Can local agroforestry systems survive for rural development and sustainable ecosystems in dryland areas? A case study in Timorese Mamar systems

M R S Moata, P Rosario, T V D Berg, D V Sinlae, Y A N Rua Ora, L D W Wardhana, A Takalapeta, and Y Benu
State Agricultural Polytechnic of Kupang, Jl. Prof. Dr. Herman Yohanes Lasiana, Kupang-NTT, Indonesia.

Corresponding author email: rosita.moata@gmail.com

Abstract. Mamar is a traditional agroforestry system established many years ago on Timor Island. It can maintain water reservoirs, natural habitat, and ecology conservation to support the livelihoods of local people. Although, Mamar is a symbol of heritage, “people will not leave it, but also do not want to see it” an unmanaged system. This study aims to understand the challenges and potential developments of the Mamar. A study on ecosystem services and the potential sustainability of Mamar was conducted in Ponain village using four sampling locations. Data was collected from observation, focus group discussion, laboratory analysis, and secondary data. The results showed that the change of land use from agroforestry to monoculture had reduced the quality of topsoil, water, and the biodiversity of local plants. Mamar could provide good services for the ecosystem, but we are unsure if it can be sustained because the youth tend to leave the Mamar. However, it seems likely this heritage can survive with strong partnership from Pentahelix collaboration (government, education, business, community, and media), applying multifunctional ecosystem (Agro ecotourism and community-based tourism), and eventually creating a business model. This collaboration will help to improve ecosystem and economic services, as well as rural development.

Keywords: land uses, rural development, pentahelix

1. Introduction

Agroforestry is a branch of agriculture [1], defined as integrated systems of woody plants, non-woody plants, and livestock in the same area for community welfare improvement. It is a dynamic system of integrated plants and animals to sustain social, economic, and environmental needs [2]. In addition, this system plays an important role as potential climate change mitigation and adaption system [3].

Mamar is a traditional agroforestry system in Timor Island, the eastern part of Indonesia, consisting of annual, perennial, woody crops and animals [4]. This system has been established for many years by socio-culture and belief. There are three different layers with different functions and characteristics: core zone (“Aibaun”) [4] or wet zone comprises of protected spring water; buffer zone (“Kopa”) comprises of perennial woody plants, and developing zone (annual crops) comprises of food crops and livestock [5] both are dry zones [4]. Timorese’s people generally maintain their local agroforestry naturally with less input from agricultural systems [4].

Previous research explained some reasons for the transformation of agroforestry to monoculture
systems: production, income, efficiency, optimal yield, and a manageable system. However, agroforestry provided better ecosystem services and a more profitable system than the monoculture systems. As traditional agroforestry, Mamar contains multiple mixed natural ecosystems that provide various ecosystem services and trees with multiple functions [6].

Ecosystem services provide services to humans and social welfare through the processes of natural systems [7]. This indicator will value an ecosystem. There are four types of ecosystem services: supporting, provisioning, regulating, and cultural services. Several roles of the Mamar for ecosystem services: 1) supporting ecosystem services requires support from other ecosystem services. Mamar provides higher biodiversity ecosystems than monoculture [8], for pest and disease control [9], water management, root penetration, and residues input [10, nutrient cycle and availability [11, 12], and biota activities [13].

Soils under mixed cropping provide the best quality compared to forest and cropping systems alone [14]; 2). Provisioning ecosystem services gain direct service from the system, for food, fodder, spices, building material, fiber, and lastly 3) regulating and cultural services, such as climate, water, and air regulation. Mixed cropping has lower soil erosion [15], surface run-off [10], windbreaks, soil moisture, air temperature, soil temperature, light availability, and humidity regulation [11], and the most important role is carbon sequestration (carbon stock) [16, 17]. For cultural services, Mamar provides for the spiritual and emotional needs of local people, especially the betel nut (Areca catechu), which has a very high cultural value (customary service) for weddings, a symbol of love. However, more than half of the rural population is less aware of agroforestry activities [18] due to the quality of human resources (education, ages). Most youths tend to migrate to urban areas, and only elders maintain the Mamar with no regeneration. Therefore, improving the model of rural development becomes crucial for a sustainable ecosystem.

Rural development can be achieved by implementing a sustainable livelihood framework [19] (Figure 1). The sustainable livelihood framework includes five elements: Vulnerability Context, Livelihood Assets, Transformative Structures, Livelihood Strategies, and Livelihood Outcomes. Moreover, livelihood assets include natural, financial, physical, human, and social capital.

