Analysis and Enabling Framework (BAEF) is the second step of the TNA. The objective of this exercise is to find barriers and challenges that could potentially arise during the transfer, deployment and/or diffusion of the technology (Nygaard and Hansen, 2015) and find effective, appropriate solutions and methods to overcome the barriers. Barriers are prioritized and grouped into different categories such as institutional, legal, technical, social, and cultural.

Divided into two parts, desk review and consultation, this BAEF analysis was conducted in a consultative manner where relevant entities with the knowledge of the technologies and first-hand experience in introducing/implementing them were engaged through interviews and workshops. The BAEF for Timor-Leste was conducted between May and October 2023, following the completion and submission of the TNA report in April 2023. It followed six (6) suggest steps namely organizing the process, screening of barriers, listing all identified barriers, selecting the most essential barriers, decomposing the selected essential barriers, and logical deduction of barriers (problem tree). A total of thirty (30) financial and non-financial barriers were identified for eight (8) selected technologies representing the two (2) sectors (**SLM in agriculture** and **infrastructure and natural methods to prevent erosion**). Additionally, a total of thirty (30) financial and non-financial measures were identified and recommended.

In terms of categories of technology, conservation agriculture and crop rotation is considered as *non-market good* like the rest of the seven (7) technologies selected for adaptation. The implementation of this technology by the Ministry of Agriculture, Livestock, Fisheries, and Forestry (MALFF) and partners can continue to be *public good* as it is now. A total of four (4) barriers were identified during desk review and consultation with relevant stakeholders (i.e., MALFF, AI-Com, FAO, DFAT, and Raebia), namely: high capital cost, limited availability of inputs and services, strong attachment to slash and burn, and limited knowledge. To break these barriers, the BAEF analysis identified and recommended measures such as improved access to capital, improved supply chain for tools and equipment, extensive campaign and socialization, and capacity building.

Water management and restoration is a technology that can be adopted and deployed by BTL, MALFF and partners at national scale as *public good.* A total of three (3) barriers were identified, namely: lack of fundings, limited knowledge, and lack of an integrated approach in water management and governance. According to information collected during the assessment, breaking these barriers requires measures such as linking community groups with potential donors, integration of water restoration plans into water management system, and capacity building.

Biochar is categorized as *non-market good* which can be adopted and deployed by MALFF and partners at national scale as *other good*. Desk review and consultation with a single stakeholder who has been conducting studies on this technology led to the identification of five (5) barriers, namely: high cost and time constraint for collection of raw materials, the absence of a market for biochar, limited information, lack of technical skills, and limited access to raw materials. To address these barriers, the assessment recommended various measures such as improved access to capital, market assessment, extensive campaign and socialization, and capacity building.

Categorized as *non-market good,* composting is a technology that can be adopted and deployed by MALFF and partners at national scale as *other good*. During the BAEF analysis, four (4) potential barriers were identified, namely high production cost and time constraint, land requirement, lack of market information, and poor integration of compost into urban waste management. Improved access to capital, market assessment, extensive campaign and socialization, and integration of compost in urban waste management were identified and recommended as measures to break these barriers.

Soil bioengineering can be adopted and deployed by the Ministry of Public Works (MPW) and partners at national scale as *public good*. The BAEF analysis for this technology identified lack of financial allocation for soil bioengineering in infrastructure development, lack of investment in research and development (R&D), and limited information as main barriers. Additionally, it highlighted committed budget line for soil bioengineering activities, investment in R&D, and extensive campaign and socialization as measures to address the barriers.

Unlike other technologies*, tarabandu* is a technology that has been embedded in Timor-Leste's customary system of common pool resource management. It can be widely re-introduced and deployed by MALFF, the Ministry of Tourism and Environment (MTE), and partners at national scale as *other good*. The BAEF analysis for this technology suggests lack of allocation of funds for *tarabandu* enforcement, limited opportunities to diversify sources of income, and weak governance as the three (3) main barriers. Additionally, it highlighted committed budget for *tarabandu* monitoring, strengthening local governance, and establishment of alternative source of livelihood as measures to address the barriers.

Mangrove plantation is *non-market good* that can be adopted and deployed by MALFF, MTE, and partners at national scale as *other good*. According to the BAEF analysis, its large-scale adoption and deployment is hindered by lack of fundings, urban sprawl and human encroachment of mangrove habitats, and the practice of free grazing. In terms of measures to respond to these barriers, the analysis recommends committed budget to fund community-based mangrove restoration, developing spatial planning for coastal areas, and effective management of free grazing.

SALT technology can be deployed by MALFF, NGOs and partners at national scale as *other good*. A total of five (5) barriers identified in the BAEF analysis consist of limited opportunities to diversify sources of income, the practice of free grazing, strong attachment to slash and burn, limited information, and lack of technical skills. Measures to address these barriers consist of subsidies to support rural farmers' transition to sustainable farming practices, conducting R&D on SALT, extensive campaign and socialization, capacity building, and promoting the practice of confined raising in livestock management.

Overall, the BAEF analysis for the eight (8) selected technologies has led to identification of various financial and non-financial barriers along with their measures. There are some barriers which are commonly found across technologies, namely limited access to capital, limited access to information, lack of capacity building activities, and the practice of free-range livestock. Similarly, some common measures found across technologies include improved access to capital, market assessment, extensive campaign and socialization, training and capacity building, and promoting the practice of confined raising in livestock management.

To overcome the identified barriers for adoption and deployment of the eight (8) technologies, this BAEF analysis has identified an enabling framework that consists of political, institutional, and regulatory framework. They encompass existing programmes, policies, organizational structures, rules, norms for service provision, National Constitution and decree laws that create conducive environment for introducing the recommended measures. Overall, the extensive analysis conducted in this report provides a strong foundation for developing and formulating project ideas in the following step of TNA, Technology Action Plan (TAP).

1. Introduction to BAEF

1.1 Background

The Barrier Analysis and Enabling Framework (BAEF) is the second step of the Technology Need Assessment (TNA). The objective of this exercise is to find barriers and challenges that could potentially arise during the transfer, deployment and/or diffusion of the technology (Nygaard and Hansen, 2015) and find effective, appropriate solutions and methods to overcome the barriers. Barriers are prioritized and grouped into different categories such as institutional, legal, technical, social, and cultural.

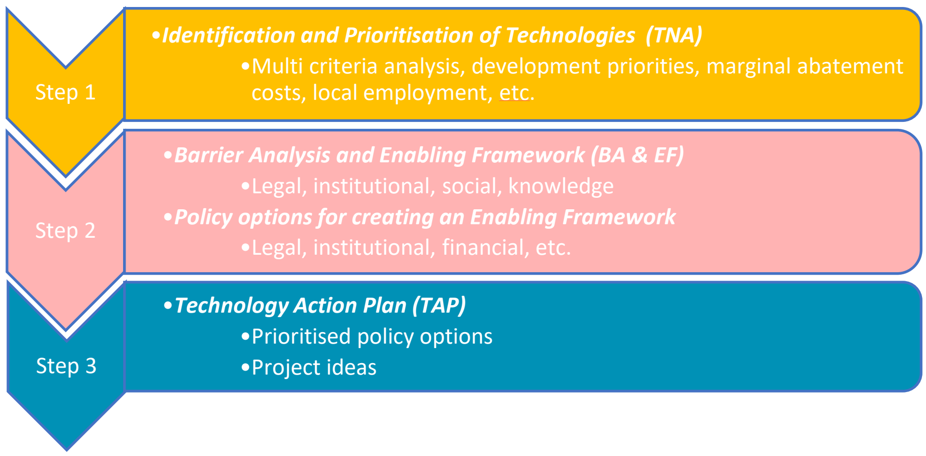

Figure 1: The three stages of TNA Assessment (source: adapted from UNEP DTU Partnership, 2019)

The first step of TNA, which involves identification and prioritization of technologies, concluded with a list of technologies for adaptation (see **Error! Reference source not found.**) through extensive consultation with national stakeholders and analysis. Therefore, this BAEF report only specifically covers the two sectors and its technologies.

Climate Change Adaptation	
Sector 1: Sustainable land management in agriculture: 1. Conservation Agriculture (CA) and Crop Rotation 2. Water Management and Restoration 3. Green Char 4. Composting	**Sector 2: Infrastructure and natural methods to prevent erosion:** 1. Soil bioengineering 2. *Tarabandu* 3. Mangrove plantation 4. Sloping Agriculture Land Technology

Table 1: List of selected technologies for adaptation (Source: GoTL, 2023)

With the emergence of various agriculture technologies and advanced ways of farming, step 1 of TNA is needed to identify and prioritize the ones suitable for local context through participatory process and thorough analysis. Step 2 plays a crucial role in assessing existing barriers that hinders the adoption and deployment as well as measures to establish enabling frameworks to overcome those barriers.

1.2 Process for the identification of barriers and measures

BAEF is conducted in a consultative manner where relevant entities with the knowledge of the technologies and firsthand experience in introducing/implementing them are engaged through interviews and workshops. The BAEF for adaptation for Timor-Leste was conducted in parallel with the mitigation one between May and July 2023, following the completion and submission of the TNA report in April 2023. In general, the process of identifying barriers and measures is divided into six steps, namely:

1. Organizing the process
2. Screening of barrier
3. Listing all identified barriers
4. Selecting the most essential barriers
5. Decomposing the selected essential barriers
6. Logical deduction of barriers (problem tree).

In the first step of the process, TNA consultants identified existing working groups in the realm of climate change and their members. As a Climate Change Working Group (CCWG) led by DNAC has been established prior to TNA project, it was not necessary to establish a new working group but rather to tap into information and resources available within this group. Other relevant agencies which are not part of CCWG were also included in target stakeholder for consultations/workshop. Table 2 has the complete list of target stakeholder consulted in the process.

Category	Name of Institutions
National Government Agencies	Directorate General of Agriculture of (MALLF), Directorate General of Forestry, Coffee and Industrial Plant (MALFF), The National Authority for Electricity (ANE, IP), National Directorate of Pollution Control, National Directorate of Terrestrial Transport, Environmental Legal Office, National Authority of Water and Sanitation (ANAS, IP), National Director Spatial Planning,
Development partners	Delegation of European Union to Timor-Leste, Asian Development Bank (ADB), UNDP, FAO, UNICEF, Department of Foreign Affairs and Trade (DFAT), JICA
NGOs	Raebia, Permatil, KFF, Ho Musan Ida/With One Seed, Habelun Ai-parapa, Laudato Si Movement Timor-Leste (LSA-TL), FCOTI, ADTL, TROBAS, LCOY-TL, Mercy Corps, CVTL
Research agencies/programmes	Agriculture Innovations for Communities in Timor-Leste (AI-COM), TOMAK (Toos ba Moris Diak)
Youth Group	Timor Leste Organic Fertilizer (Tilofe), Juventude Hadomi Natureza (JHN)

Table 2: List of institution included in the Step 1 of BAEF

During step 2, a list of relevant literatures (see References) was reviewed to help develop a list of target stakeholders for consultation and a set of questions. This step also involved one-on-one interviews with key stakeholders from national agencies, development partners, and civil society organizations (see ANNEX

III). A total of 19 individuals were consulted either through one-on-one interviews or focus groups discussions. There was also a second TNA public workshop on BAEF held on the 20th of July 2023 to confirm pre-liminary findings on BAEF.

During the next few steps, data from desk review and consultations were analysis to allow for screening, selection in term of relevance, decomposing and logically deducting selected barriers into problem tree analysis which is a logical framework approach to outline causal relationships between barriers (see ANNEX II: Problem Trees). The problem tree developed for each technology also received inputs from stakeholders during the BAEF workshop.

At the end of the six (6) steps, a total of forty-five (45) barriers were identified for the eight (8) technologies (see ANNEX III: List of barriers and measures identified during consultation process). A problem tree for each technology was developed using inputs from desk review and one-on-one consultation. They were then validated during a BAEF workshop. Based on the problem tree analysis and discussion during the workshop, only 30 barriers were selected due to relevance and strong evidence of their direct causal relationship with low rate of adoption and deployment of the eight technologies. Some barriers were eliminated due to lack of supporting evidence while others were merged as one when they are closely related.

The set of selected barriers were used to developed measures by translating barriers into solutions. The costs and benefits of measures were then assessed to determine whether they comply with policy objectives. Once assessed, selected measures were included in programmes. Eventually, a set of thirty (30) measures were formulated based on information provided during consultation and desk review.

2. Sector 1: Sustainable land management in agriculture

During step 1 of TNA, four technologies in **sustainable land management in agriculture** sector have been identified, namely (i) Conservation agriculture (CA) and crop rotation; (ii) water management and restoration; (iii) green char; (iv) Composting. The four prioritized technologies aim to increase agriculture productivity by improving access to inputs such as soil, water, and fertilizer. Meanwhile, they also aim to enhance the resilience of the agriculture sector to impacts of climate change.

Following the multi-criteria analysis (MCA), the four technologies were considered priorities as they have the lowest associated cost, provide the highest economic, environmental, and social benefits, and are highly acceptable by communities to implement them. In addition, all of them are not new technologies in the country. In fact, they are mainly technologies which have been introduced in the country and still require an upscale and expansion.

2.1. Pre-liminary targets for technology transfer and diffusion

Agriculture sector is the primary livelihood for around 64% of Timor-Leste's population engaged in agricultural activities with a majority relying exclusively on low input and output subsistence farming (Lopes and Nesbitt, 2012). The farming system is based on shifting cultivation and shallow soils characterize the terrain. However, agriculture productivity is low due to limited access to and adoption of production increasing technologies (Tomak, 2016; Jensen et al., 2014; Lopes and Nesbitt, 2012), the use of low-quality seeds and fertilisers (Tomak, 2016; FAO, 2003), limited supply of irrigation (World Bank, 2019), and poor soil conditions (Paudel et al., 2022). Climate change is anticipated to have the biggest negative impact on agriculture. An increase in the frequency and intensity of extreme climatic events will further reduce agricultural productivity[1].

It is the goal of the IX Constitutional Government of Timor-Leste to enhance national food security, reduce rural poverty, support the transition from subsistence culture to business production of agricultural and promote environmental sustainability and conservation of the country's natural resources (GoTL, 2023). Furthermore, Timor-Leste's national climate adaptation[2] and strategic national development documents[3] acknowledge that a key to more efficient production and enhanced competitiveness in agriculture sectors rests in the availability and utilisation of production inputs. Table 3 shows that the level of production of maize and rice in the last 8 years (2015-2022) remains below the target set for 2028. It is in the interest of GoTL to increase the level of production of rice from 86,000 tons (2022 forecast) to around 114,650 tons to respond to 70% of the total national demand (which is around 160,412 tons). Therefore, introduction and adoption of production increasing technologies, including the four technologies selected for this sector, in Timor-Leste is seen as one of the tools to assist the Government achieve the 2028 goal not only for maize and rice but also for other agriculture products.

[1] Typically, extreme climatic events in Timor-Leste are related with ENSO episodes. During the 2016 El Niño, government records suggest that maize and rice output declined by 40% and 57%, respectively (USAID, 2017); if ENSO events become more frequent and/or extreme, agricultural productivity and food supply disruptions would certainly grow in tandem.
[2] The National Actional Plan for Climate Change
[3] The Strategic Development Plan 2011-2038 and IX Constitutional Government Programme 2023-2028

Year	Produces	
	Maize (in tons)	Rice (in tons)
2015	64,795	71,541
2016	57,409	60,000
2017	59,148	80,000
2018	83,643	No data*
2019	75,690	80,000
2020	77,606	48,000
2021	80,100	70,000
2022 (forecast)	87,000	86,000
2028 (target)	191,250	114,650

*Data is not available

Table 3: Production level of corn, rice, and tubers based on existing data from 2015- 2021, forecast data for 2022, and the target set for 2028 in Timor-Leste (adapted from FAO/GIEWS Country Cereal Balance Sheet 2015-2022 and GoTL, 2023)

Overall, pre-liminary target for technology transfer and diffusion of the four selected technologies is 141,141 of Timorese families (agricultural households) whose livelihood depends on agriculture. According to Timor-Leste 2019 Agriculture census, these household holdings conduct agriculture activities in a gross cultivated area of 509,226.5 Ha. The timeline for achieving the pre-liminary target is 2030 which is parallel to that of Timor-Leste's SDP 2011-2030. It is also important to align the timeline for achieving the pre-liminary target partially with the five-year term (2023-2028) of the IX Constitutional Government.

