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The role of agroforestry in farmers' strategies and its contribution to the well-being of rural people in Timor-Leste

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ABSTRACT

Many countries have integrated agroforestry into their sustainable development policies, particularly in Southeast Asia. In Timor-Leste, the national strategy to promote agroforestry has adopted a modern, technique-oriented approach focused on crop rotation, intercropping and agro-silvo-pasture. In so doing, it has largely overlooked the pre-existence, diversity and performance of traditional agroforestry systems (AFS). The data collected in seven villages located in four districts of the eastern municipalities of Timor-Leste identified five common AFS: home garden, crop field and fallow, young agroforest, forest garden and silvopastoralism. The combined use of the customary AFS by rural households depends on the households' ability to access the four types of capital (land, financial, labour and social) underpinning their development strategies. Four rural household archetypes were therefore distinguished. Six farming strategies used by these archetypes were identified: cattle specialisation, palm and tree product harvesting, crop intensification, diversification of off-farm and on-farm income, abandonment of farming, and survival. Each of these farming strategies combine certain customary AFS. The diversity and complexity of AFS require a better description of how they function and a better understanding of how they fit into the heterogeneous development strategies of rural households before actions are considered to improve their performance.

KEYWORDS

Farming system; livelihoods; basic necessities; South east Asia

Introduction

The concept of agroforestry is now sufficiently broad and generic to cover the diverse configurations encountered in tropical countries. Agroforestry is defined as a land use system that integrates trees and shrubs on farmlands and rural landscapes to enhance productivity, profitability, diversity, and ecosystem sustainability. It is a dynamic, ecologically based, natural resource management system that, through the integration of woody perennials on farms and in the agricultural landscape, diversifies and sustains production and builds social institutions. Agroforestry is an integrated approach of using the interactive benefits from spatially or chronologically combining trees and shrubs with agricultural crops and/or livestock (Umrani and Jain 2010).

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Due to the polyvalence, diversity (Torquebiau 2000), and multiple environmental (Nair et al. 2009, 2022), social (Aumeeruddy-Thomas 1994) and economic (Torquebiau and Penot 2006) benefits of agroforestry, many countries have integrated it into their national sustainable development policies, particularly in Southeast Asia (Octavia et al. 2022). This is the case in Timor-Leste, which considers agroforestry to be an approach that contributes to ensuring food security, rural poverty reduction and the protection of environmental services. These three objectives are mentioned in the Ministry of Agriculture and Fisheries (MAF) Strategic Plan (GoTL 2011) and are detailed below.

First, agriculture is the main source of food, employment, and income for two-thirds of the population of Timor-Leste, who mainly live in rural areas. Since independence, a government priority has been to achieve food security at the national scale. By 2030, according to the National Food and Nutrition Security Policy ([RDTL] Republica Democratica de Timor Leste 2017), the target is that '*people in Timor-Leste will be well-fed principally from increased variety of locally produced safe and nutritious food for healthy and productive lives while witnessing carefully managed agroecosystems*'. Timor-Leste's Strategic Development Plan 2011 to 2030 aims to increase agrobiodiversity with a focus on nutritious and high-yield crops including coffee, coconut, and other potential cash crops such as cocoa, cashews, and spices (Paudel et al. 2022).

Second, agriculture generates around 90% of export revenues (not including oil) and plays a vital role in the economic development of rural communities, with over 70% of families in Timor-Leste relying on some sort of farming activity for the maintenance of their livelihoods (GoTL 2011; Bond et al. 2020). However, most people are subsistence farmers with limited access to markets and infrastructure. They mainly practice rain-fed agriculture based on traditional knowledge. These factors restrict agricultural productivity and other livelihood options for households. As a result, 42% of the population lived under a 2.15$/day poverty line in 2014, especially in rural areas (Chandra et al. 2016).

Third, agroforestry is considered to be a means to protect environmental services and to fight deforestation. Deforestation is mainly correlated with the extension of agricultural practices. About 93% of households derive their energy from wood, whereas about 39% of the population collect food from the forest (Paudel et al. 2022). Deforestation and forest degradation result from unsustainable farming techniques as well as the reduced practice of traditional terrace farming. These threats to forests and environmental services are likely to increase as the population in Timor-Leste is growing by 2.7% per year, and is projected to reach 1.8 million by 2030 (Paudel et al. 2022). However, this pessimistic prospect must be put into perspective. In Timor-Leste, the forest area covered 963,000 ha in 1990 compared to 921,000 ha in 2020 ([FAO] Food and Agricultural Organization 2020). Over this 30-year period, the annual deforestation rate was 0.15%, and the global deforestation rate was 4.36%. This deforestation rate is much lower than that for tropical moist forests in the insular Southeast Asia sub-region, which was estimated to be 20.05% over the same period (Vancutsem et al. 2021).

To contribute to the achievement of these three national objectives, the government wishes to develop agroforestry systems (AFS) and plant one million trees. A national strategy for the development of agroforestry is currently being finalised by the [DG FCIP, MAF, PSAF] Directorate General of Forests, Coffee and Industrial Plants, Ministry of Agriculture and Fisheries, Partnership for Sustainable Agroforestry] (2022). However, this strategy has adopted a mainly technical view of agroforestry, which is divided into three categories ([DG FCIP, MAF, PSAF] Directorate General of Forests, Coffee and Industrial Plants, Ministry of Agriculture and Fisheries, Partnership for Sustainable Agroforestry] 2022): crop rotation systems (based on temporal arrangement of crops and trees), intercropping systems (based on spatial arrangement of crops and trees), and agro-silvo-pastoral system (based on a temporal and/or spatial combination of agricultural crops, trees and livestock). In the same spirit, Paudel et al. (2022) have defined four different agroforestry models for Timor-Leste: (i) alley cropping, which involves planting hedges of trees arranged according to contour lines; (ii) trees-along border pattern, which involves planting trees/shrubs along the border (hedgerow); (iii) random mixers, which involves irregularly spacing trees while planting and simultaneously growing the annual crop in stratum underneath; and (iv) alternate rows, which involves planting trees in regular alternate rows and seasonal cultivation done in between the rows. These generic models can be broken down into nine existing successful agroforestry models, which can be distinguished according to the main export crop grown and the agro-ecological zone (DG FCIP et al. 2022).

The use of 'modern' agro-ecological and technical variables to categorize agroforestry may explain the perceived poor performance of existing AFS in Timor-Leste. It is argued that a lack of knowledge and capacity prevent rural people from engaging in the development of more extensive and efficient AFS. As Paudel et al. (2022) wrote, '*the agroforestry [. . .] system has been practiced traditionally by farmers in the country; however, the lack of knowledge and experience, limited institutional capacity, and lack of funding have impeded the wider implantation of the agroforestry system in Timor-Leste*'. This assumption is also echoed by DG FCIP et al. (2022), whose agroforestry development strategy aims to ensure that '*local communities are aware of the status and trends of agriculture and forest land as well as the potential of agroforestry and its connection with environmental, social and economic development*' and that *'local communities are trained with necessary skills and knowledge about agroforestry systems and techniques*'.