![Figure 1. Sustainable livelihood framework.](image-source)

2. Material and methods
Sample areas were in Ponain Village located in Kupang Regency, East Nusa Tenggara (ENT) Province, Indonesia. Ponain is part of the Amarasi District and is located at 10°12'23.8"S 123°51’11.6”E 42 km from Kupang City, the capital city of the ENT province. This village has 2,383 inhabitants living in a 13.54 km² area, divided into 560 households. The Ponain landscape is dominated by a hilly area with an elevation of 200-600 m above sea level. The climate in the Ponain area has an average temperature of 20-34 °C and average precipitation of 1,164 mm/year with three to four months of the wet season from November to February, while the rest will be the dry season.
Interviews and Focus Group Discussion (FGD) were conducted with local people in Ponain Village, Youth, and stakeholders. Data was presented using SWOT analysis and description. Moreover, two soil samples (0-30cm depth) of four areas were collected from Mamar 1 & 2, edge (areas in between), and agriculture lands, with total areas of the Mamar, was 104.11 ha. The location of soil samplings was from the agricultural area 30 m from the edge, edge area, Mamar -1 area 10 m from edge, and Mamar-2 30 m from the edge. Then samples were analyzed for soil organic matter, soil water content, and soil carbon (Figure 2).

3. Result and discussion
3.1 Horticulture and local agroforestry services

Mamar systems in Ponain were established in the 1800s and left behind since the 1990s when horticultural products had a better price in the local market. The transformation of agroforestry into a monoculture system negatively impacts soil quality, carbon storage, biodiversity, and pest and disease control but positively impacts production. Common crops grown in the monoculture system were tomatoes (*Solanum lycopersicum*), bitter melon (*Momordica charantia*), chili (*Capsicum frutescens*), and mustard greens (*Brassica juncea*). Meanwhile, the four main products of Mamar in Ponain Village are bananas, coconuts, betel nuts, and areca nuts. These monoculture crops are more marketable products and provide a better income than agroforestry products.

The Mamar in Ponain were approximately 104,105 Ha with space 2.0-2.5 m in between, but those trees covered not all area. Mamar is in upland areas, while horticulture is in lowland areas. There were annual crops such as spices crops (turmeric, ginger, lemongrass) and food crops (cassava, sweet potato, and other fruit plants) in the Mamar. These products are usually sold at the local market about 15 km from the village with different prices for each plant. The market chain of Mamar's products is mainly from producer —middleman—retailer —consumer. In recent years, Mamar's products' market has reduced due to changing market demands on horticultural products. The agricultural department started it through a field extension worker who introduced the horticulture farming system to the local people during the 1900s, continued by NGO's (non-government organization) programs on horticulture.

Exposure to horticulture continued in the early 2000s when a non-governmental organization conducted capacity-building projects in agriculture, especially horticulture. As the prices of horticulture products were higher than Mamar products, villagers chose horticulture over Mamar. As a consequence, Mamar has been a side income generator for villagers. However, total income from Mamar's products
is not promising and differ for each plant, for example, Banana IDR 5,000-6000/bunch; coconut 1,000-1500/item; Areca Nut 30,000-35,000/bunch; Betel Nut 20,000-23,000/bundle compared to horticulture product only one period could earn IDR 5,000,000-8,000,000, and it can be harvested two to three times a year depending on the commodity.

Agroforestry could provide some services like (1) carbon sequestration, (2) biodiversity conservation, (3) soil enrichment, and (4) air and water quality [21]. Ecosystem services from Mamar were more significant than the horticulture system. Farmers are aware of the benefits of Mamar in the (Aibaun zone) as a center of spring water for lowland areas where horticulture took place. Nevertheless, some other services from the Mamar were ignored by local people like water, nutrients, and air regulation; and carbon sequestration. Soil nutrient is the capital of the agroforestry system [22]. However, soils from agriculture lands contain declining soil organic matter (SOM), water content, and soil carbon than in edge as well Mamar's areas (Figure 3). Therefore, it is confirmed Mamar could provide better ecosystem services regarding water and nutrient regulation.

![Figure 3](image-url). The quality of soil & biomass in agriculture, edge, and Mamar lands (Soil organic matter, soil water content, and carbon biomass).