Conservation agriculture and crop rotation should specifically target 42,745 agricultural households who practice land tillage (i.e., conservative and conventional). The majority of these farmers reside in Ermera and Manatuto municipality. For water management and restoration, the target can be narrowed down to 28,965 agricultural households reported to irrigate their land using surface water only (68%), underground water only (11%), both surface and underground water (14%), and other sources[4] (7%). Target for biochar and composting can be 2,984 agriculture households reported to use inorganic fertilizer.

2.2 Barrier analysis and possible enabling measures for conservation agriculture and crop rotation

2.2.1 General description of conservation agriculture and crop rotation

According to World Bank (2019), land degradation is a concern in Timor-Leste due to the steep terrain in the country and other factors such as deforestation, inappropriate agricultural practices, forest fires, over-grazing, and demographic pressures. As such, only a quarter of the country's land is suitable for agriculture (World Bank, 2017). Unsustainable agriculture practices in Timor-Leste, deforestation, over-grazing, lack of fallowing, continuous ploughing, harrowing and rotovating, together with the widespread practice of burning organic matter on the soil's surface before planting, are among some of the contributing factors to land degradation. Due to these farming practices, most of the cultivable soils of Timor-Leste tend to lack structure, are low in organic matter, lack water-holding capacity and are prone to erosion. In managed

[4] Municipal water supply, rainwater etc.

agricultural lands, degradation typically results in reductions of soil organic carbon stocks, which also adversely affects land productivity and carbon sinks (Olsson et al., 2019).

Sustainable land management (SLM) has been recognized as key to reducing the rate of land degradation (Haregeweyn et al., 2022). Many literatures highlight the effectiveness of SLM's measures and practices in preventing land degradation by adapting to biophysical and socio-economic conditions aimed at the protection, conservation, and sustainable use of resources (i.e., soil, water, and biodiversity) and the restoration of degraded natural resources and their ecosystem functions. Conservation agriculture (CA) is one of the SLM practices which applies three interrelated principles: minimum soil disturbance, biomass mulch soil cover, and crop diversification (FAO, 2022). Crop rotation is a traditional practice that involves the sequential planting of crops over time (McDaniel et al., 2013). CA has been widely promoted and implemented in croplands in a few countries worldwide, including Timor-Leste.

Combining CA and crop rotation has the potential to improve soil properties, reducing soil erosion, mitigate pressure from weed, insect, and pathogen, and improving productivity (Bullock, 1992; Copeland & Crookston, 1992; Gurr et al., 2003; Smith et al., 2008; Macdaniel et al., 2013; Kassam et al., 2018; Haregeweyn et al., 2022). Overall, if these SLM technologies are combined in an effective way and adopted in large agricultural lands, they can contribute not only to increased production but also to generating many other ecosystem services such as water flow and supply, resilience to drought, nutrient cycling and restoration of soil fertility, carbon stocks in soil and biomass and reduced GHG emissions etc. Additionally, they can potentially reduce the cost of inputs for farmers.

In 2013, MALFF in collaboration with FAO and NGO partners tested the CA techniques, including intercropping with legumes, through demonstration plots in the communities, as well as in MALFF research stations. This collaboration has led to the development of manual for CA, with a dedicated section on crop rotation, for agricultural practitioners, researchers, and agriculture extension officers. Urdín (2016) highlights that two main advantages of using CA were observed during the introduction and testing of CA in Timor-Leste, namely i) increased efficiency in the cultivation of maize through a reduction in the amount of both labor needed and fuel used and ii) increased maize yield when CA practices were applied properly.

There are variety of crop rotations implemented in Timor-Leste, such as inter-cropping maize with velvet bean and cultivating velvet bean prior to food crop and mung beans after rice plantation. ANNEX IV: List of six legumes which has been introduced and tested in Timor-Leste agriculture between 2013 and 2016. provides a list of six legumes which has been introduced and tested in Timor-Leste's agriculture between 2013 and 2016. Of all the legumes tested, the two local varieties of cowpea (Vigna unguiculata) tested ('fore masin' and 'fore metan') proved to have the best adaptability in all agro-ecological zones.

According to data from MALFF, between 2013-2018, CA techniques were tested and adapted for different farm sizes, soils, crop types, and climatic zones. Farmers' reaction to those techniques has been overwhelmingly positive, particularly those with large farm sizes on flat lands. At least 4,000 farmers across seven municipalities (Baucau, Manufahi, Manatuto, Aileu, Ermera, Lautem and Ataúro) have adopted and are practicing CA technologies on a total of around 200 ha farm field. Their experience has shown increased yields of up to 125% and reduced labor costs by at least 50%.

The GoTL sees the importance of further promotion of CA and crop rotation as a key strategy for future development of the agriculture sector in Timor-Leste. Despite many farmers experiencing good results from using CA technologies, farmers face some barriers in adopting this practice on their farms. The following sub-section will present barriers identified during the consultation process with the key stakeholders.

2.2.2 Identified barriers for conservation agriculture (CA) and crop rotation (CR)

In terms of categories of technology, conservation agriculture and crop rotation is considered as *non-market good* like the rest of the seven (7) technologies selected for adaptation. The implementation of this technology by MALFF and partners can continue to be *public good* as it is now. A total of four (4) barriers – which are categorized into financial and non-financial barriers – were identified during desk review and consultation with relevant stakeholders (i.e., MALFF, AI-Com, FAO, DFAT, and Raebia).

2.2.2.1 Economic/financial barriers

i. <u>High capital cost for purchase and maintenance of equipment</u>

   Capital is a limiting factor for farmers' use of conservation agriculture (CA). This barrier is also confirmed through one-on-one interviews and group discussion with relevant stakeholders where high capital cost is seen as a barrier for adopting and scaling up this technology. They argue that a shortage of money and other resources (e.g., lack of agriculture inputs) hinders agricultural activities and adoption of new technologies which require high capital investment. Additionally, most of the farmers in Timor-Leste often find it difficult to access credit for funding agricultural activities and other needs (i.e., purchasing equipment and tool, operation and maintenance, and research and development). This is further exacerbated by a lack of private investment in the agriculture sector as highlighted in MALFF's 2012 reports.

ii. <u>Limited availability of inputs and services</u>

   Ideally, inputs and services should be easily and promptly available to the farmers at affordable prices. However, farmers in Timor-Leste face obstacles in terms of the availability of required inputs and services for new technology to secure outputs. While CA tools (e.g., lee seeders, jab planters, rotavators) are made available with the support of some agriculture projects, this opportunity is only extended to farmers (beneficiary groups) that are integrated into the CA projects in certain areas.

2.2.2.2 Non-financial barriers

i. <u>Strong attachment to slash and burn farming</u>

   Most farmers in Timor-Leste have been practicing the same conventional, unsustainable farming techniques for many generations (e.g., "slash and burn", grazing and burning of crop residues and ploughing/digging of soils). Despite the obvious indicators of increased land degradation due to unsustainable conventional farming practices and frequency of extreme weather events, farmers do not feel the urge to move to new methods that generate promising results. As farmers become accustomed to land tillage practices, they become more reluctant to adopt CA.

ii. Limited knowledge on methods and benefits of CA and CR

Farmers dwelling in rural areas have limited access to information and knowledge about new farming practices, agricultural input information, agriculture production and marketing information. Reluctance to adopt this technology can be the result of limited access to information. Although CA and CR has been promoted in Timor-Leste since 2013 and proven to improve household food and nutrition security and reduce disaster risks associated with climate change, access to this information by target groups outside of the study areas/demonstration plots seems to be limited. This is mainly due to the absence of Government's investment in large-scale campaigns and socialization to increase farmers' knowledge on this technology.

2.2.3 Identified measures for conservation agriculture (CA) and crop rotation (CR)

Desk review and analysis of primary data on barriers to CA and CR have led to the identification of the following economic/financial and non-financial measures.

2.2.3.1. Economic/financial measures

i. Facilitate farmer's access to capital (i.e., micro-loan and grants)

Facilitating smallholder farmers' access to financial services in the country is an important step to enable them to acquire capital. Farmer can use the capital to purchase the much- needed equipment and tools which can be used to increase quality and quantity of their production. In many instances, farmers are not aware of different micro-loan services available in the country apart from the saving-and-loan group/cooperatives.[5] This can be the result of limited information in the municipalities as well as low level of literacy among the farmers groups. By adopting this measure, farmers will be provided with the basic support needed to access micro-loans and grants.

ii. Improve supply chain for CA tools/equipment through domestic supplier to reduce dependence on import

The outsourcing of CA tools/equipment (i.e., manual crimper-roller, hoes, machetes, and long-handled sickles[6]) through local providers needs to be strengthened, especially in the case where they can be developed by local manufacturers.[7] Improving the supply chain for the tools/equipment can also be extended to maintenance service. By adopting this measure, the country can sustain the supply chain and at the same time minimize the risk of being completely dependent on imports which can be easily disrupted by externals events (i.e., conflicts and global pandemics).

2.2.3.2 Non-financial measures

i. Conduct extensive education and awareness raising campaign on CA and CR

Investment in education and awareness raising campaigns at national and local level to increase farmers' access to credible information and improve their knowledge of the technology. This measure can be realized through establishing new platforms or using existing ones to disseminate

[5] An established informal system which provides very small amount of capital (between USD 100 - 300)

[6] While there are local industries to supply the last two tools, market for the first two tools relies heavily on import.

[7] It is a common knowledge that Timor-Leste's economy is highly dependent on imports of goods from neighboring countries due to lack of development of local industries.

information on research findings and best practices to target groups. It can also clarify doubts and pre-conceived notions shared among the farmers' group about the benefits and drawbacks of CA and CR.

ii. Provide farmers with more opportunities for capacity building

It is evident that some methods of CA and CR, such as the use of machetes to remove weeds and hoes to create mulching, has been practiced by Timorese farmers for many generations. Nevertheless, it is important to expose them to other methods (i.e., crop rotation using mung beans and the application of herbicides) through capacity building programmes. The opportunity should be extended to farmers in areas which have not previously received support from any national and international agencies.

iii. Promoting the practice of confined raising in livestock management

A bottom-up approach to regulate livestock might work more efficiently than the conventional top-down approach mainly because community members participate in the process of establishment, socialization, and enforcement of the rules and regulations. It can effectively facilitate the transition from open range to confinement, reducing the risk of loss from livestock free gazing in agriculture fields.

2.3 Barrier analysis and possible enabling measures for water management and restoration

This section provides a general description of status of water management and restoration in Timor-Leste and how it is related to SLM in agriculture in Timor-Leste. It then elaborates on the identified barriers to adopt and enabling framework required to facilitate the adoption and deployment of this technology.

2.3.1 General description of water management and restoration

Historically, Timor-Leste has abundant of freshwater resources, which comprises of surface water and groundwater. With a total internal renewable water resources of 8.13 Bm^3/year, which is equivalent to 6,319 m^3/year for each person in Timor-Leste, there is sufficient water for human, economic, and environmental development needs in the country (ADB, 2020). However, there is a lack of adequate infrastructure, institutions, and management. The current conditions in the country combined with inadequate infrastructure investments and capacity to manage water resources has translated into a low level of water management, high levels of catchment degradation, and high vulnerability to climate change (World Bank, 2004).

According to a 2004 day by World Bank, total actual water withdrawal in Timor-Leste was at around 1,172 Mm^3/yr or 14% of the actual renewable water resources. Water use in agriculture sector for irrigation purposes accounts for 90% of the total annual freshwater withdrawals[8] from free or unregulated river intakes. Without proper water management and restoration efforts in place, water withdrawal during the dry season becomes difficult, limiting the number of areas that can be irrigated during the dry season.

[8] Approximately 1,071 Mm^3 /yr (91%) was used for irrigation and livestock, 99 Mm^3 /yr for domestic use (9%), and only 2 Mm /yr for industrial use.

Enhancing water management requires important investments in the development of infrastructures, institutions, and management capacity.

The management of water resources in Timor-Leste fell under the responsibility of Directorate General of Water and Sanitation of Ministry of Public Work (MPW) before it was transferred to BTL E.P. in 2020. It also involves National Directorate for Management of Forestry, Watershed and Mangrove Area of the Ministry of Agriculture, Livestock, Fisheries and Forestry (MALFF). However, investment in water management tends to focus more heavily on irrigation and distribution of clean water for household consumption rather than on conservation and restoration of springs and aquafers.

Restoration is an integral part of sustainable water management. It refers to a large variety of measures and practices, which can vary considerably in size and complexity, that are aimed at restoring the natural state and functioning of the river system, lake, or wetland to enable its sustainable and multifunctional uses (Brachet et al., 2015). Promoting the adoption of this technology in Timor-Leste's agricultural development is crucial provided that irrigation accounts for 90% of the water use form total annual freshwater withdrawals[9] from free or unregulated river intakes. Additionally, as climate continues to prolong drought and increase the frequency of extreme rainfall days, this technology can help alleviate the pressure on surface water and groundwater by limiting excessive withdrawal during dry season and allowing them to recharge during wet season.

Water management and restoration technology is not completely new to Timor-Leste. In the last ten years, partnership and collaboration between GoTL (i.e., MALFF, SEA, and MPW), development institutions (World Bank, ADB, and UNDP) and local NGOs (i.e., Permatil, Raebia, and Netil) has increased efforts to introduce water restoration practices in different parts of the country.

2.3.2 Identified barriers for water management and restoration

Water management and restoration is a *non-market good* that can be adopted and deployed by BTL, MALFF and partners at national scale as *public good*[10]. A total of three (3) barriers were identified during desk review and consultation with relevant stakeholders (i.e., Permatil, Rede Hasatil, BTL, and MALFF) and categorized into financial and non-financial barriers.

2.3.2.1 Economic/financial barriers

i. Lack of fundings to support local community's initiatives

The restructuring of water management from Ministry of Public Work to BTL has led to more investment in clean water distribution system; Unfortunately, it has not translated into allocation of fund to support water restoration activities. To date, there is still limited investment that targets water conservation activities in the upstream areas using nature-based approaches such as tree planting and construction of recharge ponds as well as research and public outreach on water uptake of different tree species in agroforestry. If this trend continues, extraction of

[9] Approximately 1,071 Mm^3 /yr (91%) was used for irrigation and livestock, 99 Mm^3 /yr for domestic use (9%), and only 2 Mm /yr for industrial use.

[10] This reflects the **non-excludable** (when one person uses a good, it does not prevent others from using it) and **non-rivalrous** (they can be consumed by multiple people simultaneously without reducing the availability of the good for others) nature of water sources (i.e., surface water and ground water).

surface water and groundwater will eventually exceed the recharging capacity of groundwater, leading to more water scarcity in dry season.

While nature-based approaches for water restoration are not costly, one cannot expect the impoverished, vulnerable, and under-resourced communities to handle this task in isolation from government and non-government actors. Community mobilization will not take place when financial means to facilitate group activities (i.e., socialization and labor work) and to purchase material and equipment are not available. Consequently, local initiatives to restore water sources will decline in the absence of a real effort to bridge the financial gap.

2.3.2.2 Non-financial barriers

i. Limited knowledge on water conservation methods

Although water conservation has gained more prominence in Timor-Leste than in the past – thanks to local NGOs' (Permatil and Rede Hasatil) effort to promote it – it has not been adopted and deployed in many water-scarce areas in the country. It can be argued that communities dwelling in rural areas still have limited knowledge on several water restoration methods and their effectiveness due to limited access to information. Often time, the information is not widely available in formats (electronic and hard copies) and languages (i.e., tetum and other local languages) that suit local community's needs and conditions. Consequently, once the knowledge gap widens, communities will become less convinced about the benefits of sustainably managing and restoring water sources.

ii. Lack of an integrated approach in water management and governance

Water sources are considered as public good due to their non-rival and non-excludable nature. As public goods constitute a market failure, it is important that there are institutional arrangements for their governance and management. In Timor-Leste, the institutionalization of water management is only limited to clean water supply and distribution system. Another equally important aspect, water restoration, is not equally prioritized mainly due to the adoption of a more consumption-oriented approach rather than an integrated one that balances both extraction and restoration activities. Although BTL E.P.'s vision statement attributes environmental elements to impact assessment of water infrastructure projects, it does not explicitly highlight the importance of water restoration activities. Additionally, there is no linkage between BTL's water infrastructure work with the forestry department of MALFF which is responsible for water resources management. This condition will likely shift the ecosystems to more degraded states if it remains unaddressed.