This dominant vision of agroforestry in Timor is reminiscent of a tree plantation policy implemented 15 years previously. This policy promoted a technocratic model featuring large-scale plantations that discarded traditional smallholder plantations, required the reorganization of land and labor, routinely imported material and social technologies, and relied on external donations (Bond et al. 2020). These plantation estates tended to reproduce social class distinctions through land use concentration and privilege, and to exacerbate conflicts (Shepherd and McWilliam 2013).

This view of agroforestry tends to overlook the major role that trees have played in the historical evolution of agricultural systems in Timor-Leste and eastern Indonesia. Friedberg (2014), for example, described the customary management of useful trees in food crop practices, and their contribution to maintaining biodiversity. More broadly, Guillaud (2015) listed four principles that in this region organise cropping systems according to three plant families (tubers, cereals, palms). These farming systems strive to achieve the greatest possible diversity by including plants with successive cycles or complementary

needs. The fine line between wild and domesticated leads to the notion formulated by Denham (2005) of a 'managed landscape' rather than opposing spaces specifically devoted to cultivated production and wild spaces, a notion that Guillaud (2015) assimilated with that of agroforests.

Finally, defining AFS based on technical and agro-ecological criteria tends to neglect their socio-economic importance and justification. On the one hand, cropping systems are an integral part of social systems; their design, implementation and dynamics can be explained by the evolution of norms, perceptions and projections of societies (Guillaud 2015). On the other hand, AFS have always broadened the range of plant and animal resources mobilised in production systems to maintain or improve livelihoods. The main motivation for rural populations to maintain or plant trees in the tropics is their direct and indirect utility (Martin et al. 2021).

The historical and social analysis of AFS shows that farmers in Timor-Leste have been applying AFS principles and practices for many decades, and often centuries. These AFS are built on customary knowledge, traditional rules and local capacities that have been the foundations of their sustainability, diversity and resilience. To encourage the practice of agroforestry at the national level, improving traditional AFS through a better understanding of these systems may be more effective than promoting technical models that rural communities may not easily accept or understand.

Many dynamics influence the evolution of traditional AFS. For example, changing ecological conditions force farmers to modify their agroforestry practices. However, AFS also are influenced by the development strategies adopted by rural households, and mainly by the farming systems in which they are embedded. It therefore is not enough to describe traditional AFS in order to identify their limitations and ways to overcome them. It also is necessary to understand why these AFS are mobilised by rural households in their strategies to improve their living standards. This second stage of analysis aims to develop approaches to support the maintenance, improvement, and extension of AFS that are adapted and adopted by rural households as part of their farming and development strategies.

The objective of this article is to illustrate this analytical approach by showing, on the one hand, how traditional AFS are mobilised differently in the development strategies of rural households and, on the other hand, the extent to which traditional AFS contribute today to covering the basic needs of rural populations and to enabling these populations to finance future investments. This work is based on data collected in seven villages located in four districts of the eastern municipalities of Timor-Leste. The results obtained contribute to a broader discussion in favour of participatory agroforestry that is realistic and adapted to the aspirations of rural populations.

Analytical steps and frameworks

Our analysis was broken down into three steps to clarify the interactions between, on the one hand, AFS and their mobilisation in farmers' production strategies and, on the other hand, the influence of AFS on the current and future coverage of people's needs, as illustrated in Figure 1.

The first step of the analysis was the ecological description of the types of AFS found in the eastern municipalities of Timor-Leste and how these may vary according to the

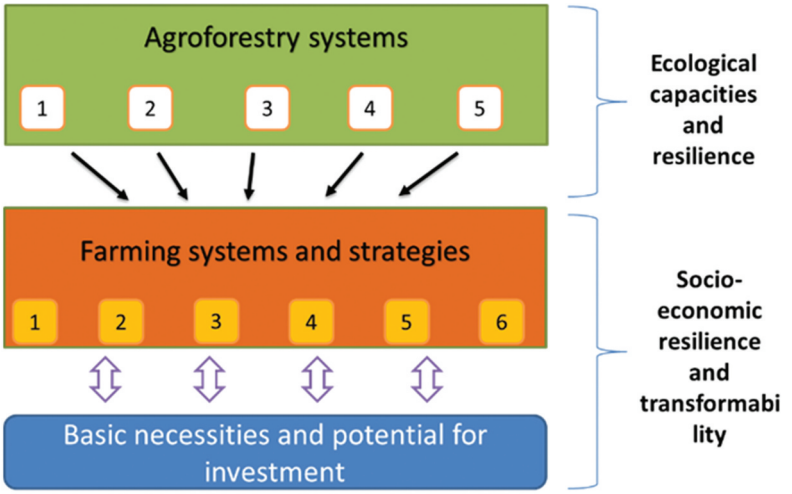

Figure 1. A three-tier framework of analysis.

environmental characteristics of the four selected districts. It also was an opportunity to introduce the land tenure rules and user rights associated with AFS.

The second step of the analysis described the farming systems, defined as specific combinations of production factors (land, workforce, and capital) for the purpose of crop and/or livestock production that is common to a group of farms (Cochet and Devienne 2006). Our analysis showed how these farming systems in Timor-Leste were based on specific combinations of AFS in relation to access to production factors. This analysis relies on agrarian system concepts to study historical and environmental dynamics and to characterise the diverse practices of different production systems (Cochet 2011; Levard et al. 2019). The theoretical framework provided by the 'farming system' approach (Barral et al. 2012) was complemented by the notion of 'sustainable livelihood' to study the resilience capacities these systems provide to the households that practice them. We have adopted a notion of livelihood that comprises the capabilities, assets and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation (Chambers and Conway 1992; Carney et al. 1999). The sustainable livelihood approach suited well the analytical framework used for the study of agrarian systems in the context of Timorese rural societies that still rely heavily on agricultural activities. By coupling the agrarian diagnosis with the sustainable livelihood approach, we sought to determine the livelihood assets, livelihood strategies and livelihood outcomes linked to the farming systems and household strategies that value (or not) AFS in terms of ecological, social, and economic resilience. As a result of combining these two analytical frameworks, four production factors were selected to study the capacities of rural households and their choice of livelihoods strategy in relation to AFS: access to land, the (direct and indirect) availability of cash, the availability of (family) labour, and social capital. These key variables explain how AFS are combined in different ways by Timorese rural households to develop various strategies for improving their livelihoods.

