Food and Agriculture Organization of the United Nations

World Agroforestry Centre

Agroforestry in rice-production landscapes in Southeast Asia
a practical manual

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This manual is intended to help rural advisory and agricultural extension workers guide farming communities in the establishment of agroforestry practices in rice-production landscapes in Southeast Asia. It sets out the steps to be taken to successfully integrate trees in rice-fields and associated farms and landscapes and presents practical tools that can be used by extensionists when supporting farmers who are implementing agroforestry practices on their farms.

The ultimate aim of this guide is to support farmers in increasing the overall productivity of their farms while increasing resilience to climate change, improving the health of the surrounding environment, and enhancing the livelihoods of their communities.

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Front cover: Mango trees in a rice field in Lao PDR © FAO/Prasit Wangpakapattanawong

Back cover: A farmer in her tree nursery, Viet Nam © FAO/World Agroforestry Centre

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Preface

In recent years, it has become widely accepted that overall productivity of agricultural systems cannot be measured only on the basis of crop yield but should also take into account the products and services delivered by the agroecosystem as a whole.

With this recognition, FAO designed the Regional Rice Initiative (RRI) for Asia[1] in 2013 to support countries in improving policies and strategies to promote sustainable management of rice agroecosystems. RRI, comprising regional and national components, developed pilot projects in Indonesia, Lao PDR and the Philippines. The Assessment of Trees Outside Forests in Asian Rice-production Landscapes[2] project was a pilot implemented under RRI. The project aimed to evaluate the extent of trees outside forests at selected sites in the three countries and to collect information on the uses and functions of trees in rice-production landscapes.

The results provided evidence that trees in rice-production landscapes can contribute to improving local socio-economic and environmental conditions. Planted or naturally regenerated trees found in homegardens, along roads and streams, in agroforestry systems, in small woodlands, along hedges and in fallows have proven to be excellent sources of goods and services to increase the socio-economic and environmental sustainability of agricultural landscapes. Trees on agricultural land can provide food and non-food products, support adaptation to climate change, increase biological diversity, regulate hydrological and nutrient cycles, protect the soil and improve nutrition and income. As a result, they can play an important role in mitigating and adapting to the multiple stressors that agricultural systems are currently facing and, consequently, in increasing food and nutrition security of rice-based farming communities. The project not only objectively demonstrated the benefits of trees outside forests in rice-production landscapes but also documented farmers' awareness of the value of tree resources.

This manual has been developed by FAO in collaboration with the World Agroforestry Centre to provide practical tools and guidelines for the implementation of agroforestry practices in rice-production landscapes in Southeast Asia. It builds on the findings of the Asian Rice-production Landscapes project and the FAO *Advancing Agroforestry on the Policy Agenda: A Guide for Decision-makers*[3] (released in 2013) and takes advantage of ICRAF's extensive experience with, and knowledge of, agroforestry practices. We hope that this manual will prove useful for promoting the integration of trees outside forests as part of sustainable management of these landscapes.

[1] FAO, 2015c
[2] FAO, 2014
[3] FAO, 2013

Acknowledgements

The authors extend our deep appreciation to the many thousands of farmers and government officers throughout Southeast Asia for their time and knowledge provided during the many projects, consultations and field visits over more than two decades and, most recently, conducted specifically for the making of this manual in Indonesia, Lao PDR, the Philippines and Thailand. In particular, for their help in organizing visits to rice-production landscapes with agroforestry, in Indonesia we thank Riyandoko, Elok Mulyoutami, Lia Dahlia and James M. Roshetko; in the Philippines, Agustin Mercado Jr; and in Lao PDR, Natjan Chairat and Vilaphorn Visounnarath.

The production of this manual has provided us with the opportunity to compile the knowledge and experience of many people over many decades not only in Southeast Asia but throughout the world. In this regard, in particular, we thank the researchers and communicators of the CGIAR Research Program on Forests, Trees and Agroforestry.

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Introduction: who should read this book and how to use it

This manual has been created for rural advisors and agricultural extension workers to help them guide farmers in the integration of trees into farms in rice-production landscapes, whether rainfed, irrigated, upland or lowland.

There is a growing interest from regional and local governments and others in agri-business development and environmental management to implement agroforestry practices as a means to strengthen farmers' resilience to climate change, as well as to fluctuations in market prices and crop yields. Trees provide benefits throughout the year and over many decades that help to spread both economic and environmental risks. We know that by integrating trees, farmers' food and nutrition security and incomes increase and this helps nations in the region achieve their agreed contributions and commitments to the *ASEAN Vision and Plan for Food, Agriculture and Forestry 2016–2025*[1].

The manual sets out the steps to follow to ensure success. While it covers many of the aspects of designing, planning and maintaining productive and resilient rice and agroforestry systems, it is still quite general because people have modified their practices over time using their own unique knowledge and skills in response to the particular conditions of the landscape. The wider social and political environment is likewise unique to each country and changes over time in response to internal and external influences. Accordingly, advisors will likely need to seek more detailed, specialist knowledge — from international, national and local agricultural, agroforestry and forestry experts and leading farmers — to apply it to the particular landscapes in which they work.

Rural advisors and agricultural extension workers using this manual have their own detailed knowledge of the landscapes and people in which they work. They should also consider themselves as facilitators who bring together all the people who have an interest in a particular landscape to share their knowledge, experience, hopes and concerns so as to achieve results. Even rice mono-cropping is a complex interplay of different people and physical elements; adding trees increases the complexity and the need to work together in different ways to optimize the synergies and minimize the interference between crops and trees.