2.3.3 Identified measures for water management and restoration

2.3.3.1. Economic/financial measures

i. Link community group with potential donors and investor

Empirical evidence shows that community's commitment to perform reforestation and bioengineering works tends to diminish in the absence of fundings. Based on interviews, the money is needed to purchase tools and equipment and to provide snacks/meals[11] for the voluntary labor works provided by the community members. Linking them with relevant external actors (i.e., national and municipality governments, development partners, and CSOs) can enable them to break the financial barrier. Funding from external actors can also be allocated to support research and development of other low-cost, nature-based solutions.

2.3.3.2. Non-financial measures

i. Integrate water restoration plans in water management system

To change the status quo of the water management system in Timor-Leste, there needs to be more emphasis on integrating restoration and conservation activities in the system. This means that relevant agencies (i.e., BTL and MALFF) must strengthen the institutionalization of water management through introduction of rules and regulations that promote groundwater restoration in areas prone to drought and groundwater deficits. The rules and regulations can be adopted and enforced at Suco level with the support from relevant actors such as facility management groups and local community. They can also be integrated into MALFF forestry's reforestation and afforestation programme at Municipality and Suco level.

ii. Provide community groups with more exposure to water restoration methods

As suggested by key informant interviews, there is more than one water restoration method that the community can adopt. The most common one is the pond which has no concrete structure on the bottoms and sides, allowing a high rate of absorption. The other one is a pond system which is layered with concrete at the bottom to prevent absorption from happening. In this case, only excess water is absorbed in the upper part of the ponds (sides) where no concrete is applied.

While these methods are simple to build and cost-efficient, they might not sound convincing to those communities who are not familiar with them. Hence, it is important to expose them to those methods through field practice and site visits to areas where they can observe the tangible results. This measure also encourages peer-to-peer learning where the community can share their story with others to increase buy-in for the technology.

2.4 Barrier analysis and possible enabling measures for green char/biochar

This section provides a general description of the status of green char/bio char production in Timor-Leste and the barriers for its wide-scale adoption in the country.

2.4.1 General description of green char/bio char

It is evident that limited access to and adoption of production increasing technologies and low quality of agriculture inputs (i.e., fertilizer, chemicals, and vegetable seeds) continue to hinder optimization of agriculture productivity in Timor-Leste (Tomak, 2016; Jensen et al., 2014; Lopes and Nesbitt, 2012; FAO, 2003). Nevertheless, the supply of agriculture inputs in Timor-Leste has undergone a substantial change in terms of the availability, quality, and price (Tomak, 2018). Unfortunately, it has not resulted in an overall increase in agriculture productivity. Farmers still have low purchasing power due to limited access to

[11] Normally is only covers lunch meal

capital. In addition, they are less inclined to use inorganic fertilizers due to its impact on land degradation. Therefore, there is a need to introduce alternative options of fertilizers that are low cost, organic, and "greener" that correspond with Timor-Leste's context.

Biochar is seen as a promising technology since it can be incorporated into soil management systems with the added benefits for smallholders to improve crop production and incomes. Biochar refers to carbon-rich material, produced by pyrolysis or heating of organic biomass in the absence of oxygen, used as a soil amendment to improve soil fertility (da Costa et al., 2021). Sources of feedstock for biochar products are mainly from agricultural and forest biomass residue. Interest in biochar application in agriculture stems from the potential increase in crop productivity, soil health and climate change mitigation. Wijitkosum (2020) argues that there is clear evidence that incorporating biochar into soil improves its properties, increases crop yield and growth, and increases the efficiency of fertilizer use. Additionally, pyrolysis is optimal for biochar production since the main aim is to produce an agronomically useful char product with no adverse environmental outcomes. Another advantage of biochar production is that it can be operated at various scales, making it suitable for smallholder farmers to adopt.

Biochar materials in Timor-Leste are sourced from several types of organic waste, such as rice-hull, wood shaving and coffee husk (da Costa et al., 2021). Since 2017, a collaborative research program to improve agricultural productivity and profitability in Timor-Leste between the Ministry of Agriculture and Fisheries and partners (AI-Com and UNTL), supported by the Australian Centre for International Agricultural Research (ACIAR), has been using rice-hull biochar as the main type of biochar in their research across the country. Different biochar treatments[12] have been used on rice, horticultural crops, legumes, and tubers during the dry and rainy seasons. Their research has concluded that treatment of rice-hull biochar with other materials (organic and inorganic) has shown large positive responses with a greater economic return from the horticultural crops in some plots.

To date, the application of bio char is still limited to research purposes. As more research programmes start to explore the potential benefits of bio char for Timor-Leste's agriculture, it is crucial to look at barriers and enabling framework for its wide-scale adoption and deployment.

2.4.2 Identified barriers for green char/biochar

Biochar is categorized as *non-market good* which can be adopted and deployed by MALFF and partners at national scale as *other good*. Desk review and consultation with a single stakeholder who has been conducting studies on this technology led to the identification of the following five (5) barriers.

2.4.2.1 Economic/financial barriers

i) <u>Collection of raw materials is high cost and time consuming</u>

The production of biochar requires the use of raw material such as wood shaving, coffee husk, rice husk in excess quantity. A few research on the subject suggests that there is 30% recovery rate of the input. The problem is access to high volume of these specific materials is quite rare and is only limited to individuals who operate in the value chain of the same products such as carpenters, coffee pulpers, and rice millers. As a result, for individuals interested in adopting this technology but lacking access to these materials, it is a pre-requisite that they invest in collection system. In addition, the location of collection points for raw materials might add another layer of barrier

[12] Treatments comprised of rice-hull biochar, combining rice-hull biochar with animal manure as well as combining rice-hull biochar with inorganic fertilizers (N, P and K).

when they are scattered in areas far from the processing location. The inputs required for such a collection system can consist of time, organic waste, land, vehicles (i.e., pick up and loaders), fuels, and personnels. As per unit cost of each input can exceed smallholder farmer's budget, the cost benefit analysis might not be in favor of adopting the technology.

ii) No market for biochar yet

Market demand for biochar is not there when farmers are not aware or convinced of its benefits to SLM in agriculture. In the absence of a local market demand, potential suppliers are not interested in investing in biochar production because they see no business prospect in it.

2.4.2.2 Non-financial barriers

i) Limited information on biochar's production and benefits

The production and application of biochar for improving soil fertility is an old tradition commonly used by farmers in many parts of the world. The upsurge of enthusiasm in the application of this technology has only permeated Timor-Leste at an early phase of research and development (R&D) which is led by UNTL and AI-Com. As a result, information on its production and associated benefits are still scarce to target groups. Limited access to such information is a barrier for adoption of this technology because farmers do not know its benefits.

ii) Lack of technical skills

There are five production techniques for biochar, namely pyrolysis, hydrothermal carbonization, gasification, flash carbonization and torrefaction (Yaashikaa et al., 2020). Pyrolysis is the most common technique which requires careful performance. When the type of feedstock and the conditions during pyrolysis are not right, the produced biochar will not have the right chemical and physical properties, resulting in contrasting effects on soils and crops. To date, there is no information on how many farmers in Timor-Leste have practiced and mastered this technique. It is difficult to promote adoption of this technology if opportunities to acquire this technical skill are not provided to target groups.

iii) Limited access to raw materials

As already mentioned above, access to high volume of specific organic materials (input) for biochar production in Timor-Leste is quite rare and is only limited to individuals who operate in the value chain of the products (i.e., carpentry, coffee plantation, and rice farming). Farmers with no free access to organic materials will have to consider the additional cost of purchasing them from local suppliers. In addition, the scattered location of collection points of raw materials might add extra transport cost. Together, they pose a barrier for adoption to individuals interested in this technology but do not have the means (i.e., time and money) to invest in it.

2.4.3 Identified measures for green char/biochar

2.4.3.1 Economic/financial measures

i. Facilitate farmer's access to capital (i.e., micro-loan and grants)

Facilitating smallholder farmers' access to financial services in the country is an important step to enable them to acquire capital. Farmer can use the capital to invest in mobile (i.e., mini trucks, motor bikes and tools/equipment) and immobile assets (i.e., land and mini warehouse) which can be used to increase quality and quantity of their production.

ii. <u>Conduct market assessment on biochar production</u>
While the use of charcoals in agriculture is known to some farmers, there are no studies on the biochar's market in the country apart from the research on the effectiveness of the technology in increasing agriculture production conducted by MALFF and partners. Further studies which assess biochar's demand and supply at the national or municipality level can help inform farmers about where potential suppliers of raw materials and buyers of the final products are. The information will help them decide on whether to invest in the technology and the scale of production that they would like to reach as well as providing them with a rough estimate of their profit margins.

2.4.3.2 Non-financial measures

i. <u>Providing information on the production technique and benefits of biochar</u>
Investment in education and awareness raising campaigns at national and local level to increase farmers' access to credible information and improve their knowledge of the technology. This measure can be realized through establishing new platforms or using existing ones to disseminate information on research findings, best practices, and success stories to target groups. It can also clarify doubts and pre-conceived notions that might exist.

ii. <u>Providing training on biochar production to farmers</u>
Bridging the existing capacity gap on biochar production methods in farmer community in Timor-Leste requires training opportunities that allow them to learn some production techniques which are suitable for local needs. In this case, training on pyrolysis technique can come in handy provided that this technique is well studied in the country. However, training in other techniques is also recommended if research in other techniques can prove their feasibility in the country. The training activities can be integrated into the curriculum of farmer's field school (FFS) organized MALFF.

2.5 Barrier analysis and possible enabling measures for composting

This section provides a general description of the status of composting in Timor-Leste and the barriers for its wide-scale adoption in the country.

2.5.1 General description of composting

There are various environmental, social and health issues in many parts of the world that have poor solid waste management. Organic waste is known for posing a wide range of environmental challenges such as leachate production, greenhouse gas (GHG) emissions, offensive odors, and soil/water contamination when left untreated at dump sites (Hettiarachchi et al., 2018). On the other hand, if managed properly using sustainable recovery alternatives, including composting, this organic waste can reduce pollution, conserve resources, and prevent damage to ecosystems (Hettiarachchi & Machado, 2020).

Composting is the natural process of biological decomposition and stabilization of organic waste which turns organic materials such as crop residues and other wastes with animal manures into humus (Oppliger & Duquenne, 2016; Dollhofer & Zettl, 2017; UNDP, 2020). Its final product comes in the form of cheap and effective organic mulch that can be used as an alternative to commercial fertilizers to improve the soil nutrient status and other properties. Nutrient recycling embedded in the concept of composting supports the idea of transitioning to a circular economy, which is currently being discussed in many international circles (Hettiarachchi et al., 2020).

A 2013 data from ADB estimates that the 352,553 inhabitants of the capital city, Dili, generates around 250 tons of waste. Only about 55% of it is disposed in the dump site while the rest are dumped into rivers, sea, burned and buried. Organic waste constitutes 98% of the municipal waste (Ximenes & Maryono, 2021). Although there is no available literature on the practice of composting or other technology in Timor-Leste, it is safe to say the practice is still not common at household level due to various reasons, including lack of space, proper knowledge, incentives. Nevertheless, there are a few youth-led organizations in Timor-Leste that have tapped into composting market, producing humus to supply local demand. One of them is TILOFE which started its operation in 2018. Their annual humus production level has reached up to 65 tons. It is worth exploring the barriers which limit the adoption of this technology in Timor-Leste, a country where there is increasing population and urbanization and where agriculture is the main source of income and land degradation is a major problem.

2.5.2 Identified barriers for composting

Categorized as *non-market good,* composting is a technology that can be adopted and deployed by MALFF and partners at national scale as *other good*. A total of four (4) barriers were identified and categorized into the following economic/financial and non-financial barrier.

2.5.2.1 Economic/financial barriers

i) <u>Compost production is high-cost initially and time consuming</u>

The production of compost requires the use of brown (i.e., dried plant materials, fallen leaves, shredded tree branches, cardboard, newspaper, hay, straw, and wood shavings) and green (i.e, kitchen scraps, coffee grounds and chaff, animal manures and fresh plant and grass trimmings) organic material. While most of the materials can be easily collected from private/public spaces for free, others (i.e., animal manures, hay, straw, and wood shaving) might have some financial cost and can be time consuming because they must be purchased from suppliers, transported to the production site, and processed on-farm for a few months. Not every farmer is enthusiastic about this technology because they are not willing to spend money, time, and effort on the production process.

ii) <u>Space requirement for compost production</u>

While it is true that compost production can take place in either a small yard or a big farmland, there is a strong preference for the latter due to the following advantages. Firstly, big space can accommodate the decomposition of large volumes of organic material which translate into high yield of compost. Secondly, it provides options for farmers to keep the location of organic piles far from and reduce the impact of unpleasant odor on houses. As a result, farmers who own small land will have to acquire more land if they are to produce compost in larger quantities for both on-farm use and off-farm sale.

2.5.2.2 Non-financial barriers

i) <u>Lack of market information on compost</u>

Market information on compost is an important component in developing marketing strategies and plans. It comprises of essential data such as consumer behaviors, market demands and supply, actors, and future trends. When information meant to guide farmers is scarce, they are convinced whether their investment on off-farm sale will generate a return.

ii) Poor integration of composting in urban waste management

Waste management in urban areas of Timor-Leste is a difficult problem to tackle. The capital city, Dili, is becoming the focal point of waste generation where traditional waste management methods (i.e., source reduction, reuse, and landfill) are falling short of handling the influx. Although compost has been widely known as one of the sustainable methods to tackle the problem, it has not been properly integrated into urban waste management in the country. There is no system in place to promote segregation of organic waste from non-organic one and encourage citizens to do more compost. As a result, only a small fraction of people who are aware of the advantages of composting adopt this technology while the rest continue to overlook it.

2.5.3 Identified measures for composting

2.5.3.1 Economic/financial measures

i. Facilitate farmer's access to capital (i.e., micro-loan and grants)

This measure echoes the point stated in Section 2.4.3.1. Facilitating smallholder farmers' access to financial services in the country is an important step to enable them to acquire capital.

ii. Conduct market assessment on supply chain and compost

Although the use of compost in agriculture is common in Timor-Leste, there are limited studies on the compost market. Existing research is mostly limited to the effectiveness of this technology in increasing agriculture production. Studies which assess compost's demand and supply at the national or municipality level can help inform farmers about where potential suppliers of raw materials, buyers of the final products, and consignment stores are. The information will help them decide on whether to invest in the technology and the scale of production that they would like to reach as well as providing them with a rough estimate of their profit margins.

2.5.3.2 Non- financial measures

i. Provide information on the production technique and benefits of composting

Investment in educational and awareness raising campaigns at national and local level can improve farmers' access to credible information as well as increasing their knowledge of compost production technique and its benefits as organic fertilizer. This measure can capitalize on new or existing media platforms to disseminate information on research findings, best practices, and success stories to target groups.

ii. Proper integration of waste separation into urban waste management

Urban areas generate different types of waste, including food garbage which is one of the raw organic materials used for composting. In most cases in Timor-Leste, food garbage is used to feed livestock (mainly pigs). However, in areas where there is no livestock, this organic waste mostly ends up in mixed garbage bins. Hence, if households separate their waste and discard it in facilities provided by the city/village authorities, they can contribute to supply chain of raw material for compost producers who are willing to collect it. At the same time, they can reduce various health and hygiene issues derived from poor urban waste management systems.

2.6 Linkages of barriers across technologies

The barriers hindering the four technologies in SLM in agriculture sector were found to be financial, technical, human capacity, education/knowledge, institutional, and cultural. The financial barrier found across all four technologies is mainly associated with high capital/investment cost for inputs. Farmers operating in large-scale agriculture production who earn stable profit are more likely to overcome this barrier than the ones operating in small-scale production. In addition, the absence of local markets for particular technologies, namely biochar and compost, creates reluctance for farmers to invest in them.

Barriers in access to information and limited human capacity are commonly found in all four technologies. It is evident that farmers dwelling in rural areas tend to have limited access to information and capacity building opportunities. Often time, relevant information is not widely available in formats and languages that can be properly accessed by rural communities. In comparison to the well-informed and educated farmers, the rural farmers face more difficulties to overcome technical and human capacity barrier when knowledge and capacity gap remain unaddressed.

The institutional barrier in water management and restoration technology highlights deficiency in establishing governance arrangement which integrates both consumption-oriented and conservation-oriented approach as well as strengthening inter-agency coordination.