The third step of the analysis examined how these farming systems do (or do not) cover the basic necessities of rural households and the extent to which AFS are present in the investment strategies of different types of farmers. It relied both on the data collected through the sustainable livelihoods framework and a Basic Necessities Survey (BNS). The BNS approach is based on the United Nations definition of poverty as a 'lack of basic necessities.' Through a participatory approach, local people define the goods (assets) and services they believe are basic necessities, meaning '*something that all household should have, and none should do without*'. This approach has been used for almost twenty years under the framework of rural development (Davies and Smith 1998) and conservation-oriented projects (Detoeuf et al. 2018; L'Roe et al. 2023) in tropical countries.

Methods for data collection

The three steps of analysis of AFS, of farming systems and of their contribution to the economy of rural households required the implementation of a survey protocol consisting of seven data collection methods (Table 1)

The collection of agro-ecological and socio-technical information was based on the agrarian diagnosis approach (Barral et al. 2012). The aim of these surveys was to (i) describe the diversity of farming systems and their technical systems, (ii) determine the key events in the agricultural evolution of the area and the current dynamics, and (iii) define the AFS and their place in the farming systems. For this, focus group discussions, landscape observations, field surveys and semi-structured interviews were conducted in the field with farmers. The aim was to learn about technical, economic, environmental and social transformations, and to understand their determinants, whether local, regional, national or even international (Cochet and Devienne 2006). Information also was collected on technical systems, particularly to establish a work schedule and refine the characterisation of AFS. In addition, data about non-agricultural activities were gathered to gain a vision of the overall activity system (Gasselin et al. 2014). The semi-structured questionnaire was organised into five parts: (1) the identification of the household structure and its social capital (age, family composition, education, kinship connections); (2) the household's history (displacements, first access to land, animals); (3) the

Table 1. Methods for data collection.

Information sought	Methodological tools	Number of surveys
Introduction of the survey team and the purpose of the survey; history and infrastructure of the village; pre-diagnosis of cropping systems and their location	Focus group discussion, at the village(s) scale	5
Agro-ecological information: landcover, location of main agroforestry systems	Landscape transect at the village(s) scale	5
Agro-ecological information: characterisation of soil and tree biodiversity	Field surveys in various AFS plots	27
Socio-technical information: cropping and livestock systems, agroforestry systems, and farming systems	Semi-structured questionnaire with households	42
Basic necessities	Focus group discussion at the village scale	7
Socio-economic information: households' economic and investment strategies; basic necessities	Household interview	136
Restitution of preliminary results	Focus group discussion at the village(s) scale	5

distribution of production factors (land, work force and equipment); (4) the characterisation of the different cropping systems, their location and functioning, their production and repartition between self-consumption and sale; and (5) the characterisation of the different livestock breeding systems, their products, management and relation with cropping systems. About eight to ten households were interviewed in each village, with a particular focus on ensuring that a broad range of situations and circumstances were represented (i.e., near/far from the village centre, young and old people). The interviews were conducted in *Tetun* (Timorese lingua franca) or in the local vernacular language. These different data collection methods (group discussions, field observations, individual interviews) were selected to facilitate the refinement and triangulation of information within a short period of time.

The BNS combined a collective approach of identifying basic necessities during the focus group discussions held in each village with a verification of the presence of these basic necessities during individual interviews with rural households. The first step allowed us to draw up a list of basic necessities and indicators adapted to the situation of the population in each village. This list of basic necessities was then inserted into the individual questionnaires in order to find out: (1) whether the household met these basic necessities, (2) whether the household wished to increase the number of or access to these necessities, and (3) what means the household would mobilise to achieve this objective. This last question provides information on the investment options available to the household and, indirectly, on whether its investment potential is linked to one or more AFS.

Finally, individual interviews with households were carried out to estimate the present and future assets available to them to improve their living conditions in a rural environment where agriculture is expected to be the main economic activity. The first part of the interview consisted of collecting standard household information that could partially explain the status of household assets: age of the household head, household size, level of education, membership of formal or informal groups, length of residence in the village. The second part of the interview aimed to quantify assets by assessing agricultural production (for self-consumption or trade), financial capital (farm income and other income), livestock capital (number of large animals), and social capital (relationship with the *Knua* head). The assessment of agricultural production was localised and related to the five AFS described previously, namely: home garden, crops and fallow, silvopastoralism, young agroforest, forest garden.

These first two parts of the questionnaire helped to establish a typology of farmers in each of the villages. This was intended to understand and characterise the diversity of production strategies while at the same time corroborating the parallel technical surveys of farming systems. The typology of farmers was essentially based on two criteria: annual income level and main sources of income. The sources of income could be associated with the types of primary production of the households and/or off-farm activities. Other variables were used to describe the socio-economic characteristics of each type of farmer, such as the age or sex of the household head and his/her social capital (i.e. link with the *Knua* head), but these variables proved not to be discriminating.

Table 2. Number of individual interviews conducted in the sampled districts.

District	Manatuto		Los Palos		Viqueque	Baucau	
Aldea	Nu-Ahuk	Dambuahun	Tchaivatcha	Nairete	Kraremaruk	Cairiri	Ossoluga
Sample	15 households (112 inhabitants)	19 households (124 inhabitants)	16 households (114 inhabitants)	18 households (129 inhabitants)	17 households (120 inhabitants)	26 households (182 inhabitants)	25 households (121 inhabitants)
Total population	455 inhabitants	318 inhabitants	100 households	90 households	90 households	895 inhabitants	940 inhabitants
% of sampling	*25%*	*39%*	*16%*	*20%*	*19%*	*20%*	*13%*

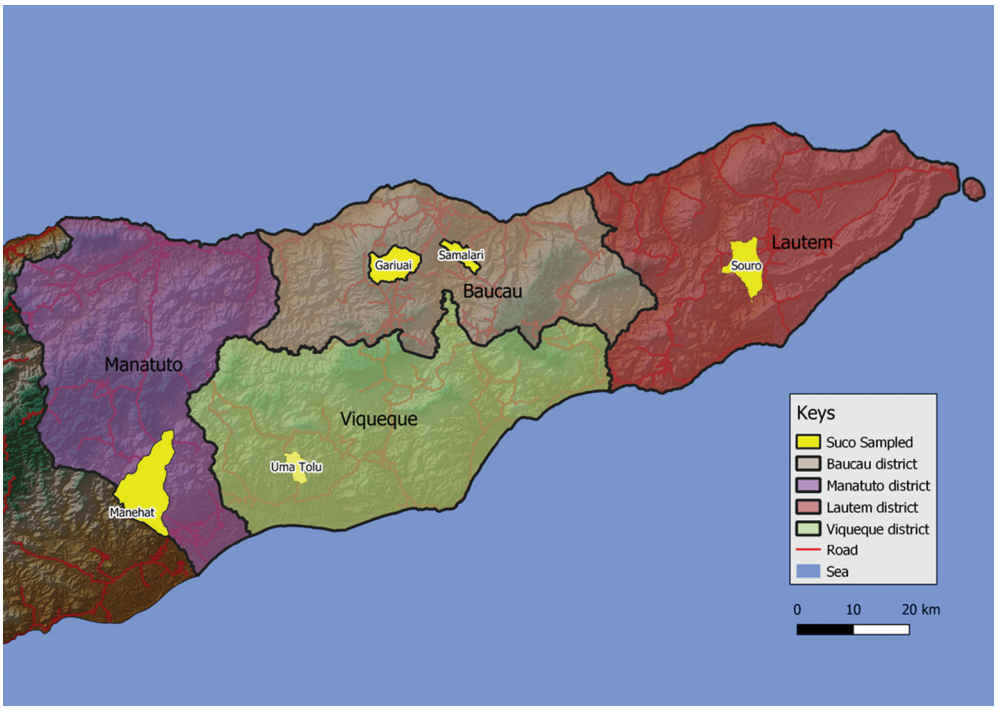

Figure 2. Location of the sampled districts and suco.