There is gender equity in agricultural practices in both agroforestry and agricultural lands. Men are likely to be responsible for agroforestry, while women are responsible for horticulture. Men tend to do hard jobs like cutting and climbing the trees, carrying the product, and harvesting. Meanwhile, women tend to do water crops besides household activities (cooking and taking care of the children). Nevertheless, since horticulture required more hours for farm management (fencing, planting, fertilizer, irrigation, and harvesting) and produced more income, farmers had left the Mamar, and the task's division became less clear. However, women still play a meaningful role in agroforestry to preserve food security [23].
Management of the Mamar system declined year to year and was left behind, especially for youth people. Transfer of knowledge about Mamar to the next generation only happens when the children join their parents in the Mamar during the weekend. Storytelling about the history of Mamar as a symbol of the kingdom or big family inheritance happened when outside people conducted research or among internal family members. The ancient developed Mamar from planting trees by a young man as an obligation before marriage, while a young lady needs to do traditional weaving fabric ("menenun"). Previously, the people kept spring water in wet Mamar as a source of life (daily consumption and water irrigation) and protected it with customary law. Currently, young people enter the Mamar only to get additional cash (pocket money) or when horticulture crops could not be produced during the dry season. Thus, horticultural products will be used for food and cash crops, while Mamar's products will generate additional income.

Figure 4. Several capitals influencing local agroforestry system.

Several capitals influenced Mamar's system in Ponain (human, natural, physical, financial, and social capitals) (Figure 4). Human capital is related to formal and informal education; natural capital refers to land and water availability and quality; physical capital refers to agricultural mechanization; financial capital refers to income sources (credit money), and social capital is mainly related to faith groups. Although these factors affect the Mamar, the impact of land-use change to the loss of Mamar may ultimately happen.

However, additionally, the government is also playing an important role in Mamar's sustainability. The government has "5P programs" that promote agriculture, animal husbandry, fishery, plantation, and tourism. These programs indirectly support the land-use conversion to get more production in horticulture and livestock areas. Deforestation of Mamar's areas surrounding the spring water may indirectly impact the availability of water then eventually affect water irrigation for horticulture at lowland areas. It is made worse by the additional impact of climate change that has seen increased temperatures and reduced annual rainfall, long drought seasons, and less wet months.

3.2. The SWOT analysis for local agroforestry system

Strength, Weakness, Opportunities, and Threats (SWOT) is an analysis tool to construct a strategic plan to convert weakness into strength, maintain opportunities, and minimize threats. The management system of Agroforestry will be better in sustainability and productivity when SWOT analysis has been applied [24, 25] and is used for rural development strategic plans [26, 27].
Table 1. SWOT analysis for local agroforestry and strategic development.

| Strengths (internal)                                                                 | Weakness (internal)                                                                 |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| ● Springwater at upland was used for horticulture farming at lowland                | ● No regeneration plants to replace the old trees.                                  |
| ● Traditional law for growing trees & punishment for disobeying one                 | ● Reducing rule of the customary institution                                         |
| ● Village rule to care cattle at the fenced farm because agriculture is the main livelihood than animal husbandry | ● Business in horticulture requires full-time activities & resources                |
| ● Mamar belongs to a big family (kingdom), so no one could sell without permission from the elder family | ● All stakeholders and the farmers themselves want to keep the Mamar but have no idea the appropriate way to manage the system with comparable production to horticulture |
| ● Strict rule for cutting the trees in the Mamar unless holding permission from village government | ● Mamar's production is low and cheap                                               |
| ● Mamar is a family "piggy bank" that could be harvested & sold to the market when needed. | ● The price for Mamar's product did not change over a period of time (same price for many years) |
| ● Organic farming program from the local church                                    | ● Lack of local people awareness for reforestation and maintenance of the Mamar      |
| ● There are local markets for Mamar's products                                       |                                                                                     |
| ● Mamar's products can be collected while waiting for harvesting horticulture products. |                                                                                     |
| ● Head village habits to grow some trees (1-2 plants) annually                      |                                                                                     |
| ● Banana, coconut, betel nuts, and areca nuts are the main income-generating products for educational affairs. |                                                                                     |
| Opportunities (external)                                                             | Threats (external)                                                                  |
| ● Program development of district government "program 5P": agriculture, animal husbandry, fishery, plantation, and tourism. | ● More and fast income generating from horticulture products                        |
| ● The village government program was on agriculture & livestock.                    | ● No more cultural rule for youth to grow trees in the Mamar                         |
| ● All stakeholders (head of the village, faith leader, youth, and extension worker) agree to keep the Mamar | ● Less interest of young generation to maintain the Mamar                             |
| ● Shame or prestige if a household selling their Mamar because it is self-esteem symbol of Amarasi people | ● Some of the Mamar's areas have been pawned to other relatives for education needs |
| ● Seed aid program from the forest department                                        | ● Reduced level of soil water content                                                |
| ● Coconut shell can be used for copra with reasonable price and potential for VCO (virgin coconut oil) products. | ● Land-use changing                                                                 |
|                                                                                      | ● Pest infection to young coconut tree damaged some of the trees in the Mamar        |
|                                                                                      | ● Alternative income from other jobs that provide more & quick money                |
|                                                                                      | ● Youth is more interested in horticulture, migrant, rental bike than working in the Mamar |
|                                                                                      | ● Lack of water will hinder the growth of Mamar's trees.                             |