Analysis of cultural barrier shows that most farmers in Timor-Leste have practiced the unsustainable farming techniques (e.g., slash and burn, grazing and burning of crop residues and ploughing/digging of soils) for many generations. Despite the obvious indicators of increased land degradation (i.e., landslide, infertile soil, and loss of soil biodiversity) due to the continuation of unsustainable practice coupled with high frequency of extreme weather events, many farmers do not feel the urge to switch to new practices that generate promising, sustainable results.

This BAEF analysis reveals linkages among the barriers. For example, financial barrier tends to worsen technical, human capacity and education/knowledge barriers provided that it limits allocation of funds and investment in purchasing equipment/machines, implementing training activities and conducting campaigns. Additionally, human capacity and institutional barriers are closely interlinked. Institutional functions (i.e., planning, socialization, monitoring, and rules enforcement) cannot be effectively implemented when human resources are not properly equipped with the right level of knowledge and skillset. Lastly, education/knowledge barrier is also influenced by cultural barrier. When access to scientifically proven information is scarce, people continue to attach to cultural practices and beliefs that might not be climate friendly.

2.7. Enabling framework for overcoming the barriers

To overcome the identified barriers for SLM in agriculture sector, this BAEF analysis has identified an enabling framework that consists of political, institutional, and regulatory framework. The political framework encompasses national programmes and policies that aim to enhance adoptions and deployment of certain technologies. Examples of this framework are the National Strategic Development Plan (SDP) 2011-2030 and the Programme of the 9th Constitutional Government which aim to enhance national food security, reduce rural poverty, support the transition from subsistence culture to business production of agricultural, and promote environmental sustainability and conservation of the country's natural resources. Hence, they can facilitate the large-scale adoption of all four technologies. Likewise, policy such as social credit programme launched by the Government in 2021 which targets Timorese entrepreneurs also falls into political framework. This policy creates a conducive environment for implementing measures that aim to facilitate access to capital such as microcredit which is identified in all three technologies (CA, composting, and biochar). Moreover, another policy worth mentioning here is the establishment of farmers' markets which sell local agriculture products in the capital city since 2019. While it strengthens the implementation measures that aims to establish markets for agriculture products (outputs), it can also pave the way for marketing agricultural inputs that can be produced locally such as fertilizers (from both compost and bioengineer) and other tools (i.e., machetes and hand hoes).

Institutional framework that enables implementation of measures to overcome institutional, technical, human resources and information barriers refers to formal organizational structures, rules, and norms for service provision. It can be existing functional structures in the Government agencies (i.e., MALFF and BTL) and development partners which allocate specific roles and responsibilities (i.e., planning, implementing, quality assurance etc.) to their specific a directorate/department. For example, each agency listed in Table 4 has its own directorate which holds specific functions that can accommodate implementation of each identified measure.

In terms of regulatory framework, the BAEF analysis found sees the national tax law – which offers a slightly low rate of 10% business tax in the country in comparison to the global average of 23% – as a good incentive for local entrepreneurs to conduct agrobusiness using technologies from this sector such as CA, composting, and charcoal.

The matrix below provides a list of measures which corresponds to the financial and non-financial barrier elaborated from Section 2.2 Barrier analysis and possible enabling measures for conservation agriculture and crop rotationto Section2.5 Barrier analysis and possible enabling measures for composting. It also provides a list of agencies which are responsible for the implementation of the measures.

Technology	Barriers	Enabling Measures	Responsible agencies
Conservation agriculture (CA) and crop rotation	1. High capital cost for purchase and maintenance of equipment 2. Strong attachment to slash and burn farming practices inherited from ancestors 3. Limited knowledge on methods and benefits of CA and CR 4. Limited availability of inputs and services	1. Facilitating farmer's access to capital (i.e., micro-loan and grants) 2. Conducting CA and crop rotation campaign at national and local level 3. Increasing the frequency of capacity building activities on CA and crop rotation for all farmers 4. Improving supply chain for CA tools and equipment through domestic suppliers to	1. Development partners, MALFF, financial institutions 2. MALFF, development partners 3. MALFF, development partners 4. Private sector, MALFF, development partners

		reduce dependence on imports	
Water Management and restoration	1. Lack of fundings to support local community's initiatives 2. Lack of an integrated approach in water management and governance 3. Limited knowledge on water conservation methods	1. Linking community group with potential donors and/or investors 2. Integrating water restoration plans in water management system 3. Providing capacity building on water conservation techniques to community groups	1. NGOs, MALFF, local authorities, development partners 2. BTL E.P., MALFF, Permatil 3. Development partners, BTL E.P., MALFF, Permatil
Biochar	1. Collection of raw materials is high cost and time consuming 2.1 No market for biochar yet 2.2 Limited access to raw materials 3 Limited information on biochar's production and benefits 4 Lack of technical skills	1. Facilitating farmer's access to capital (i.e., micro-loan and grants) 2. Conducting market assessment on biochar production to link farmers with potential supplier of raw materials (i.e., wood shaving, coffee husk, and rice husk) 3. Providing information on the production technique and benefits of biochar 4. Providing training on biochar production to farmers	1. AI-Com, UNTL, MALFF, development partners 2. AI-Com, UNTL, MALFF, development partners 3. AI-Com, UNTL, MALFF, development partners Development partners, financial institutions , MALFF

Composting	1.1 Compost production is high-cost initially and time consuming 1.2 Space requirement for compost production 2. Lack of market information on compost 3. Poor integration of composting in urban waste management	1. Facilitating farmer's access to capital (i.e., micro-loan and grants) 2. Conducting research on market for compost 3. Providing market information to potential compost suppliers Integrating of waste separation in urban waste management	1. Development partners, financial institutions, MALFF 2. AI-Com, UNTL, MALFF, development partners 3. AI-Com, UNTL, MALFF, development partners 4. MSA, MALFF, NGOs, households

Table 4: List of barriers for technologies in sector 1, enabling measures, and responsible agencies

3. Sector 2: Infrastructure and natural methods to prevent erosion

During step 1 of TNA, four technologies in **infrastructure and natural methods to prevent erosion** sector have been identified, namely (i) soil bioengineering; (ii) tarabandu; (iii) mangrove plantation; (iv) slope agriculture land technology (SALT). The four prioritized technologies aim to minimize deforestation and other practices that increase the risk of upland erosion as well as mitigating coastal erosion and nearby marine ecosystems.

Following the Multi-criteria analysis (MCA), the four technologies were considered priorities as they have the lowest associated cost, provide the highest economic, environmental, and social benefits, and are highly acceptable by communities to implement them. One of them, *tarabandu,* is a customary practice in common pool resource management that has been embedded in Timorese culture for many generations. The others are mainly nature-based approach technologies that have been practiced in some parts of the countries by communities in upland and coastal areas to maintain road infrastructures and secure agriculture lands. Hence, the TNA provides ample opportunities for their upscale and expansion.

3.1 Pre-liminary targets for technology transfer and diffusion

High-quality road and bridge infrastructures provide solutions to many rural parts of Timor-Leste where landslide and floods regularly interrupt road connections in the country, restricting mobility of people and goods (i.e., inputs for agriculture production and agriculture produces) (GoTL, 2011). To address this infrastructure challenge, the SDP 2011-2030 has prioritized significant investments in road rehabilitation, repair, and improvement. Nevertheless, the strategic document neither factors in climate change impacts on road and other infrastructures development nor considers nature-based solutions. As a result, the quality and sustainability of some infrastructures remains questionable. This creates a problem of inefficiency in the use of financial resources (i.e., state budget, grants, and loans) in a country where infrastructure contributes to 16 % of the total annual state budget allocation between 2008 -2013 (USD 1,584.8 million).

Nature-based solutions (NbS) seek to maximize the ability of nature to provide ecosystem services that help address a human challenge, such as climate change adaptation, disaster-risk reductions, or food production (The Nature Conservancy, 2021). They can deliver a triple benefit when deployed properly, supporting agricultural production and resilience, controlling erosion, mitigating climate change, and enhancing biodiversity. Compared with civil engineering, NbS offers many advantages such as cost reduction, limited impact on the environment, and production of ecosystem services (Moreau et al., 2022).

Timor-Leste's Second National Communication under the UNFCCC, the National Determined Contribution (NDC) 2022-2023, and National Adaptation Plan (NAP) elaborate the importance of integrating nature-based solutions such as mangrove ecosystem protection and bioengineering into climate adaptation efforts to combat both inland and coastal erosion. These documents reflect on past and ongoing efforts to introduce simple, low-cost, and effective nature-based solutions in the country. For example, between 2016 –2021, MALFF in collaboration with UNDP and other national stakeholders implemented a GEF-funded project, Coastal Resilience Building (CRB), which has restored and protected 47% of total mangrove ecosystem (4,831 Ha) in the north and south coast of the country. Literature reviews show that introduction of sloping agriculture slope technology (SALT) in different parts of the country has occurred as early as 2007[13] through Local Initiatives for Food-security Transformation (LIFT) Project with the support from the European Commission and Austrian Development Cooperation (ADA). Similarly, soil bioengineering has been prevalent in various infrastructure projects funded by GoTL and development agencies (i.e., GEF, GCF, World Bank, and ADB). In 2012, the World Bank even developed a field guide on soil bioengineering for slopes stabilization in Timor-Leste.

Pre-liminary target for technology transfer and diffusion of soil bioengineering and SALT can be 60% of the approximately 70.000 ha of total cultivated land in Timor-Leste. For mangrove plantation technology, the target can be 53% of total mangrove area which was not covered by CRB project (2,560 Ha). *Tarabandu* can help enhance management of land and coastal resources in which these technologies are applied.

The timeline for achieving the pre-liminary target is 2030 which is parallel to that of Timor-Leste's SDP 2011-2030. It is also important to align the timeline for achieving the pre-liminary target partially with the five-year term (2023-2028) of the IX Constitutional Government.

3.2 Barrier analysis and possible enabling measures for soil bioengineering

3.2.1 General description of soil bioengineering

Timor-Less is highly exposed to weather hazards and recurrent disasters due to heavy monsoon rains, steep topography, widespread deforestation and land degradation, cyclones, and strong winds. In 2019, the World Risk Index identified Timor-Leste as the 20th country most at risk in the world for natural disasters due to its geographical location and very limited capacity to prepare for and recover from climate-related shocks (FAO, 2021). Therefore, adopting climate-resilience infrastructure models and NbS to prevent erosion is crucial.

Soil bioengineering is the use of living plant materials to construct structures that perform an engineering function (World Bank, 2012). Deemed as a useful and effective technology for slope stabilization and soil conservation, soil-bioengineering is simple, low cost, and effective, requires little to no maintenance, is environmentally friendly, and sustainable. It is a complementary and cost-effective addition to conventional hard engineering approaches that use rock-based and concrete physical structures (ADB,2018). It is particularly important for roads in Timor-Leste, where adjacent slopes have a plethora of stability problems. The technology can significantly reduce the risk of erosion by establishing vegetation in combination with timber and/or rock-based engineering structures to anchor and protect shallow-seated earth masses, preferably as soon as possible after cutting the slope.

There have been numerous efforts to introduce and enhance adoption of soil bioengineering in Timor-Leste. In 2012, World Bank even developed a field guide on soil bioengineering for slopes stabilization in Timor-Leste for upland and coastal areas as part of capacity building for Ministry of Public Works (MPW), forestry department of MALFF and relevant practitioners. This has contributed to mainstreaming of soil bioengineering in many other projects in the country, including the UNDP's Strengthening the resilience of small-scale rural infrastructure and local government systems to climatic variability and risks (SSRI)

[13] It is possible that SALT might have been introduced in Timor-Leste earlier than that; However, literature review only shows the LIFT project's documentation of the introduction of this technology in Timor-Leste. No national stakeholder provided information one earlier introduction of this technology.

project, and ADB's Road Network Upgrading Project, and Word Bank's Timor-Leste Road Climate Resilience Project[14].

3.2.2 Identified barriers for soil bioengineering

Soil bioengineering, *non-market good*, can be adopted and deployed by Ministry of Public Works (MPW) and partners at national scale as *public good*. The BAEF analysis for this technology identified three (3) main economic/financial and non-financial barriers as shown below.

3.2.2.1 Economic/financial barriers

i) Lack of financial allocation from state budget on bioengineering

The allocation state budget for infrastructure centers on development of hard engineering structures such as road, bridges, retaining walls, and drainages. While this strategy responds to the country's need to improve transport and mobility, it does not address the sustainability of the infrastructures in the long run due to the absence of funds for bioengineering works. In most cases, bioengineering is considered as an optional element in infrastructure development; hence, it is not a prioritized item in infrastructure fund.

3.2.2.2 Non- financial barriers and measures

i) Lack of investment in research and development (R&D)

The Ministry of Public Work – the government entity responsible for the development, construction, and maintenance of the vital infrastructure of the country – has established three civil engineering laboratory facilities (in Dili, Baucau and Liquiça) in 2017. While the laboratory is used to test the quality of hard engineering such as roads and bridges, it does not include bioengineering work. As a result, there are not many R&D activities on bioengineering.

ii) Limited information on bioengineering's benefits

Bioengineering was largely introduced and integrated into Timor-Leste's infrastructure in 2012. During the same year, the World Bank even developed a field guide on soil bioengineering for slopes stabilization in Timor-Leste. There is also a list of infrastructure projects funded by bilateral/multilateral agencies that incorporated bioengineering in the design. However, knowledge about the benefits of bioengineering has not been mainstreamed due to limited information available to the public. For instance, there are not many publications on the Dili-Ainaro Road project which has outstanding bioengineering features to highlight its roles in soil stabilization and erosion prevention. As a result, the low-cost and effectiveness of bioengineering features in improving public infrastructure continues to be completely overlooked.

3.2.3 Identified measures for soil bioengineering

1.2.3.1 Economic/financial measures

i. Committed budget line in national allocations for soil bioengineering

   This measure addresses the core issue of financial allocation in infrastructure development projects which generally does not prioritize soil bioengineering activities in high-risk erosion areas. It assures that each major infrastructure project implemented in high-risk erosion areas will have a specific budget item on soil bioengineering to support hard-engineering structures as needed.

[14] Implemented by Ministry of Public Works of Timor-Leste

3.2.3.2 Non-financial measures

i. <u>Conducting R&D in soil bioengineering</u>
   Conducting R&D in soil bioengineering in Timor-Leste offers various benefits. Firstly, it provides opportunity for collaboration between line ministries (MPW, MSA, and MALFF), academic/research institutions agencies to explore different soil-biongineering methods through a scientific approach and identify the ones that suit different terrains in Timor-Leste's highland and low-land areas. Additionally, findings and recommendations from the research will be a basis for updating the World Bank's field guide for soil bioengineering.

ii. <u>Conducting extensive campaign and socialization on soil-bioengineering</u>
   The campaign is an opportunity to share findings on studies on soil-bioengineering as well as providing general information on the benefits of combining bioengineering with hard engineering in infrastructure development. The target group includes technical staff of MPW, MSA, and MALFF (at national and municipality level), contractors (private sectors) and local communities who provide labor work for infrastructure projects.

iii. <u>Conducting trainings on soil-bioengineering</u>
   This measure aims to bridge the capacity gap on soil-bioengineering methods. The training can be embedded into capacity-building activities for technical staff from relevant line-ministries, engineers, supervisors from contracting companies, and workers. The training modules need to incorporate findings from various R&D activities for Timor-Leste context.

3.3 Barrier analysis and possible enabling measures for tarabandu

3.3.1 General description of tarabandu

In Timorese traditional governance system, decisions over resource management are usually vested in local authorities, such as secular leaders (Liurai) and ritual leaders (Lia-Na'in) who hold the role to enact and enforce customary law. *Tarabandu*, an example of customary tradition of community regulation, is commonly used to caution people that property is private or that harvest prohibitions remain in force (McWilliam, 2002; Meitzner Yoder, 2007; Palmer & de Carvalho, 2008; McWilliam et al., 2014). The performance of tarabandu ritual by Lia-Na'in, usually after consultation with local leaders and members of community, dominates the domain of traditional governance of common pool resources (Meitzner Yoder, 2007; Palmer & de Carvalho, 2008;).