The third part of the individual interview assessed the coverage of basic necessities by households and explained their investment strategies to improve their living conditions in the medium term. This last part of the interview helped to identify investment strategies that are based on the development of AFS.

These individual interviews were held with 136 rural households In January and February 2022, the distribution of which is presented in Table 2. The sampling rate varied between 13% and 39%, which suggests that the responses can be considered representative (UNSD United Nations Statistics Division 2005). The households

interviewed were selected randomly by travelling through the different neighbourhoods of the village in order to interview people from the different *Knua* – defined as both the ancestral territory and the kin-based ritual community (Thu 2020).

In each village (*aldea*), a restitution of our surveys and preliminary results was organised. This consisted of a short open meeting with on average about ten attendees that was held in the presence of the village chief. It presented the typology of the farming systems and associated development strategies identified in the village. This presentation was followed by a discussion about the typology of farming systems and the main difficulties and challenges at the village level.

Justification of the case studies

Timor-Leste is characterised by a diversity of geological bedrocks due to the 'locked continental collision' produced as the Australian crustal plate moves north eastwards towards and underneath the Eurasian plate (Thompson 2011). This collision has created multiple topographic and soil structures that are also interrelated with climatic differentiation between the northern and southern coastlines. To illustrate this geographic and climatic diversity, the study was carried out in five *suco* – the administrative term to design a group of 3 to 10 *aldea* – of the eastern districts of Timor-Leste (Figure 2).

There are also major differences between the *suco* in terms of commercial isolation.

All in all, the selection of the sampled villages relied on three criteria: (1) landscape differentiation: highlands, plateau, lowlands, and valleys; (2) climate disparities; and (3) market access: road, distance to cities at the district and national level (Baucau, Dili). Seven villages were selected to cover the diversity of physical and economic situations in eastern Timor-Leste (Table 3), with two villages per district, except for the Viqueque district where, due to time constraints, only one village was sampled.

Results

- Main characteristics of traditional AFS

By combining agro-ecological and socio-technical data, it was possible to identify five types of customary AFS in the study sites (Table 4).

First, home gardens are a mixture of (annual and perennial) crops, old and young trees and palms (spontaneous and planted, managed for several uses such as food, wood or medicine), bushes of condiment and other aromatic herbs (Picture 1). A small animal husbandry (pigs, chicken) may also be managed inside, close to the house and in front of the slope (if there is) so the manure can be washed by rain and fertilize trees downstream. In Tetun language, this AFS takes several names according to their specific characteristics: *to'os uma hun* (the field at the foot of the house), *to'os uma oin* (the field in front of the house), or *quintal* (the orchard).

Table 3. Main biophysical and enclavement features of the case studies.

Suco from DISTRICT	Village	Topography	Annual rainfall	Distance to main town – Access to market	Bedrock
Manehat	Nu-Ahuk	Highlands	South Coast	50 km	Lolotoi complex, Barique formation, Dilor Conglomerate, Aluto Formation
from MANATUTO		700–800 m	2100 mm	Remote	
	Dambuahun	Valleys	South Coast		
		350–500 m	1900–2000 mm		
Soru	Caivaca	Plateau	North Coast	6–7 km	Baucau Limestone
from LAUTEM		450–500 m	1700 mm	Close	
	Nairete	Plateau	North Coast		
		480–520 m	1700 mm		
Umatolu	Krarek-Maruk	Lowland	South Coast	30 km	Bobonaro Scaly Clay and Dilor Conglomerate
from VIQUEQUE		70–100 m	1500–1600 mm	Medium	
Gariuai	Cairiri	Plateau	North Coast	14 km	Baucau Limestone
Samalari		580-630 m	1300–1600 mm	Close	
from BAUCAU	Ossoluga	Valleys		27 km	Viqueque formation and recent fluvial sediment
		130-330 m		Remote due to seasonal river crossing	

Table 4. Main characteristics of traditional AFS.

		Baucau	Manatuto	Lautem	Viqueque
Home garden	Occurrence	+++	+++	+	+
	Location	Next to the house			
	Main crops, palms, and trees	Corn, lemon, beans, tubers, fruit trees	Corn, vegetables, fruit trees	Corn, vegetables, fruit trees	Banana, ginger, fruit trees
	Use	Fruits, staple crop, animal food			Cash crop, fruits
	Main constraints	Competition for light between staple crops and trees, land ownership needed to get the authorisation to grow trees, dense settlement, renewing of old trees			
	Opportunities	Cooling of temperature (trees), secured land tenure, diversification of nutritious food and self-reliance, capital assets (trees, land, animals)			
Crops and fallow	Occurrence	+++	+++	+++	+++
	Location	Valley and plains	Valley	Plain	Plain
	Main crops, palms, and trees	Corn, peanut, cassava, pumpkin	Corn, rice, cassava	Corn, rice, cassava, coconut, teak	Corn, rice
	Use	Staple crop, animal food and fodder, cash crop			Staple crop
	Main constraints	Renewal of soil fertility limited by land accessibility (fallow rotation), market price changes			
	Opportunities	Cash provision, food base for self-consumption, feed and fodder provision, firewood provision			
Young agroforest	Occurrence	+++	+++	++	++
	Location	Hills, plains, former Crop & Fallow	Hills Former Crop & Fallow	Hills, former Crops & Fallow becoming, Living Hedge & Crops	Plain bottom (close to the river), former Crops & Fallow becoming Living Hedge & Crops
	Main crops, palms, and trees	Cassava, corn, pumpkin, papaya, banana, citrus trees, coconut	Betelnut, candlenut	Coconut, teak	Banana, ginger, Gmelina, teak
	Use	Cash crop, firewood provision and secured productive land for the future			
	Main constraints	Land property access/recognition, livestock degradation, market price changes			
	Opportunities	Diversification of farming system, cash provision, securing land tenure for heirs			
Forest garden	Occurrence	++	+++	+++	+
	Location	Hills, gully	Hills, gully	Hills, gully	Hills, upland
	Main palms, and trees	Coconut, palm wine, fruit trees, teak, gmelina, bamboo	Betelnut, candlenut	Coconut	Teak
	Use	Fruits and cash crop	Cash crop	Cash crop	Fruits
	Main constraints	Renewal of old trees, accessibility (far from housing and/or steep slopes), segmentation of land between descendants			
	Opportunities	Carbon stock, securing land tenure within the family and *knua*, capital assets (timber, cash crop), resilience to climate and market changes, firewood, stapple crop and fodder provision			
Silvopastoralism	Occurrence	+++	+++	+++	+++
	Location	Lowland and plains, rocky hills	Valley	Plains and rocky hills	Plains and rocky hills
	Main vegetation	Grass and scattered trees, savannah, secondary forests	Secondary forest, grass and scattered trees	Grass and scattered trees, savannah	Grass and scattered trees
	Use	Pasture/Land available for possible expansion of crop fields/Firewood/Traditional medicine			
	Main constraints	Competition between livestock (free grazing, fire rotation to renew the grass) and fields that can lead to conflicts between villages and/or inhabitants			
	Opportunities	Carbon stock, firewood and fodder provision, access to resources for all, non-formal land and farming regulation (empowerment for community)			