Based on the SWOT analysis, there are several strategies to develop Mamar systems together with rural development by:

1) Improving management of the Mamar through:
   a. Regeneration trees, pruning, reforestation;
   b. Applying cutting-replacing model (before cutting, growing new plant);
   c. Setting the spacing between trees to get the better circulation of light, water, and nutrition;
   d. Following previous management system from the elders;
   e. Applying the model of selective cutting.
2) Creating a socio-ecology business model for sustainability of local agroforestry by strengthening Pentahelix collaboration and applying multifunctional ecosystem (Agro-ecotourism and community-based tourism) using ecosystem services.

3.3. Pentahelix stakeholer, multifunctional ecosystem, and business model

![Pentahelix collaboration model](image)

**Figure 5.** Pentahelix collaboration model for local agroforestry and rural development.

Pentahelix collaboration (Figure 5) was used for community services and industry [29], is an appropriate approach for rural development of the Mamar system. Each stakeholder plays an essential role that can creating a business model. The community consists of the landowners who kept their Mamar as a prestigious symbol of their family, religious and NGO's (non-government organizations) as a local institution in the community. These institutions empower people through training, preaching, and advising. From those institutions, there will be a transfer of knowledge to youth groups in the community. The government will influence development by making regulations for local agroforestry management and providing programs and aids for agriculture, forestry, and livestock. Academic educational institutions will play the role of improving the knowledge, skills, and attitude of their students and youth groups in the village through formal and informal education, training, research, and community service programs. The business community will help in creating agro-ecotourism businesses, holiday/tour packages, and community based-tourism. Finally, the media will promote these services across various media platforms to attract domestic and international tourist.
Changing the new paradigm from subsystem farming system becomes a multifunctional ecosystem. This new paradigm will change people's mindset to become an entrepreneur in ecology and agriculture. Previously only three main products could be sold. However, in this new paradigm, all types of ecosystem services will become a source of income, such as relaxation, education (research, field practice), and recreation besides uncountable services like water and air regulation, oxygen supply, and carbon sequestration; those are crucial for human life. Furthermore, creating a business model (Figure 6) of agro-ecotourism combined with community-based-tourism by involving local people, especially youth, and utilizing all kinds of ecosystem services will encourage them to be more active and creative maintain local agroforestry as a symbol of heritage.

Integrating horticulture into agroforestry areas at the outer layer will balance economic income for both seasons (wet and dry seasons). The inner layer will keep soil and water conservation and biodiversity of local trees. The horticulture area requires enough water that comes from wet Mamar. Therefore, horticulture will not be a competitor of the Mamar but complementary. Horticulture will help the farmers to earn higher incomes from production. Meanwhile Mamar will help all people to have a better environment and ecosystem through its services. Value chain analysis for the main products of the Mamar will help to develop the business model. Management of agroforestry cannot do one-handedly but shall think in an integrated multifunctional landscape. Eventually, rural development and a sustainable ecosystem of local agroforestry may be achieved.

4. Conclusion
Land use transformed from agroforestry to monoculture systems has changed its ecosystem services. The Monoculture system provides promising income but reduces the quality of soil, water, and carbon than local agroforestry. Youth as the new generation of the village would normally continue this local agroforestry that provides better ecosystem services, but they tend to leave. A strategic plan for rural development is balancing the system by integrated multi-farming system through combination multifunctional ecosystem and social involving become an alternative way for sustainable rural development program. Creating a business model involving Pentahelix stakeholder collaboration and applying a multifunctional ecosystem may increase income and rural community welfare and keep landscape, even global ecosystem, from climate change effect. Local agroforestry is a better agricultural practice for mitigation and adaptation of climate change.

Acknowledgments
The authors wish to thank the field assistance: head of the village, landowners of the Mamars, youth, and other colleagues. We also would like to thank the technical staff in the laboratory and financial support from DIPA Politani Kupang 2018-2019. Finally, I wish to thank for 2nd ICSP committee, which
held this conference and gave us a place to present our work.

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