Tarabandu is quite distinguished from other selected technology due to its nature and origin. Having the State recognition of customary systems' significance, such as that of t*arabandu's*, in local governance renders plentiful opportunity to promote the potentiality of hybrid management model for natural resource management as seen in the case of forest protection and marine protected areas (MPAs) which adopt community-based approach. In other programmes, such as the Coral Triangle Support Programme (CTSP), community members, under the guidance of suco council and local conservation group, designed their own *tarabandu* rules and regulations and sanctions for the marine protected areas. The same process was replicated during the process of establishing the MPAs in Atauro. Moreover, it is the community members themselves who voluntarily enforce and monitor the *tarabandu* in their MPA.

The effectiveness of *tarabandu* rules in the current community-based natural resource management (CBNMR) remains a challenge. While it is deemed as an effective, conflict sensitive, and locally owned tool concerning CBNRM, it is not a panacea for various environmental and social issues in the country. Timor-Leste's sixth national report to UNCBD highlight that monitoring and assessment of the *tarabandu* enforcement and outcomes is lacking mainly due to limited fundings and technical staffs. In addition, empirical evidence shows that Timor-Leste continues to face a suite of environmental challenges including ongoing deforestation (for both agriculture and timber) for both commercial purposes and domestic needs and biodiversity loss even in the areas where *tarabandu* rules have been enacted. Therefore, it is important to take a step back to reassess why *tarabandu* has not been as effective, identify barriers to its adoption and deployment, and propose measures to overcome them.

3.3.2 Identified barriers for tarabandu

Unlike other technologies*, tarabandu* is a technology that has been embedded in Timor-Leste's customary system of common pool resource management. It is a *non-market good* that can be widely re-introduced and deployed by MALFF and Ministry of Tourism and Environment (MTE), and partners at national scale as *other good*. A total of three (3) barriers were identified and categorized into the following economic/financial and non-financial barrier.

3.3.2.1 Economic/financial barriers

i) <u>Lack of financial allocation from state budget on *tarabandu* enforcement</u>

The allocation state budget for environmental sector (then Secretary of State for the Environment), which is responsible for implementing habitat protection and biodiversity conservation, is relatively small in comparison to sectors such as infrastructure and social welfare. Only a small fraction of the budget is allocated for the responsible agency and combined with other fund (bilateral and multilateral funds) for socialization and establishing *tarabandu* rituals in protected areas; however, the budget is not sufficient to cover crucial activities such as monitoring support for enforcement mechanism of the rules and regulation and establishment of alternative sources of livelihood for local community whose access to common pool resources are restricted. When there is no regular monitoring, the enforcement of *tarabandu* rules is weak. The disobedience of the rules is further exacerbated by economic pressure to provide for the family and the lack of efforts to identify alternative sources of income.

ii) <u>Limited opportunities to diversify household's source of income</u>

Agriculture is the main economic activity for 64% of Timor-Leste's population. The farming system is based on shifting cultivation, one of the major contributing factors to erosion and land degradation in the country. Some households in rural areas extract natural resources such as firewood, timber, and animal protein from the forest for subsistence and commercial purposes. In rural areas where *tarabandu* rules have been enforced, overextraction of natural resources (i.e., soil, water, forest products, and animal products) at alarming still prevails due to economic pressure and a highly centralized development. Often time, *tarabandu* rules were merely enacted to limit access to common pool resource without providing alternative solutions.

3.3.2.2 Non-financial barriers

i) <u>Weak governance</u>

Normally, *tarabandu* rules are designed through a participatory process involving local actors (i.e., leaders and community groups). During the process, individuals are required to work collectively to set "rules of the game" regarding access to and extraction of common pool resources and the enforcement mechanism. When locally based rules have gained widespread community support and legitimacy, the entire community can become part of the eyes and ears of the local regime's enforcement. Unfortunately, this is not the case when national and local government fail to incorporate *tarabandu* as part of natural resource management and prioritize state regulations over customary practices. Often time, the problem stems from a lack of coordination and collaboration between national and local actors in setting, socializing, and enforcing the rules and regulations.

3.3.3 Identified measures for tarabandu

3.3.3.1 Economic/financial measures

i. <u>Committed budget line for *tarabandu* enforcement</u>

This measure aims to address the financial barrier that stems from lack of fundings from the annual state budget for the enforcement of *tarabandu* rules and regulations. It helps secure fundings for both socialization for the establishment of *tarabandu* system and its monitoring activities in close cooperation with suco councils and other relevant actors. It assures that the responsible ministries (i.e., MTE and MALFF) have a consistent source of fundings throughout the whole year to implement regular field activities that strengthen community members' compliance with the rules and regulations.

ii. <u>Establishment of alternative source of livelihood</u>

Empirical evidence shows that community members are likely to show compliance with *tarabandu* rules and regulations that limit their access to resources on which their livelihood depend only when they are provided with alternative solutions. Following this logic, this measure emphasizes the need to establish alternative activities that will generate income and sustain community's livelihood. It ensures that the basic needs of community members living in areas where *tarabandu* system is enacted are met.

3.3.3.2 Non-financial measures

i. <u>Strengthening local governance</u>

This measure calls for improvement in coordination between national and local actors to ensure that all relevant actors are involved in setting, socializing, and enforcing the rules and regulations. It ensures that *tarabandu,* being a customary law, is fully incorporated into natural resource management and is regularly monitored. When locally based rules have gained widespread community support and legitimacy, the entire community can become part of the eyes and ears of the local regime's enforcement.

3.4 Barrier analysis and possible enabling measures for mangrove plantation

3.4.1 General description of mangrove plantation

Mangrove forests are an important habitat for coastal ecosystem. It is widely acknowledged that mangrove forest provides ideal breeding grounds for many aquatic species (i.e., fish, shrimp, crabs, and other shellfish) and protects coastal zones against natural hazards (i.e., storms, tsunamis, and coastal erosion). Seafront mangroves species, especially those belonging to the genus Rhizophora, have deep, twisted roots that spread over the coast like a net and trap soil which can prevent soil erosion and help in further deposition given an adequate supply of allochthonous sediment (Saudamini, 2020; Besset et al. 2019).

Timor-Leste is endowed with extensive coastline (approximately 747 km) in both northern and southern part which is home to around 9,000 ha of mangrove forest. However, since 1940 that number has declined to 4,000 Ha in 1982 due to overharvesting for timber and firewood. A 2020 data from MALFF-UNDP Coastal Resilience Building (CRB) project shows that the area has increased to 4,831 Ha and identifies around 35 species of mangroves and associate species.

There has been increasing efforts to protect and restore the mangrove ecosystem in Timor-Leste partly due to more acknowledgement of the effectiveness of nature-based solutions to adapt to the impact of climate change. Timor-Leste's Sixth National Report to UNCBD lists mangrove reforestation as a strategic action aimed rehabilitation of critical and damaged habitats and ecosystems. MALFF, the responsible government agency for coastal resource management, collaborated with UNDP and other national stakeholders to implement a GEF-funded project, Coastal Resilience Building (CRB), which has restored and protected 47% of total mangrove ecosystem in the country. Unfortunately, the survival rate of new mangrove seedlings is relatively low due to various reasons such as failure to select suitable species, limited technical knowledge, and livestock grazing. Nevertheless, the project has paved the way for more restoration and learning activities on mangrove ecosystem. A local NGO, Klibur Flora and Fauna (KFF), is currently managing a mangrove learning facility in Hera (Dili municipality). KFF has also partnered with various government agencies, development partners, educational institutions, and private sectors to implement mangrove planting and protection activities on the north coast of Timor-Leste.

3.4.2 Identified barriers for mangrove plantation

Mangrove plantation is *non-market good* that can be adopted and deployed by MALFF, MTE, and partners at national scale as *other good*. According to the BAEF analysis, there are three (3) barriers which are categorized into the following economic/financial and non-financial barrier.

3.4.2.1 Economic/financial barriers

i. <u>Lack of financial allocation from state budget on mangrove protection</u>

The allocation of state budget for forestry department of MALFF, the responsible entity for management of mangrove forests, is relatively small in comparison to other sectors such as infrastructure and social welfare. Only a small fraction of the budget is allocated for the responsible agency and combined with external fundings from private sector, and bilateral and multilateral agencies for restoring forests ecosystem; however, the budget is not sufficient to cover crucial activities for mangrove restoration such as establishing community nursery groups, monitoring the condition of planted seedlings, building fences, and establishment of alternative sources of livelihood for local community whose access to common pool resources are restricted.

Community groups lose interest to continue their operation in the absence of financial commitment from both National Government and external actors.

3.4.2.2 Non- financial barriers

i. <u>Human encroachment of mangrove habitats</u>

The rapid progression of urban spawl in coastal areas coupled with aquaculture and major infrastructure development poses a negative impact on mangrove ecosystem. They generate tons of waste and require massive land clearing and underwater dredging which threaten both coastal and marine habitats as well as their provision of ecosystem services.

ii. <u>The practice of free grazing</u>

Due to lack of regulations, most farm livestock in Timor-Leste are free to graze anywhere as guided by their owners. Wetland and mangrove forests are no exception. Living fence of vegetation has been used a low-cost, sustainable solution to stop livestock encroachment in public and private plantations; However, its application in coastal area has been met with some biophysical challenges provided that only some vegetation can tolerate salinity level and tidal current in the coastal area.

3.4.3 Identified measures for mangrove plantation

3.4.3.1 Economic/financial measures

i. <u>Committed budget line for restoration of mangrove ecosystem</u>

This measure aims to address the financial barrier that stems from lack of funding from the annual state budget for managing natural resources, including the mangrove ecosystem. It helps secure fundings for mangrove ecosystem restoration activities such as community consultation, forming community groups, establishing nursery centers, building fences, planting seedling and monitoring). When funding is earmarked and properly allocated, responsible line ministries (i.e., MTE and MALFF) will have consistent financial and logistics support throughout the whole year to implement field activities in target coastal areas.

3.4.3.3 Non-financial measures

i. <u>Spatial planning for coastal areas</u>

Land use changes in the coastal areas of Timor-Leste due to rapid urbanization and industrialization can be a threat to mangrove ecosystem. Designing a coastal spatial planning for the country can helps city administrators and planners to make better usage of coastal areas. Capturing accurate information about the environmental characteristics, biophysical conditions, and present utilization of the coastal areas, the coastal spatial planning helps minimize the impact of anthropogenic land use on coastal ecosystems. Therefore, Timor-Leste can tap on coastal spatial planning as a bridge between nature conservation and land use.

ii. <u>Promoting the practice of confined raising in livestock management</u>

This measure aims to address the issue of livestock encroachment in mangrove plantation sites. As elaborated in Section 2.2.3.2, a bottom-up approach to regulate open grazing livestock management might work more efficiently than the conventional top-down approach. The reason being community members participate in the process establishing, socializing, enforcing the rules and regulations. It can effectively facilitate the slow transition from open range to confinement, reducing the risk of loss from livestock free gazing in mangrove plantation sites.

3.5 Barrier analysis and possible enabling measures for sloping agriculture land technology

3.5.1 Description of sloping agriculture land technology

Cultivation on sloping land is common in Timor-Leste highland agriculture. The NDA estimated that 60% of the approximately 70.000 ha of the total cultivated land area in Timor-Leste is found on sloping areas. Most of the farmers who cultivate in this sloping terrain practice slash and burn where vegetation in particular plot of land is cut, and fire is set to burn the remaining foliage (Stief, 2019). Ashes are used as nutrients to the soil for the use of planting food crops. Unfortunately, many critics claim that slash and burn contributes to a number of persistent environmental problems, including soil erosion. This is mainly due to the fact that fields where vegetations are slashed and burned are likely to lose roots and temporary water storages. What is left behind is soil that can no longer prevent nutrients from leaving the area permanently. Overall, this farming system is not effective to meet the demand of crops in the market and subsistence due to low productivity (Sharma et al., 2010).

Resource conservation technologies such as agroforestry, terrace farming, hedgerow intercropping, and Sloping Agricultural Land Technology (SALT) can reduce soil loss and increase food production (Lamichhane, 2012). For the TNA, SALT has been selected as one of the technologies to reduce erosion due to its suitability to biophysical conditions and promising economic, social, and environmental benefits.

SALT is a soil conservation-oriented farming system developed in the Philippines by Mindanao Baptist Rural Life Center (MBRLC) in late 1970s. FAO (2018) defines SALT as a farming system where slopes are divided into strips of land for cultivation and separated by double hedgerows of nitrogen fixing plants which are planted along the contour lines. These hedgerows act as erosion barriers to stabilize slopes, enrich soil, provide fodder, fuelwood, and biomass. When the hedgerows grow to 1-2 meters tall, they are trimmed to half a meter and the biomass is placed in cropping alleys for soil amelioration and nutrient recycling. In comparison to conventional hill slope farming, SALT has lower risk due to crop diversity, high frequency of harvest, regular income, and higher productivity per unit of land is achieved without degrading available land resources (FAO, 2018).

Literature reviews show that introduction of SALT in different parts of Timor-Leste has occurred as early as 2007[15] through Local Initiatives for Food-security Transformation (LIFT) Project with the support from the European Commission and Austrian Development Cooperation (ADA). USAID's Avansa Agriculture project implemented between 2016-2021 also disseminated information on SALT. However, there are no sufficient accounts on the implementation and results of SALT farming from the relevant projects. This makes it challenging to identify barriers for adoption and deployment of this technology as well as measures to overcome those barriers.

[15] It is possible that SALT might have been introduced in Timor-Leste earlier than that; However, literature review only shows the LIFT project's documentation of the introduction of this technology in Timor-Leste. No national stakeholder provided information one earlier introduction of this technology.

3.5.2 Identified barriers for SALT

SALT technology is *non-market good* that can be deployed by MALFF, NGOs and partners at national scale as *other good*. A total of five (5) barriers were identified and categorized into the following economic/financial and non-financial barrier.

3.5.2.1 Economic/financial barriers

i. <u>Constant pressure to provide for the family</u>

As already elaborated in Section 2.3.2.1, for many Timorese farmers and fishers, agriculture and fisheries are their main source of livelihood. For the ones residing in the highlands far from coastal zones, they rely solely on agriculture. As access to alternative source of income become limited, they are forced to invest time and efforts in farming as many fertile lands as possible and extracting as much water as needed to yield certain level of output and meet short-term demands for both household consumption and market. As a result, they are not inclined to adopt alternative farming technologies, including SALT, which require more time for design and preparation but offer sustainability and conserve the resources (i.e., soil nutrients, organic matter, and water) in the long run.

3.5.2.2 Non- financial barriers

i. <u>The practice of free grazing</u>

As elaborated in Section 3.3.4.2, lack of regulations for livestock management contributes to more practice of free grazing, even in steep hills around the country. Living fence of vegetation has been used a low-cost, sustainable solution to stop livestock encroachment these areas; However, its application in areas with harsh biophysical condition (i.e., water scarcity and steep angle) can be challenging unless the right species of tree/shrubs are using for living fence.

ii. <u>Strong attachment to conventional farming practices</u>

This barrier is similar to the one presented in Section 2.2.2.2 for CA and CR technology. Most farmers in Timor-Leste have practiced the same conventional, unsustainable slash and burn technique in steep hills for many generations. Despite the obvious indicators of increased land degradation (i.e., landslide, infertile soil, and loss of soil biodiversity) due to unsustainable conventional farming practice coupled with high frequency of extreme weather events, many farmers do not feel to urge to switch to new technique that generate promising, sustainable results.

iii. <u>Limited information on SALT techniques and benefits</u>

This is another barrier which is closely linked to the one presented in Section 2.2.2.2 for CA and CR technology. As access to information and knowledge about new technology in rural areas becomes scarce, farmers in rural areas tend to be reluctant to adopt it. They still have many doubts about the effectiveness of the new technology. This is particularly true for SALT, a technology which is not common yet in Timor-Leste despite having been introduced in Timor-Leste as early as 2007. During the consultation process, there was not even a single agency which could pinpoint a location where SALT has been implemented or provide more detail on it. Additionally, there is misconception of what SALT technology entails mainly due to lack of credible information during intervention of past projects. It is common for farmers to mistake plain terracing technique which does not feature nitrogen fixing trees or shrubs for SALT.

iv. Lack of technical skills

Since its inception in the late 1970s, four forms of SALT have been introduced, namely simple agro-livestock technology (SALT 2), sustainable agroforestry land technology (SALT 3), and small agrofruit livelihood technology (SALT 4). Successful implementation of any form of this technology is not possible when farmers still lack some technical skills required in each step such as how to make an A-frame and apply it, how to locate and mark contour lines, how to plant seeds of nitrogen-fixing tree and shrubs etc. The fact that farmers in Timor-Leste have almost no exposure to this technology and training opportunities are still scarce makes it challenging to deploy and adopt this technology.