Picture 1. Homegarden in Nuu Ahuk aldea, Manehat suco, Manatuto district (by S.Mazin).

The second AFS combines crops and fallow (Picture 2) in which staple crops (like corn, pumpkin, or beans) and/or tubers and/or vegetables are mixed with sparse trees in lots. The crops are followed by a fallow phase during the dry season or by a more long term fallow, which may last several years. Ruminant livestock can graze inside during the fallow phase, eat corn straw and spontaneous herbs, and rest under the shadow of the trees. Trees often border the limit of the field with a wooden fence. In Tetun language, this AFS takes several names according to their specific characteristics: *To'os muda muda* (the 'moving' field), *to'os udan* (the field of the rain), *to'os la permanenti* (the non-permanent field), or *to'os foun* (the new field).

Picture 2. Crop field and fallow in Darisula aldea, Gariuai suco, Baucau district (by M.Cogné).

Picture 3. A young agroforest 'living hedge and crops' type, in Viqueque district (by M.Cogné).

Young agroforests (Picture 3) are dedicated to grow perennial crops (papaya, banana, chili. . .) that are associated with young palms and/or young trees (for fruits or wood). They are surrounded by 'old' wood fences that are complemented by shrubs (often *Gliricidia sepium*). After the third year of production, when the fertility decreases, crops are slowly replaced by spontaneous herbs and trees let to grow inside. In Tetun language, this AFS takes several names according to their specific characteristics: *to'os tuan* (the old field) or *quintal foun (the new orchard*).

Forest garden is the fourth type of AFS (Picture 4). It is an old mixture of functional palms and trees, often located near a water source. It is not bordered by any fence but there are often several forest gardens next to each other. The boundaries between the different estates can be marked by old trees, a watercourse or specific marks on certain palm trees. Forest garden is usually named as *abat laran* (the ancestors' field) in Tetun language.

Finally, silvopastoralism is done in unclosed pasture (Picture 5) that also contains spontaneous bushes, leguminous trees (like *Tamarindus*, *Leucaena*, *Sesbania*...), fodder trees (like *Ziziphus*), timber and/or woodfire trees (like *Eucalyptus*, *Timonius*. . .). The trees are scattered throughout the silvopasture area. In Tetun language, this AFS takes several names according to their specific characteristics: *pastagem* (open pasture), *ai-bobur laran* (*Eucalytus*-dominant pasture), *ai-loek laran* (*Ziziphus*-dominant pasture).

The occurrence of the 5 AFS varied according to the ecological and socio-economic specificities of each district. Among the ecological specificities (Table 3), topography, altitude, annual rainfall, continuous presence of water stream, and soil specificities (presence of rocks and soil characteristics derived from the bedrock) influenced the presence of palm or tree species and encouraged farmers to develop one farming strategy instead of others (Table 4). For example, flat lands without rocks are easy to work to grow crops such as corn. Thus, farmers would rather develop 'crop and fallow' systems in these places than grow a multi-stage AFS which would need water and could develop on well drained slopes without needing daily maintenance. Similarly, species are chosen according to the bioclimatic condition that are specific to each district, especially

Picture 4. A forest garden specialized in betelnut in Dambua Hun aldea, Manehat suco, Manatuto district (by M.Cogné).

Picture 5. Buffaloes and cows in an old rice field left to graze (by G.Lescuyer).

between the north and south coast but also considering the change of temperature related to the elevation. For example, coconut palms are characterized by farmers to be suitable for 'hot area', that is to say not under 20°C, which excludes the highlands of Manatuto. Thus, different kinds of farming strategy are noticeable only by observing the landscape.

In 2017, a typology of farming systems that took into account different agroecological zones was proposed by Williams et al. (2018). However, this typology did not highlight the agroforestry component of Timorese agriculture by focusing on other criteria such as livestock, subsistence crops (rice) or the island's historical cash crops (coconut, coffee).

Long grown subsistence and cash crops, village displacement during Indonesian colonisation and the track of road construction have historically structured the socio-economic conditions of each district and therefore influenced the adoption and/or the content of certain AFS by the farmers. For example, forest gardens were usually maintained in the former sites of villages that were displaced during Indonesian occupation (Mc William and Traube 2011) whereas home gardens were much more frequent in the villages that benefited from transportation facilities and electricity connection. On the contrary, silvopastoralism is practiced in areas located rather far from the roads and/or in areas drawing some kind of 'border' between villages.

The various ecological and socio-economic local characteristics may explain the localisation of the five types of AFS in the four districts. Moreover, temporal successions between various AFS are often observed: silvopastoral areas can be converted to crops and fallow, young agroforests can become home gardens or forest gardens (after two years of cultivation), or forest gardens could switch to silvopastoralism or to crops and fallow.

The frequency of these AFS in each district resulted also from the choices made by rural households whether or not to include them in their farming strategies.

- Main characteristics of farming strategies

The information collected through the households' interviews enabled us to categorise households according to their access to production factors (land, financial, labour and social capital, and to identify four archetypes of rural households in our study area (Table 5).

A large quarter of the population had a low access to all the assets needed to lift themselves out of poverty. At the other end of the spectrum, a small third of households accumulated social, land and economic capitals. An intermediate class of households had a medium access to all capitals, especially family capital. Finally, a minority class of households specialized in the accumulation of cattle capital.

However, the internal variability of these four households' categories means that they could often consider several farming strategies. The combination of socio-technical and socio-economic information gathered via the households' questionnaires and interviews allowed us to establish links between household archetypes and their different farming strategies (Figure 3).

Six farming strategies were predominant in our sample:

Table 5. Categories of rural households.