3.5.3 Identified measures for SALT

3.5.3.1 Economic/financial measures

i. Subsidies to support rural farmers' transition to sustainable farming practices

The measure aims to address farmers' concern with the disruptions to their source of food and income when they are adopting a new technology. Farmers who choose to adopt SALT will have to halt the planting season to prepare the land. This can potentially reduce their food supply temporarily. In this case, government subsidies can help leverage the transition period through creation of alternative source of income to cover a temporary loss of food supply and income. The measure needs to be strategically planned out and implemented to ensure that farmers will not be completely dependent on subsidies and will return to farming using new technology.

3.5.3.2 Non-financial measures

i. Conducting R&D in SALT

This measure uses the same rational presented in Section 3.2.3.2. An R&D in SALT offers an opportunity for collaboration between line ministries (i.e., MALFF and MTE), academic/research institutions, and development agencies to explore different SALT forms through a scientific approach and identify the ones that suit Timor-Leste's context. Additionally, findings and recommendations from the research can be used to develop field guide for SALT for farmers.

ii. Extensive campaign and socialization

This measure reverberates the same non-financial measure elaborated in the previous sections (2.2.3.2 – 3.4.3.3)

iii. Conducting training on SALT

This measure aims to bridge the capacity gap on SALT forms. The training can be embedded into capacity-building activities that target MALFF extensionist and farmers. The training modules need to incorporate findings from various R&D activities in SALT that suit Timor-Leste's needs.

iv. Promoting the practice of confined raising in livestock management

This measure aims to address the issue of livestock encroachment in SALT sites. It echoes similar points elaborated in Section 2.2.3.2 and Section 3.4.3.3 to reducing the risk of loss from free gazing in SALT sites.

3.6. Linkages of barriers across technologies

The barriers hindering the four technologies in the sector of infrastructure and natural methods to prevent erosion were found to be financial, technical, and human capacity, education/knowledge, institutional, and cultural. The economic/financial barrier found across all four technologies is mainly associated with lack of financial allocation from the state budget. This barrier constrains Government institutions' ability to fund plans and programmes which aim to introduce and scale up adoption of new and/or exiting technologies. In addition, limited opportunities for farmers to diversify their source of income is seen as an economic barrier. It forces farmers to continue using unsustainable farming practices which lead to land degradation and water scarcity issues.

Similar to non-financial barriers identified in SLM sector, access to information and limited human capacity are common in all four technologies in this sector. Lack of R&D in specific technology, as shown in the case of soil biongineering, can be linked to limited human capacity.

The institutional barrier in three technologies – *tarabandu*, mangrove plantation and SALT – centers on a lack of coordination and collaboration between national and local actors in setting, socializing, and enforcing the rules and regulations as well as careless practice of free grazing.

Analysis of cultural barrier in SALT draws some similarities to the one identified in SLM sector technologies. It shows that most farmers in Timor-Leste are attached to the conventional, unsustainable farming technique such as slash and burn which they have adopted for many generations. This attachment makes it difficult to switch to new practices that generate promising, sustainable results.

Similar to Section 2.6 Linkages of barriers across technologies, this BAEF analysis reveals linkages among the identified barriers for this sector. For example, financial barrier tends to worsen technical, human capacity, and education/knowledge barriers provided that it limits allocation of funds and investment in purchasing equipment/machines, implementing training activities and conducting campaigns. Additionally, human capacity and institutional barriers are closely interlinked. Institutional functions (i.e., planning, socialization, monitoring, and rules enforcement) cannot be effectively implemented when human resources are not properly equipped with the right level of knowledge and skillset. Lastly, education/knowledge barrier is also influenced by cultural barrier. When access to scientifically proven data and information is scarce, people continue to attach to cultural practices and beliefs that might not be climate friendly.

3.7. Enabling framework for overcoming

To overcome the identified barriers for SLM in agriculture sector, this BAEF analysis has identified an enabling framework that is similar to the one presented in section 2.7. The political framework encompasses national programmes and policies that aim to enhance adoptions and deployment of all four technologies either directly or indirectly such as the SDP 2011-2030, the Programme of the 9th Constitutional Government, and Timor-Leste Nationally Determined Contribution (NDC) 2022-2030. Additionally, the GoTL continues to launch campaigns to protect coastal ecosystem (mangrove) and catchment areas in close collaboration with development partners.

Institutional framework that enables implementation of measures to overcome institutional, technical, human resources and information barriers refers to existing functional structures in the Government agencies (i.e., MALFF, MPW, and MSA) and development partners that holds specific roles and responsibilities (i.e., planning, implementing, quality assurance etc.). For example, each agency listed in Table 5 has its own directorate which holds specific functions that can accommodate implementation of each identified measure.

In terms of regulatory framework, the BAEF analysis for this sector looked into enabling framework in the form of National Constitution and decree laws that acknowledge customary system such as *tarabandu* (article 2 the National Constitution), prohibit exploitation of mangrove forests (Regulation No. 2000/19 on protected areas), regulate unsustainable land use practices (Regulation No. 2000/19 on protected areas) and delegate the mandate for natural resource management for local village actors (Decree-Law No. 5/2004 on Community Authorities). They accommodate the introduction of some measures (i.e., extensive campaigns, strengthening local governance, and promoting the practice of fence livestock management) to break identified barriers for the technologies pertaining to this sector.

The matrix below provides a list of measures which correspond to the financial and non-financial barrier elaborated from Section 3.2 Barrier analysis and possible enabling measures for soil bioengineering to Section 3.5 Barrier analysis and possible enabling measures for sloping agriculture land technology. It also provides a list of agencies which are responsible for the implementation of the measures.

Technology	Barriers	Enabling Measures	Responsible Agencies
Soil bioengineering	1. Lack of financial allocation from state budget on bioengineering 2. Lack of investment in research and development (R&D) 3. Limited information on bioengineering's benefits	1. Committed budget allocations for soil bioengineering activities 2. Conducting R&D in soil bioengineering 3.1 Conducting extensive campaign and socialization on soil-bioengineering 3.2 Conducting trainings on soil-bioengineering	1. MPW, MSA 2. MPW, research agencies/academic institutions (i.e., UNTL Engineering Department) 3.1 MPW, MSA, Developing Agencies 3.3 MPW, MSA, research agencies/academic institutions

Tarabandu	1. Lack of financial allocation from state budget on *tarabandu* enforcement 2. Limited opportunities to diversify household's source of income 3. Weak governance	1. Committed budget for *tarabandu* enforcement 2. Establishment of alternative source of livelihood 3. Strengthening local governance	1. MTE, MSA, MI (PNTL), Community members 2. MTE, Development Agencies 3. MTE, MSA, MI (PNTL), Community members
Mangrove plantation	1. Lack of financial allocation from state budget on mangrove protection 2. Human encroachment of mangrove habitats 3. The practice of free grazing	1. Committed budget for restoration of mangrove ecosystem 2. Spatial planning for coastal areas 3. Promoting the practice of fence livestock management	1. MALFF, MTE, research agencies/academic institutions 2. MALFF, MTE 3.1 MALFF, MTE, KFF, mangrove groups 3.2 MALFF, MTE, KFF, mangrove groups
Sloping Agriculture Land Technology	1. Constant pressure to provide for the family 2. Limited information on SALT techniques and benefits 3. Strong attachment to conventional farming practices 4. Lack of technical skills 5. The practice of free grazing	1. Subsidies to support rural farmers' transition to sustainable farming practices 2. Conducting R&D in SALT 3. Extensive campaign and socialization 4. Conducting training on SALT 5. Promoting the practice of fence livestock management	1. MALFF, MTE 2. MALFF, Research agencies (AI-Com), Academic Institutions (UNTL) 3. MALFF, Research agencies (AI-Com), Partners (Adam Smith International) 4. MALFF, Research agencies (AI-Com), Partners (Adam Smith International) 5. MALFF, MSA

Table 5: List of barriers for technologies in sector 2, enabling measures, and responsible agencies

4. Conclusions

The objective of the Barrier Analysis and Enabling Framework (BAEF) is to find barriers and challenges that could potentially arise during the transfer, deployment and/or diffusion of the technology and find effective, appropriate solutions and methods to overcome the barriers. Conducted in a consultative manner, this BAEF analysis for the eight (8) selected technologies for adaptation was conducted through engagement with relevant entities that have strong knowledge of the technologies and many years of firsthand experience in introducing/implementing them. It has resulted in the identification of various financial and non-financial barriers and measures.

There are some barriers which are commonly found across technologies in both sectors (SLM and infrastructure and natural methods to prevent erosion). They consist of economic/financial (limited access to capital, high capital cost, lack of diversification in sources of income, and limited market information), technical (lack of capacity building opportunities, limited R&D activities, and limited access to information), institutional (poor integration of water conservation in water source management, lack of coordination between national and local actors, and the practice of free-range livestock), and cultural (strong attachment to conventional farming practices).

Similarly, there are some common measures identified across different technologies. They include improved access to capital, subsidies to farmers, extensive campaign and socialization, training and capacity building, market assessment, expanding R&D on new technologies, and institutionalization of management of natural resources, waste, and livestock. For financial measures, efforts to facilitate farmers' access to capital seems to be the most common for the SLM sector while for the other sector, it is the allocation of state budget to fund plans and programmes.

To overcome the identified barriers for adoption and deployment of the eight (8) technologies, this BAEF analysis has identified an enabling framework that consists of political, institutional, and regulatory framework. They encompass existing programmes, policies, organizational structures, rules, norms for service provision, National Constitution and decree laws that create conducive environment for introducing the recommended measures. Overall, the extensive analysis conducted in this report provides a strong foundation for developing and formulating project ideas in the following step of TNA, Technology Action Plan (TAP).

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ANNEX I: List of stakeholders

1.1 One-on-One Consultation Stakeholders

No.	Name	Institution	Position	Email Contact
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5.	Mr. Mateus Maia	NGO Raebia	Deputy	xistomartins@raebia.org / xmartins@up.edu.ph
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8.	Mr. Alito Rosa	NGO KFF	Executive Director	
9.	Ms. Joana Gusmao	Ho Musan Ida/With One Seed	Coordinator Hub Enterprise Baguia & Finance Officer.	joana@withoneseed.org.au
10.	Ms. Leopoldina Joana	With One Seed/Rai Matak	Project Manager	leopoldinaj82@gmail.com
11.	Mr. Moises Guterres De Sar	Environmental Legal Office	Chief Department	
12.	Mr. Fernandino Xavier da Costa	MAF	Chief Department	
13.	Mr. Adelino	MAF	Staff	
14.	Mr. Zecky Carmo	TILOFE	Director	zeckyhironimos@gmail.com
15.	Mr. Robert W.	AI-COM	Director	rob@livethedream.tl

16.	Ms. Joaquina Barreto	AI-COM, Ministry of Agriculture and Fishery (MAF)	Staff	quina.barreto@gmail.com
17.	Mr. Carlos das Neved	Habelun Ai-parapa	Group Leader	
18.	Dulce Gusmão	EU		Dulce-Maria.e-silva-gusmao@eeas.europa.eu
19.	Expedito Belo	UNDP	Project Coordinator	expedito.belo@undp.org

1.2. Participants of Consultation Workshop

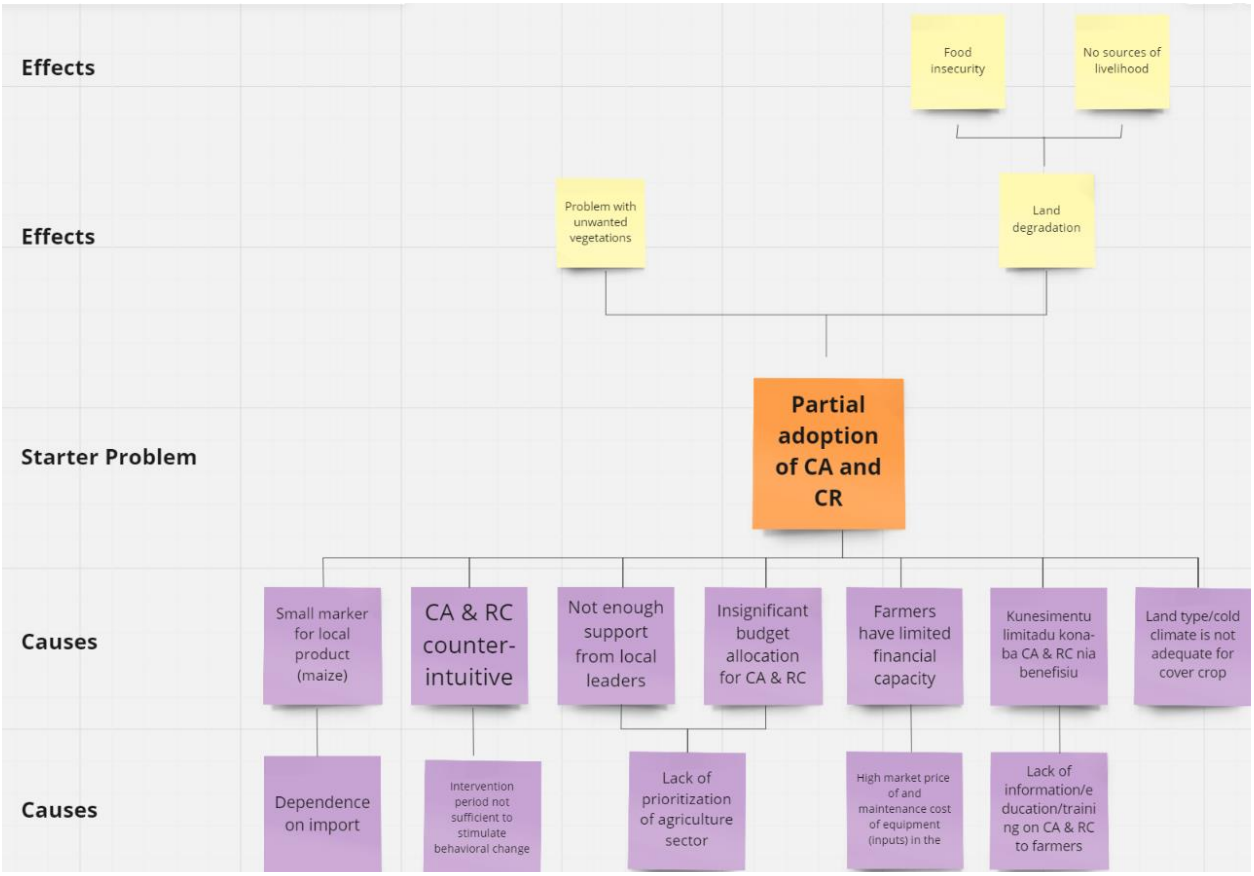
No.	**Name**	**Institution**	**Type of Stakeholder**
1.	Isaura Baptista Barros	Laudato Si Movement Timor-Leste (LSA-TL)	Youth group
2.	Albino da S. Barbosa	MAPPF	Government Institution
3.	Mercuides de Sousa	The National Authority for Electricity (ANE, IP)	Public Institution
4.	Zacarias Bosco	The National Authority for Electricity (ANE, IP)	Public Institution
5.	Liborio A. T. do Rosario	FCOTI	Foundation
6.	Jose R. O. Fernandes	MAPPF	Government Institution
7.	Armandina Clemencia	MPIE – DNOE	Government Institution
8.	Evaresto D. C	ADTL	Association
9.	Fernando Ronaldo da Costa	MPIE – DNOE	Government Institution
10.	Eligio Soares	TROBAS	NGO
11.	Antero Pinto Pereira	LCOY-TL	Youth Group
12.	Profirio Fernandes Xavier	DNTT (ADB technical Staff)	Government Institution
13.	Agustinus Bruno Halle	DNTT	Government Institution
14.	Marcia e Silva	FAO	UN Agency
15.	Apolonia Barreto	UNICEF	UN Agency
16.	Dulce Gusmão	Delegation of the European Union to Timor-Leste	International Organization

17.	Andre Neto da Silva	FCOTI	Foundation
18.	Martinho D. S da Costa	Laudato Si Movement Timor-Leste (LSA-TL)	Youth group
19.	Luis dos Santos Belo	DNAC	Government Institution
20.	Jose Barros	TOMAK - DFAT	Development Partner
21.	Claudino Nabais	FAO	UN Agency
22.	Graziela Xavier	Mercy Corps	INGO
23.	Justina Aurea Belo	NDCC	Government Institution
24.	Leonardo Rosa	NDCC	Government Institution
25.	Sofia Sagram	NDCC	Government Institution
26.	Mario Ximenes	NDCC	Government Institution
27.	Sebastiao da Costa	ANAS, IP	Public Institution
28.	Maria Resi	NDCC	Government Institution
29.	Suzana Cunha	Rai Matak – With One Seed	NGO
30.	Josafat de Araujo	CVTL	NGO
31.	Augusto Pinto	NDCC	Government Institution
32.	Zelia A. Maria	NDCC	Government Institution
33.	Vicente Ximenes	NDCC	Government Institution
34.	Roberto Amaral	NDCC	Government Institution
35.	Armando Barreto	NDCC	Government Institution
36.	Kassius Klei Ximenes	National Director Spatial Planning	Government Institution

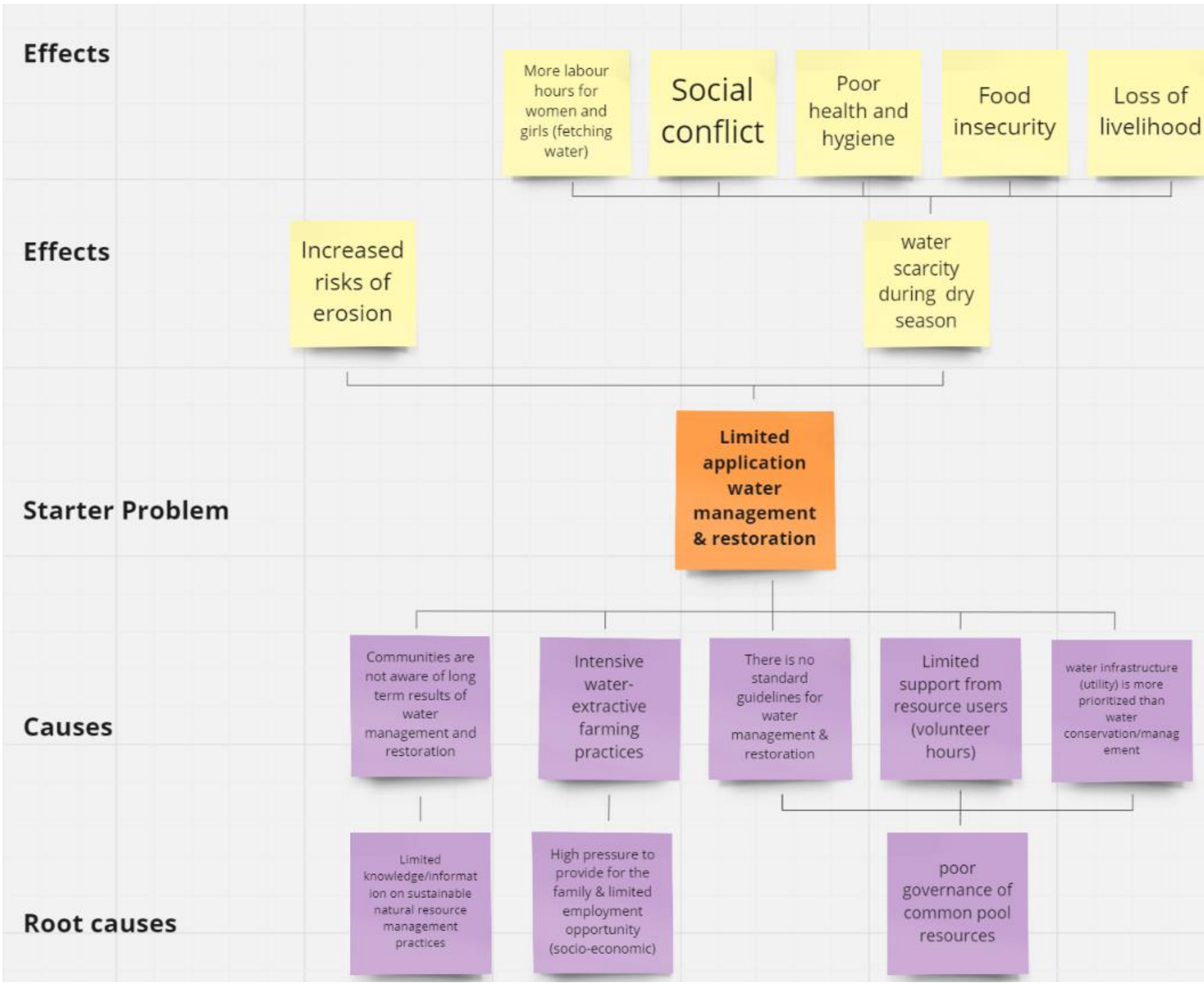
ANNEX II: Problem Trees

Sector 1: Sustainable Land Management (SLM) in Agriculture Sector

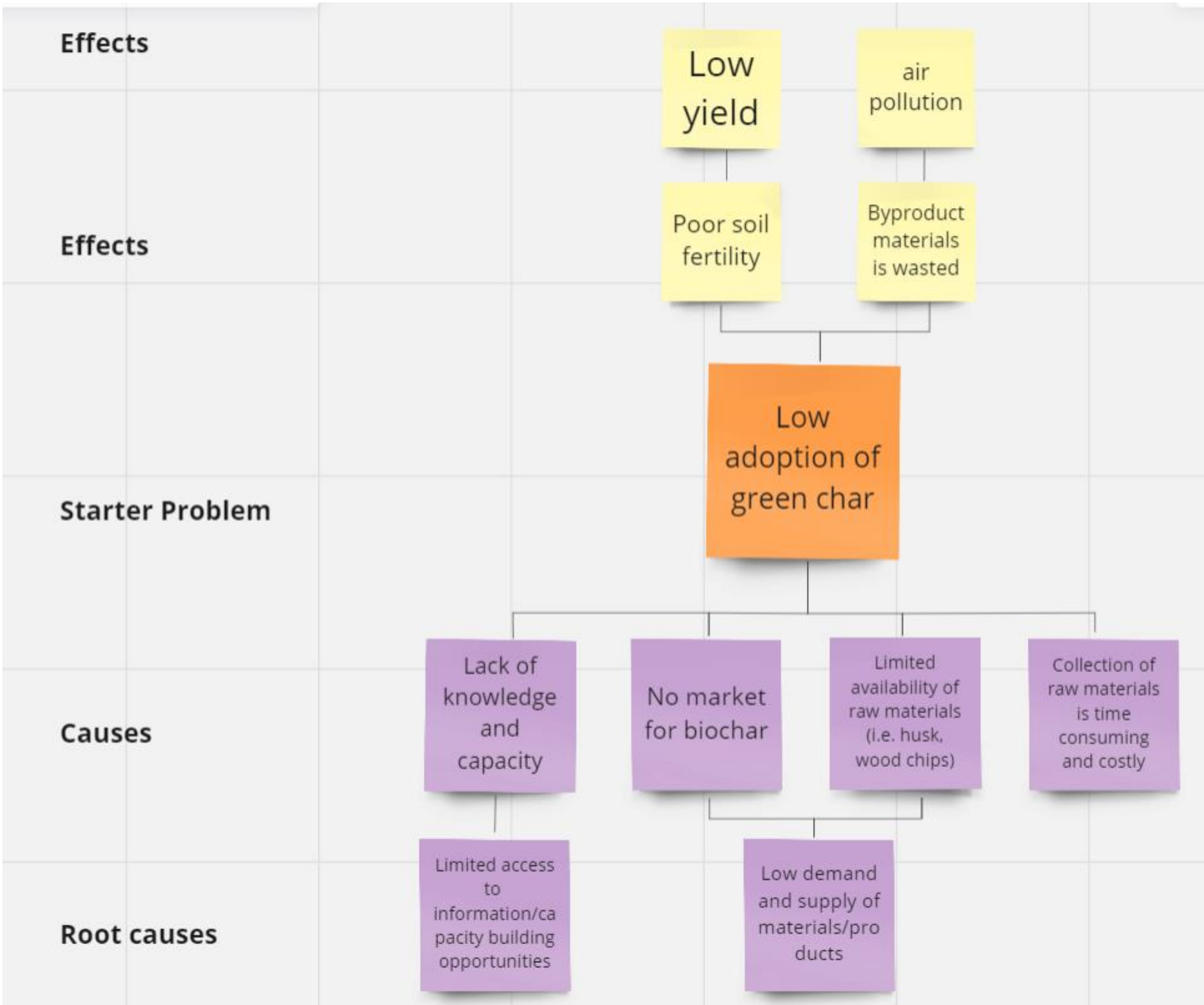
1.1. Conservation Agriculture (CA) and Crop Rotation