Rural household archetype	Land capital	Financial capital	Labour capital	Social capital	% of the total sampled households
Household with restricted access to land	Low: None (or very little) land ownership; sharecropping; land loan	Low-medium (<1,500$/yr/household)	Low-medium (family)	Low: a family at the bottom of the historical hierarchy (spiritual, political. . .); poor connection with the village head; the youngest sibling in a family or an elderly person living alone; little access to school and external facilities	27%
Household with balanced assets	Medium: landowner of a limited number of agricultural and forest plots	Medium (between 1,500$ – 4,000$/yr/household)	High (family and sometimes temporary employees)	Medium: limited connection with the village head; little access to school and/or to external facilities (NGO, government. . .)	29%
Household with important social and land capitals	High: landowner of a large number of agricultural and forest plots	Medium – high (between 2,000$ – 9,000$/yr/household)	High (family and sometimes temporary employees)	High: a family at the top of the historical hierarchy (spiritual, political. . .); close relationship with village head; the eldest sibling in a family; access to external facilities (NGO, government. . .)	31%
Household with large cattle capital	High: landowner; access rights to common land; sharecropping	Medium – high (between 2,500$ – 14000$/yr/household)	Medium (family and sometimes permanent employees)	High: a family at the top of the historical hierarchy (spiritual, political. . .); close relationship with village head; the eldest sibling in a family	14%

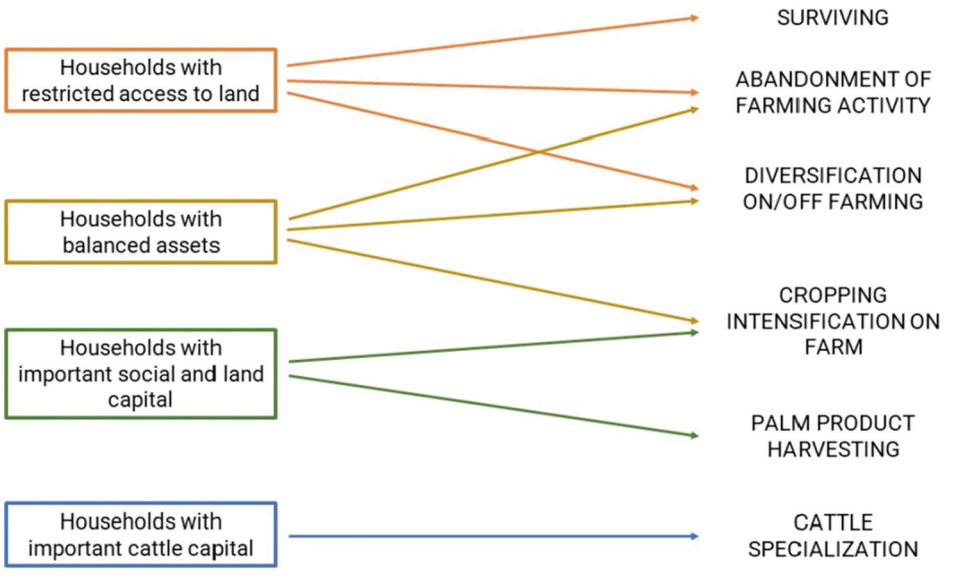

Figure 3. Links between the types of households and their farming strategies.

- *Surviving*: this farming strategy consists in using the land available for subsistence only. Sometimes it is supplemented by income from a temporary job. The goal is to produce subsistence resources (food, animal food, firewood, house materials, marketing produce, medicine, etc.) as much and as long as possible on a small surface (i.e., less than 1 ha).
- *Abandonment of farming activity*: this strategy aims to provide the minimum food basket for the household while at least one of the household heads has another source of income (i.e., pension, service or commercial job, etc.). The dynamic is either to leave the village because of land access restrictions, or to keep land to potentially build a house rather than to use it for farming activities.
- *Diversification on/off farm*: the strategy is to focus on farming activities but without a specialisation. Other sources of income help to provide funds to invest in diverse farming production. This type of household combines sufficient land (from 1-3 ha to more than 10 ha) in different locations to prepare the inheritance of the next generation. This strategy involves capitalisation of diverse resources such as land, trees and animals.
- *Cropping intensification on farm*: the household specialises in growing a few types of crops as a source of income. These crops are related to a regional value chain (peanut, tomatoes, sweet potatoes, rice, ginger, banana, etc.).
- *Palm and tree product harvesting*: the household specialises in harvesting palm and tree products as knowledge and land resources have been transferred down across generations.
- *Cattle specialisation*: the household specialises in cattle breeding, it manages little land to grow crops (mostly to provide the household's food basket) and it keeps land resources (i.e., agroforest) to transfer to the next generation. These livestock owners share other land with crops growers (especially rice and corn) to feed the animals after the harvest season and use common areas to graze their animals.

All of the farming strategies were settled in a variety of ecological and socio-economic contexts, which influenced the way in which they were applied: they promoted various agricultural and agroforestry produce and therefore they relied in different ways on the traditional AFS (Table 6). First, due to lack of access to capital, households that have adopted strategies of surviving, diversification on/off farm and of abandonment of farming activities mainly valued their home gardens and secondarily resorted to one or two other types of AFS. Households with large livestock assets depended only on sylvo-pastoral lands. Farmers involved in agricultural intensification would mainly valorise their crop fields and fallows and, to a limited extent, their home gardens or some young agroforests. In the end, it was only the palm/tree products harvesting strategy that directly depended on old and young agroforests.

These six farming strategies were not represented equally since the combination of on-farm and off-farm income was a strategy adopted by 31% of households, whereas the other farming strategies each involved between 15–20% of the households (Table 6). This choice of farming strategy indicated that a noteworthy proportion of rural households (with low or medium access to capitals) could no longer rely solely on agricultural and agroforestry products to live in rural areas. This economic diversification was undergone rather than chosen for the majority of these households,

Table 6. Reliance of the farming strategies on agroforestry systems.

FARMING STRATEGIES	% of the total sampled households	Main crops/ livestock in BAUCAU	Main crops/ livestock in MANATUTO	Main crops/ livestock in LAUTEM	Main crops/ livestock in VIQUEQUE	Main AFS used
Cropping intensification	19%	Rain-fed rice and horticulture			Banana and ginger	Crop field and fallow, home garden, young agroforest
Palm products harvesting	8%		Betelnut, candlenut	Coconut		Forest garden, young agroforest
Cattle specialisation	14%	Small ruminants	Cows	Cows or water buffaloes	Water buffaloes	Silvopastoral lands
Abandonment of farming activity	14%	Corn, banana	Cassava, taro	Cassava, coconuts		Home garden, crop field and fallow
Diversification on/off farm	31%	Corn, pumpkin	Betelnut	Coconut, corn, cassava	Banana, cassava, corn	Home garden, crop field and fallow, Silvopastoral lands
Surviving	15%	Corn, cassava	Betelnut	Coconut		Home garden, young agroforest

which undoubtedly would contribute to a gradual abandonment of farming activity for some of them in the medium term.