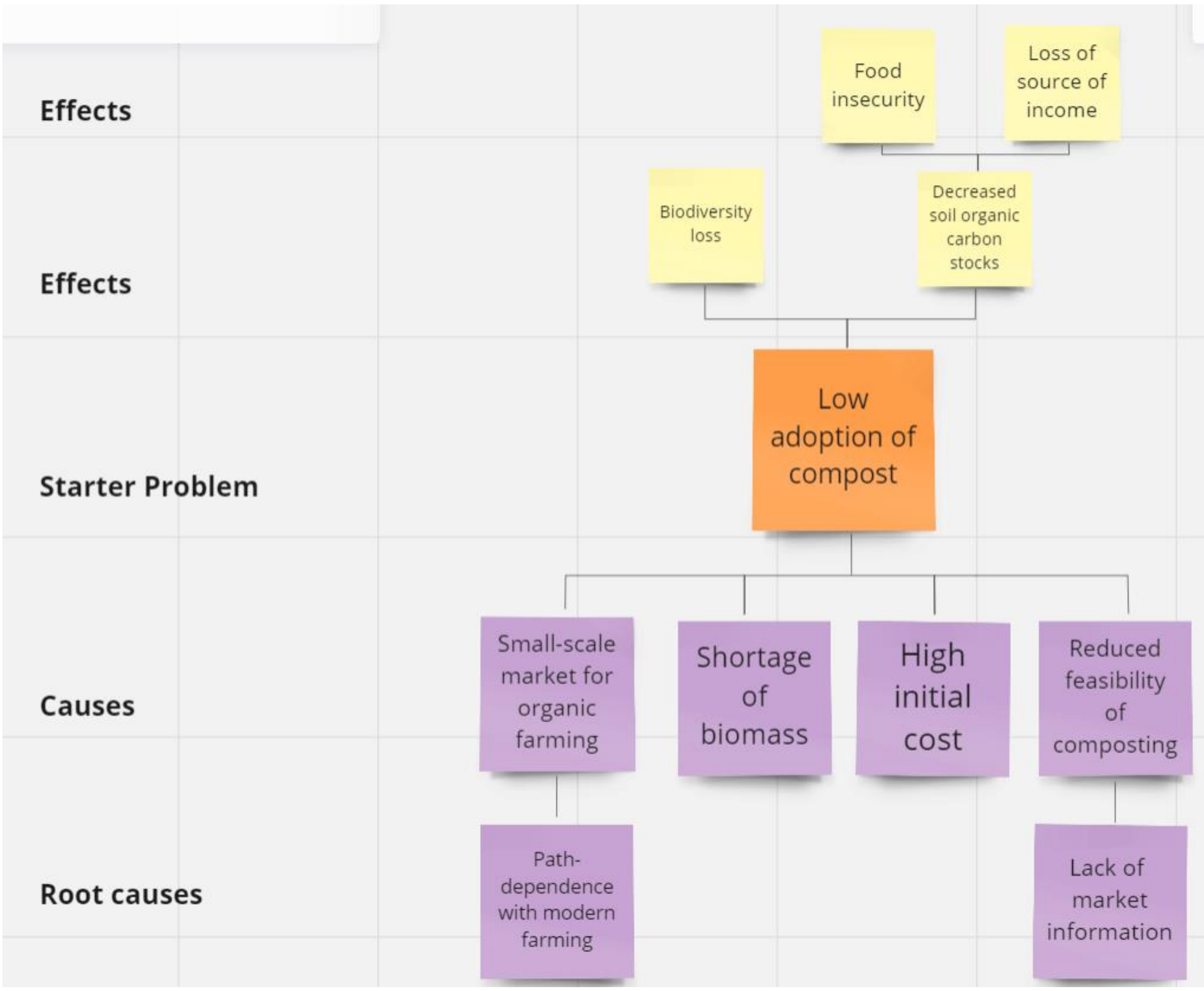
1.2. Water Management and Restoration



1.2. Green char/biochar

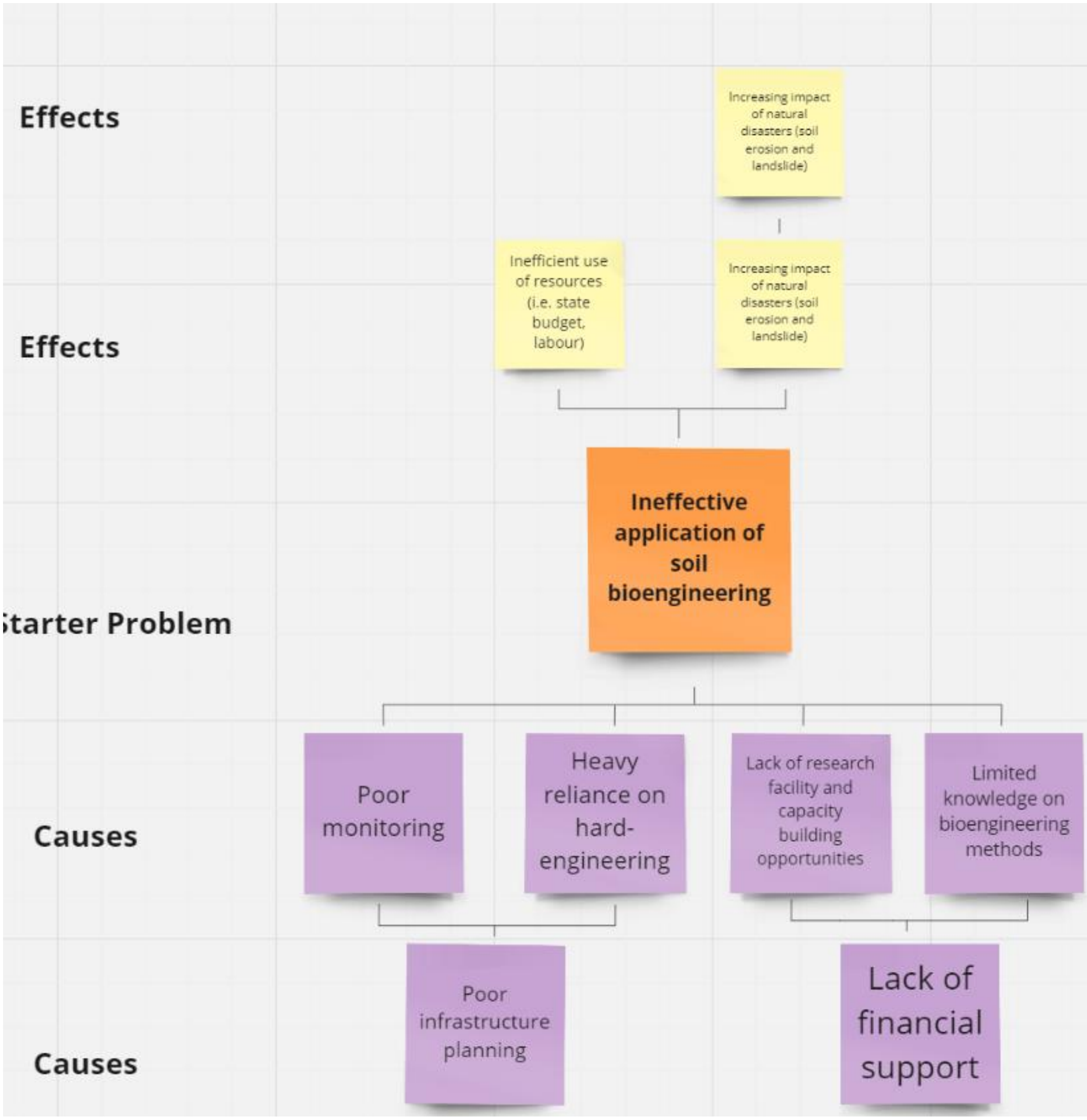


1.4 Composting

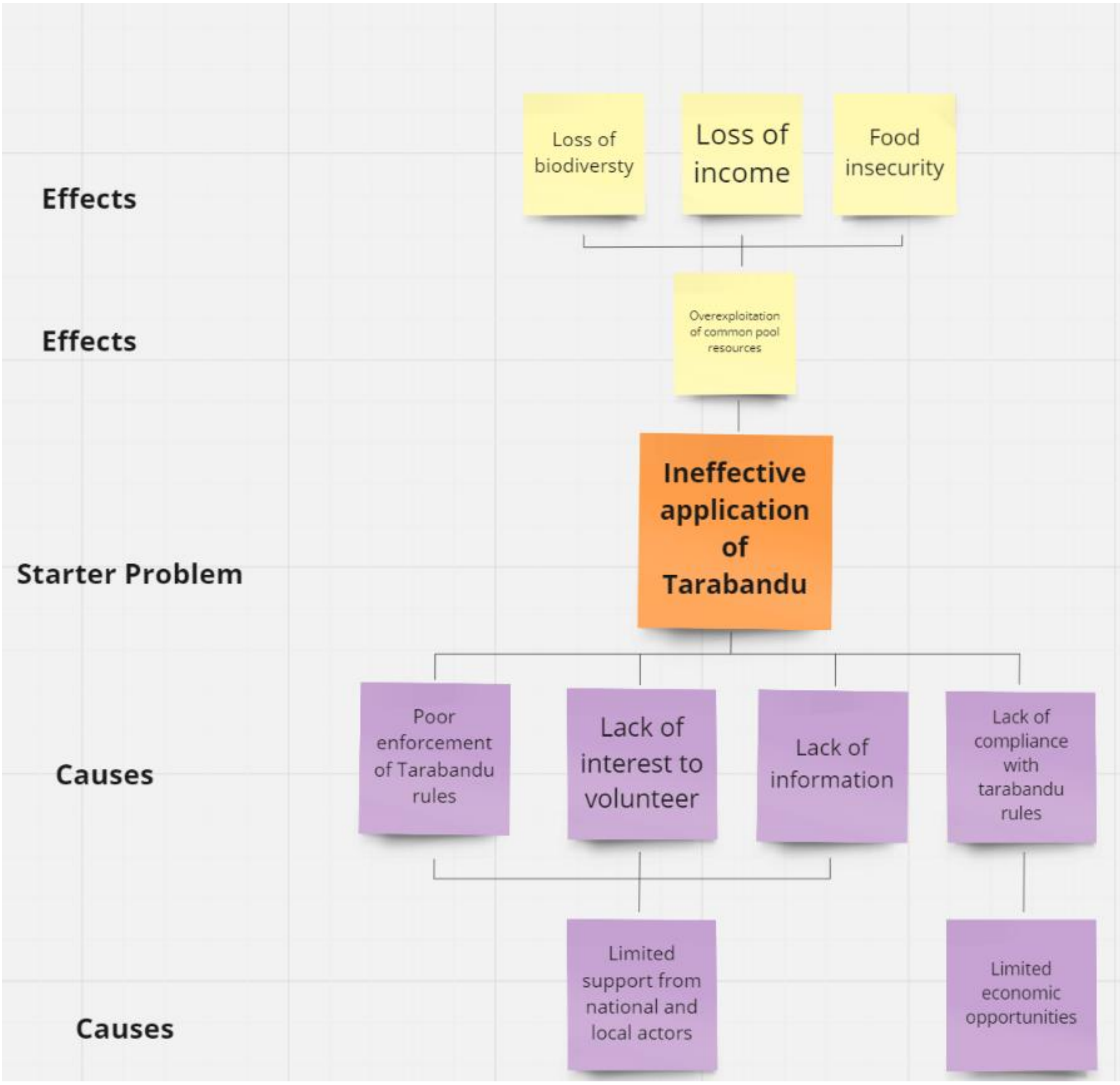


Sector 2: Infrastructure and natural methods to prevent erosion

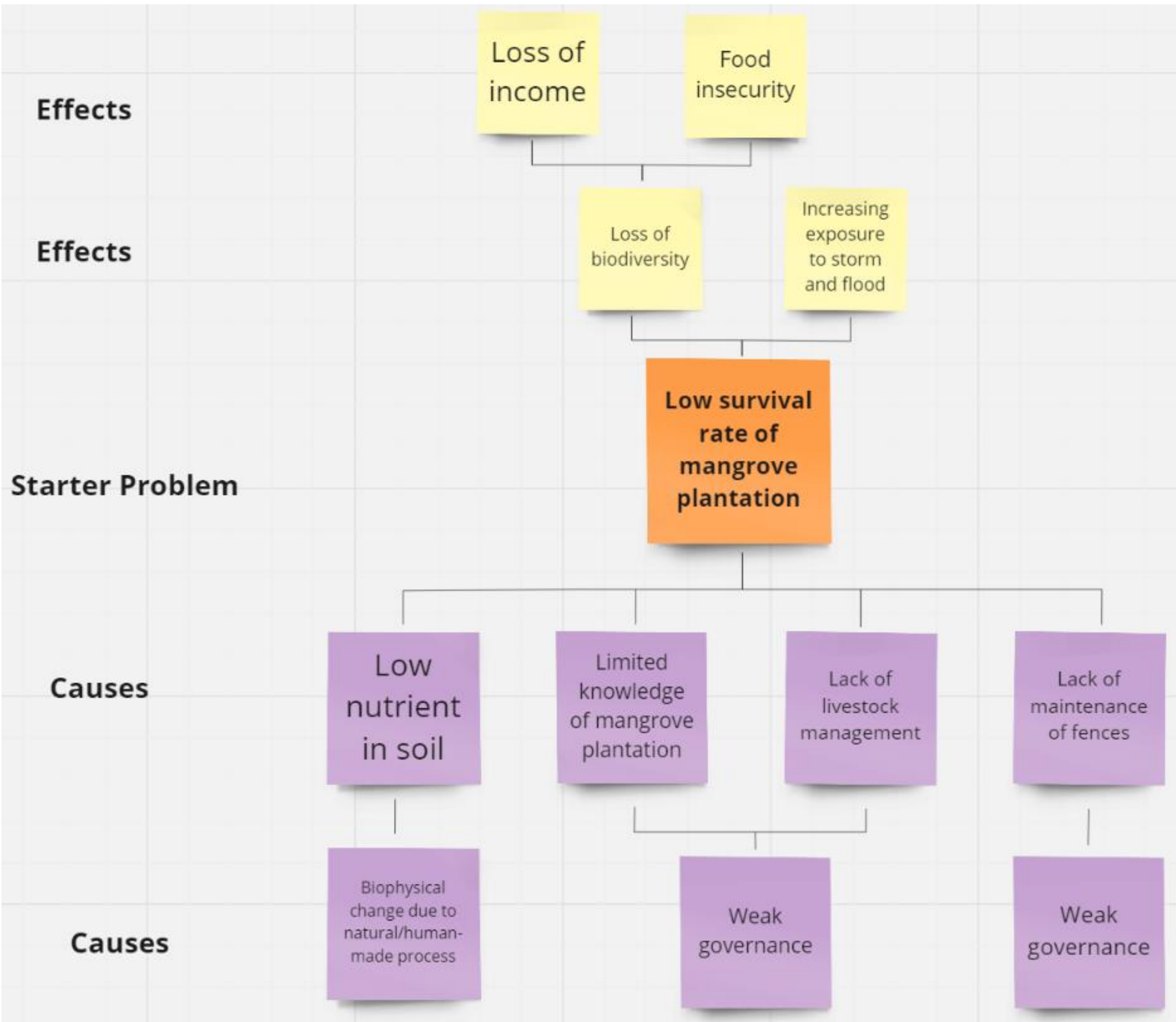
2.1 Soil bioengineering



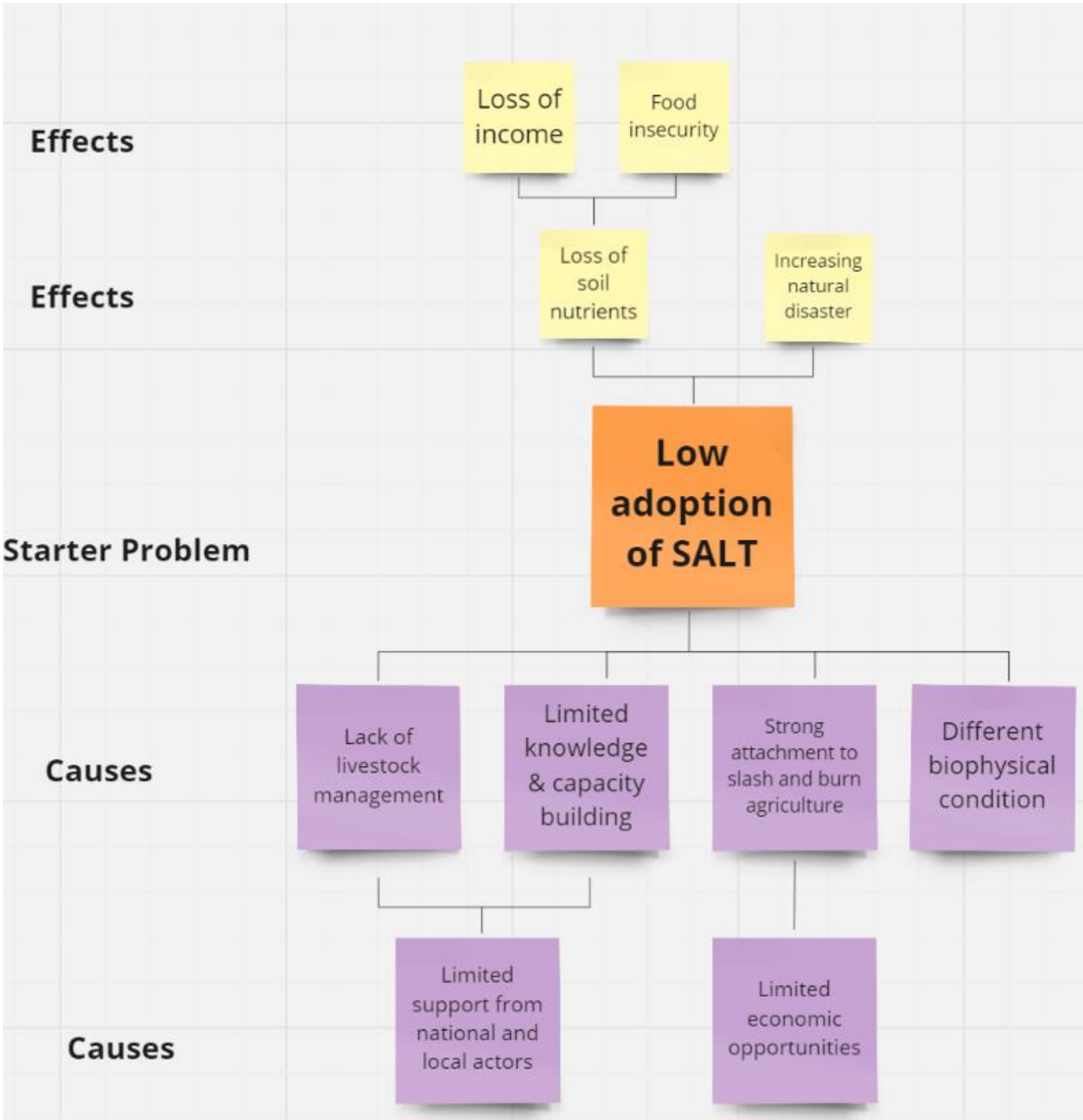
2.2. *Tarabandu*



2.3 Mangrove plantation



2.4 Sloping Agriculture Land Technology (SALT)



ANNEX III: List of barriers and measures identified during consultation process

Technology	Barriers
Conservation agriculture (CA) and crop rotation	1. High capital cost for purchase and maintenance of equipment 2. Strong attachment to slash and burn farming practices 3. Limited knowledge on methods and benefits of CA and CR 4. Limited availability of inputs and services 5. The practice of free range of livestock 6. Lack of conservation agriculture policy 7. Small market for local product 8. CA is counter intuitive 9. Insignificant budget allocation for CA 10. Land/climate type is not adequate for cover crop
Water Management and restoration	1. Lack of fundings to support local community's initiatives 2. Constant pressure to provide for the family 3. Lack of an integrated approach in water management and governance 4. Limited knowledge on water conservation methods 5. Lack of awareness of the long term results of water management and restoration 6. Intensive water extractive farming practices 7. Limited support from resource users (volunteer hours)
Biochar	1. Collection of raw materials is high cost and time consuming 2. No market for biochar yet 3. Limited access to raw materials 4. Limited information on biochar's production and benefits 5. Lack of technical skills
Composting	1. Compost production is high-cost initially and time consuming 2. Space requirement for compost production 3. Lack of market information on compost 4. Poor integration of composting in urban waste management 5. Limited availability of raw materials
Soil bioengineering	1. Lack of financial allocation from state budget on bioengineering 2. Lack of investment in research and development (R&D) 3. Limited information on bioengineering's benefits
Tarabandu	1. Lack of financial allocation from state budget on *tarabandu* enforcement 2. Limited opportunities to diversify household's source of income 3. Weak governance 4. Lack of information

Mangrove plantation	1. Lack of financial allocation from state budget on mangrove protection 2. Human encroachment of mangrove habitats 3. The practice of free grazing 4. Low nutrient in soil 5. Limited knowledge of mangrove plantation
Sloping Agriculture Land Technology	1. Constant pressure to provide for the family 2. Limited information on SALT techniques and benefits 3. Strong attachment to slash and burn practices 4. Lack of technical skills 5. The practice of free grazing 6. Different biophysical condition

ANNEX IV: List of six legumes which has been introduced and tested in Timor-Leste agriculture between 2013 and 2016.

Species	Results
Velvet bean (*Mucuna pruriens*)	- Very well performance in terms of biomass production in lowland areas - It grows vigorously, and therefore needs to be planted around four weeks after the maize is planted to avoid competition with the maize. - In southern areas the bean can survive the whole year until the main planting season in November/ December while in central and northern parts of the island it dies in June or July. - The main constraint to adopting the use of this bean as a cover crop is that, if its seeds are not collected at maturity, they can germinate prematurely the following season and become a weed that damages the crop by competing for nutrients and sunlight.
Winged bean (*Psophocarpus tetragonolobus*)	- Well performance at low altitudes and production of a good amount of biomass when planted every 50 cm - At middle altitudes it grew less vigorously. - It can be planted at the same time as maize as it grows slowly and produces much of its biomass after the maize is harvested. - In both southern and northern areas the bean dies in June/July, which means that in southern areas where there is an additional cropping season it can supress weeds until the start of the second cropping season, making it a good cover crop for the main cropping season (November–March). - Very nutritious bean that had previously been practically unknown to Timorese farmers
Lablab (*Lablab purpureus*)	- Well performance, in lowlands, although it was tested only in a few plots due to limited availability of seeds. - I can potentially survive and cover the soil until the following cropping season, which would make it a good option for northern (drier) areas as it can stand the dry season better than velvet bean. - It grows slowly and can therefore be planted at the same time as maize (at a minimum distance of 50 cm) and does not carry the risk of becoming a weed for the following crop
Cowpea (*Vigna unguiculata*)	- Two local varieties of this legume (‘fore masin’ and ‘fore metan’) proved to have the best adaptability in all agro-ecological zones (low, medium and high altitudes), producing a large amount of biomass - It can be planted at the same time as maize, although at low altitudes the spacing should be at a minimum of 50 cm. - Usually dies in April/May, it can be a good option for intercropping with maize in the southern lowlands in the main season as it can maintain biomass until the second planting season in April/May.

Lima or butter bean (*Phaseolus lunatus*)	- Irregular performance, totally covering the soil in some plots but not growing well in others - Better performance at medium to high altitudes, although not in all plots - It could tolerate the dry season, supressing most of the weeds until October. - As the plant grows relatively slowly it can be planted at the same time as maize at a distance of 50–100 cm.
Pigeonpea (*Cajanus cajan*)	- Evaluated mainly at medium and high altitudes plantation on contour lines. - While it does not produce much biomass to supress weeds, it mobilizes phosphorous in the soil, making it available for other cultivated crops - Iit grows slowly, it can be planted at the same time as maize, at a distance of 50 cm.

Table 6: List of intercropping legumes tested in Timor-Leste and their findings (adapted from Nesbitt et al., 2016)