On the opposite, specialisation in the collection of palm and tree products concerned only 8% of the households surveyed. This farming strategy, which focused on agroforestry products, was minor in these districts, and even absent in half of them.

The diversity of uses of the various AFS in farming systems demonstrated the flexibility of agroforestry in Timor-Leste, but also makes it more difficult to analyse its direct contribution to the livelihoods of rural households. It is therefore useful to complement the study of farming systems with an analysis of their coverage of basic needs.

- Coverage of basic needs

Two surveys were combined to assess the extent to which the current farming systems covered the basic needs of rural populations and offered them a source of funding for investments. First, a focus group meeting was held in each village to identify the list of what were perceived as basic needs. Individual household surveys then were used to estimate how these needs were covered and whether the farming systems – and the AFS on which they partly depended – were a possible source of funds for investment.

The list of basic necessities was homogeneous in the seven villages studied (Table 7). A set of ten necessities was systematically identified in all of the villages. Some other necessities were identified in one or two villages: proximity of an asphalt road, cooking equipment, assistance from family, birth certificates, meals, traditional events, and the existence of a church.

Access to land was the only basic necessity linked to the practice of agroforestry, since the possibility of planting and exploiting trees contributes to providing food or income for the rural households.

The coverage of these basic necessities varied by district. Table 8 displays dark red cells when a necessity was not covered by more than 50% of the households, and light red cells when it was not met by 10–50% of the households in each village.

Table 7. Basic necessities quoted in the sampled districts.

Basic necessities	Definition	Range
Access to agricultural land	Areas to grow crops or trees, for self-consumption or trade purpose. This land is considered to provide enough food for the family	1–3 plots
Ownership of large animal	At least one large animal (cow/buffalo/horse) must be owned by the household	1–2 animals
Agricultural equipment	At least one machete, one pickaxe, and one dig stick	
Cash money	Minimal amount to face unavoidable expenses every week or month	10–25 $/week
Clothes	Set of clothes to be renewed at least every year (but often every quarter)	
House	House in cement/wood/bamboo large enough to shelter all family members	
Water	Maximal distance to reach a spring, a river, a well, a tank	50–1000 m
Electricity	Access to public network	
Hospital	Maximal distance to reach the hospital	2–5 km
School	Maximal distance to reach a primary school	1-6 km

Table 8. Coverage of the basic necessities in the sampled districts.

	Baucau		Viqueque	Manatuto		Lautem	
	Ossoluga	Cairiri	Krarekmaruk	Nu-Ahuk	Dambuahun	Tchaivatcha	Nairete
Access to agricultural land							
Ownership of a large animal							
Agricultural equipment							
Cash money							
Clothes							
House							
Water							
Electricity							
Hospital							
School							

Access to land for agricultural or agroforestry purposes was a concern in 3 of the sampled villages, especially for those specialised in palm product harvesting like in the Manatuto and the Lautem districts. Although access to land was only one out of the ten basic necessities mentioned in these villages, it constituted a strong economic constraint in almost half of the villages sampled. Moreover, as the typology of rural households showed (Table 5), poor access to land was often combined with limited access to other types of capital.

- Are AFS a source of funds for investment?

The BNS provided an opportunity to ask the households about their potential sources of funds to undertake a new productive investment. The summary of their main responses, according to the districts and the farming strategies, is presented in Table 9. The sale of forest and agroforestry products was seen as a possible source of funds for the households that (1) were specialised in palm product harvesting, (2) were abandoning farming, or (3) practiced farming to guarantee a minimum living. It was not seen as a source of funds much – if at all – for the other three farming strategies.

Table 9. Main sources of funds for investment.

	Districts and villages						
	Viqueque	Lautem		Manatuto		Baucau	
FARMING STRATEGY	Krarekmaruk	Tchaivatcha	Nairete	Nu-Ahuk	Dambuahun	Ossoluga	Cairiri
Cattle specialisation	livestock breeding	livestock breeding, jobs	livestock breeding	livestock breeding, sale of crops	livestock breeding	sale of crops, livestock breeding	sale of tree products, livestock breeding
Cropping intensification	sale of crops					sale of crops	
Palm product harvesting				sale of crops, sale of tree products	sale of tree products		
Abandonment of farming		sale of crops, sale of tree products	livestock breeding	jobs	jobs, sale of tree products	livestock breeding, sale of tree products	
Diversification on/off farm	sale of crops	livestock breeding, jobs	Sale of crops, livestock breeding				sale of tree products, livestock breeding
Surviving		jobs, livestock breeding	sale of tree products	sale of crops, sale of tree products	sale of tree products	sale of tree products, sale of crops	livestock breeding, sale of tree products

Discussion

- The need to better understand the integration of AFS into farming systems

Trees and palms are present in most farming systems currently active in Timor-Leste. Five traditional AFS models were identified based on our studies in the selected districts and information from the literature. These models adapt to their natural and socio-economic environments, particularly in terms of the products grown. However, these specific local features do not call into question the definition of these five AFS models since each is found in at least half of the districts studied.

The richness of the AFS cannot be explained only by their adaptation to local ecological or economic factors. This diversity also is generated by the varying importance of the AFS and their integration into the farming systems inherited by rural households. Due to the time required for a tree to develop, the current composition of agroforests is heavily impacted by past choices, sometimes involving species whose products are less valuable today than they were several decades ago. As shown in Figure 4, the six farming systems do not depend on AFS in the same way, nor do they have a similar potential for supporting agroforestry. The dependence on AFS (on the x-axis) was assessed on the basis of two variables: the importance of trees and palms (betelnut, candlenut, coconut) in the main crops grown by the farmers (Table 6) and the occurrence of the sale of tree products as a source of investment (Table 9). The development potential of agroforestry (on the y-axis) is estimated based on the four types of capital that we used to design the household categories (Table 5).

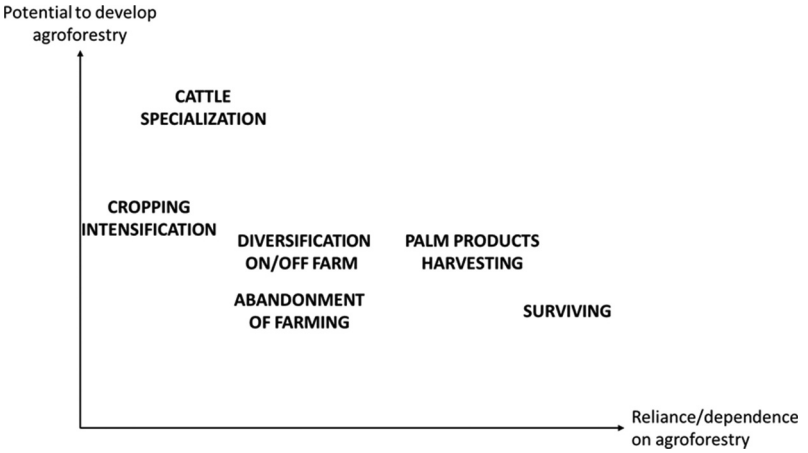

Figure 4. Farming systems' dependence on and potential to develop agroforestry.

There is an inverse relationship between rural households' dependence on AFS and their capacity to develop agroforestry. This finding runs counter to the common assumption that support is all the more effective that it targets the beneficiaries most concerned. But this assumption overlooks the heterogeneity of uses and functions provided by AFS in the diversity of farming systems. This inverse relationship between households' reliance on AFS and their ability to promote them illustrates the need to clarify the objectives of any initiative to support agroforestry.

There are two reasons why it is useful to describe and understand the diversity of AFS in rural economies before considering measures to extend or strengthen agroforestry in Timor-Leste.

First, the trade-off between the potentially conflicting objectives expected of agroforestry is rarely explicit and is sometimes even ignored. Our analyses show that there is opposition between households that are currently most dependent on AFS for their livelihoods and households that have the (social, financial, labour or land) capital to rapidly extend certain forms of AFS. For example, the choice to strengthen agroforestry-related ecological services would lead to favouring households with the capital to rapidly develop agroforestry, while the choice to use agroforestry to combat poverty in rural areas would lead to supporting mainly households practising survival agriculture. The choice of objectives sought by supporting agroforestry is facilitated by a prior understanding of AFS and the various ways in which AFS are integrated into farming systems, which themselves result from a set of capital conditions.

Second, making the effort to describe AFS and farming systems also provides an opportunity for greater consultation with rural communities in order to build on their practices, knowledge, rules and expectations. As several reforestation programmes in Timor-Leste have shown (Bond et al. 2020), involving local people starting from the design stage of a project increased its social acceptance and made a significant contribution to achieving results. This consultation stage in particular improved understanding of equity among households by considering factors such as land ownership, labour, and social networks (Schirmer and Bull 2014; Bond et al. 2020), which are often difficult for external

operators to perceive. In the case of the sampled eastern municipalities of Timor-Leste, the description of the existing farming systems demonstrated that the donor-driven 'modern' AFS cannot be structurally integrated by certain types of households because of their restricted access to land, the low availability of labour and/or their weak social capital. Under such conditions, promoting modern AFS implicitly targets the highest social class categories and risks reproducing a pattern of social inequality inherited from colonisation.

- Heterogeneous contributions of AFS to the well-being of rural households

The overall contribution of AFS to the livelihoods of rural populations appeared moderate, since access to agricultural land and woodland was only one of the ten criteria cited to cover basic necessities in the villages studied. However, the sale of tree products was seen as a possible source of funding for future investments in three of the four districts sampled.

A more precise analysis of the impact of AFS on the welfare of rural populations can be made by distinguishing between the various farming systems. Three types of contribution of AFS to rural livelihoods can then be observed. First, for low-income households with a limited number of income sources, i.e., households that have adopted survival or the abandonment of farming activities strategies, the products extracted from AFS constituted a substantial source of income. These two household archetypes mainly faced a lack of land capital to develop agroforestry. Agroforestry therefore constituted a safety net that was used either to supplement insufficient income on a recurring basis or to meet an unexpected need for money.

Second, households specialising in palm and tree product harvesting also derived significant income from agroforestry, which added to a level of annual income that was fairly high. They had the capital to strengthen their specialisation, particularly when trading conditions were good. For these households, agroforestry represented a lever for economic development.

Finally, the other categories of farmers had several sources of income, which provided them with a satisfactory livelihood level without depending on the regular exploitation of AFS. For these households, agroforestry was a marginal economic activity, but one that was practiced to maintain flexibility in their agricultural production systems and to secure landownership rights so that their children could inherit the land. These households could adapt their practices to gradually renew AFS. Technical solutions exist for renewing by 'gardening' or 'clearing', without destroying the entire stand, as young people sometimes do when they inherit an agroforest that met their parents' needs but not their own.

- Prospects for farming and agroforestry in Timor-Leste

Although 70% of the current Timorese population officially depend on agriculture as their main source of food, employment and income, the data we collected in four eastern municipalities highlighted an unexpected rural evolution: 45% of the households surveyed (i.e., 'abandonment of farming activities' and 'diversification on/off farm' types) are decreasing their reliance on farming activities. It seems that historical and social dynamics are greatly influencing the present interest in agriculture activities: the appeal of globalisation, access to school services and better connection to growing urban centres are

encouraging young people to focus on other job opportunities. In Timor-Leste, we may be witnessing a transition where households that have capital wealth, motivation and skills are shifting away from agriculture as a 'household subsistence activity' to engage in off farm activities. Such a rural transition raises questions regarding how the complex traditional AFS and associated knowledge can be preserved if specialised and professional farmers are supposed to maintain them.

However, although many rural households are leaving agriculture as their main 'business career', most still maintain certain types of AFS for other functions that rely on tree assets. These include providing complementary food and serving as historical land marks and a 'living' source of cash flows, as well as providing comfort and pleasure. In addition to contributing to food security and income generation in rural economies, customary AFS are also a way to preserve the identity and self-resilience of the island.

Conclusion

The diversity of cultures and ecosystems in Timor-Leste has led to a multiplicity of organised interactions between cropping systems, livestock, trees and palms. In the four districts where we conducted our research, five traditional AFS models were identified, the practices of which varied depending on the main agricultural commodity. As a matter of fact, most agricultural crop models combined trees/palms in space or time with cultivated crops.

There are many advantages to developing agroforestry based on traditional AFS rather than promoting approaches that are considered technically innovative but whose results are uncertain. The latter kind of technical support approach was implemented in Timor-Leste some fifteen years ago to promote tree plantations and failed to achieve the stated objectives. Unlike modern AFS, which are designed by experts to have an optimal mono-objective performance potential in relation to one or two pre-defined objectives, traditional AFS were designed and are practiced in response to local environmental, social and economic conditions. They are by nature versatile because they are the result of decisions by rural households to make the best use of the environmental and human factors available to them to maintain and improve their living conditions. However, the fact that AFS are adapted to ecological and human contexts does not mean that they do not face technical obstacles, social inequalities or economic difficulties, nor that their performance cannot be improved. The increasing degradation of forest ecosystems and the persistence of poverty in Timor-Leste show that AFS do not contribute enough to combating these problems. However, the diversity and complexity of AFS require a better description of how they function and a better understanding of how they fit into the heterogeneous development strategies of rural households before we can consider actions to improve their performance. Indeed, traditional AFS need to adapt their services and products to the needs of current farmers and new value chains. It is therefore important to identify how these needs have evolved and what farmers are planning to do to gradually renew these species. Saving existing agroforests and their soil is certainly more important than creating new ones. While conducting studies and consultations sometimes may seem like a waste of time and resources, these efforts are probably crucial for the development of agroforestry support measures that will have a proven and lasting impact.

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