The manual is organized into three sections. The first gives a background on agroforestry and on the benefits its integration into rice-production landscapes can provide to farmers. It also introduces the challenges facing rice production in Southeast Asia, particularly, those caused by climate change, and how trees can help reduce the risks faced by farmers and those who rely on them. The second section provides guidance on how to design, plan and manage trees and rice together towards integrated agroforestry landscapes. Necessarily, the section focuses on trees because we assume that this topic will be mostly new to advisors working in rice-production landscapes. The third section discusses the role of advisors and community facilitators and how they can best serve farmers to achieve mutual objectives towards integrated farming landscapes.

We recommend you read the entire manual from start to finish before setting out to integrate trees in your rice-production landscape. We also advise you to read the more detailed material suggested in the References and Further Reading section and to seek more knowledge from other organizations and leading farmers specialized in the various technologies and knowledge that are important for your particular landscape and people. Finally, we hope you will consider how your own personal knowledge and skills can be adapted to the challenge ahead and who else you will need to support you in your work. Landscapes face complex challenges and if we all share our particular personal assets together we can meet the challenges and optimize the benefits.

CHAPTER

01

Background to rice production and agroforestry in Southeast Asia

Prasit Wangpakapattanawong, Anantika Ratnamhin, Ingrid Öborn, Fergus Sinclair and Robert Finlayson

An agroforest bordering a rice field in Indonesia

CHAPTER 01

Background to rice production and agroforestry in Southeast Asia

Prasit Wangpakapattanawong, Anantika Ratnamhin, Ingrid Öborn, Fergus Sinclair and Robert Finlayson

1.1 Rice production globally and in Southeast Asia

More than 3.5 billion people[2] — around half the world's population — have rice as their staple food. In Asia, people often eat rice two or three times a day, obtaining 30 to 70% of their dietary energy from it[3]. In 2014, 31% of the global rice harvested (from about 48 million hectares) was from Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Thailand, Timor-Leste and Viet Nam[4] (Figs. 1 & 2).

But the production of rice is threatened by climate change, land degradation, water scarcity, and over-exploitation of natural resources. Combined, they put at risk the security of farmers' livelihoods and food supply in Southeast Asia. Temperatures are increasing, causing heat stress in rice. Sea levels are rising, leading to salinization of once-fertile, rice-growing river deltas. Extreme weather — such as storms, floods and droughts — is more frequent and severe and destroys rice crops or disrupts planting seasons[5].

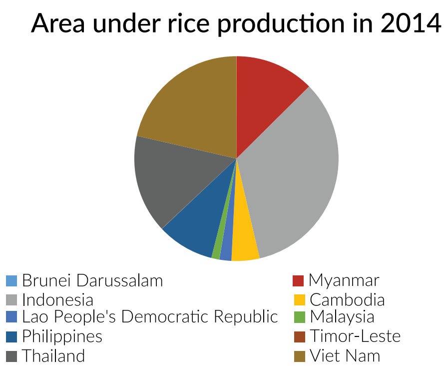

Figure 1. Area (hectares) under rice production in 2014

Source: FAOSTAT, 2016

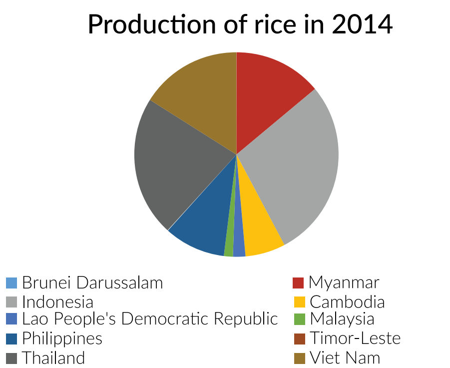

Figure 2. Production (tonnes) of rice in 2014

Source: FAOSTAT, 2016

1.2 Impacts of climate change on rice production

The International Food Policy Research Institute report, *Climate Change: Impact on Agriculture and Costs of Adaptation*[6], forecasts that by 2050 rice prices will increase between 32 and 37% as a result of climate change. The report also predicts that yield losses in rice could be between 10 and 15%[7]. A fall of up to 50% in yields by 2100 is predicted for Indonesia, the Philippines, Thailand and Viet Nam[8].

Fertilizer use is expected to increase to 134 million tonnes in 1997 to about 180 million tonnes by 2030[9]. The fertilizer markets will continue to be dominated by supplying wheat, rice and maize production.

Myanmar, Philippines, Viet Nam and Thailand (in descending order of impact) all featured in the global, *Long-term Climate Risk Index 1995–2014*[10]. These countries, and all of Southeast Asia, urgently need to adapt.

There are several major impacts of climate change that affect nearly all of Southeast Asia's rice growers[11,12].

1) Sea-level rise: river deltas and coasts are important rice-producing areas, feeding hundreds of millions of people in Southeast Asia alone. As sea levels rise, the gradients of shorelines will become steeper, resulting in degraded coastal land and flooding with sea water.

2) Reduced and erratic river flows: reduced rainfall or extreme variability owing to weather, hydropower dams and other water uses will alter river flows. Lessened river flow will combine with rising sea levels to make deltas and coasts more vulnerable to intrusion by salt water.

3) Salinity: higher sea levels and storm surges are causing inundation of coastal rice-growing areas with sea water. Rice cannot tolerate high salt concentrations: yields decrease when salinity increases.

4) Increased carbon dioxide and higher temperatures: higher levels of carbon dioxide in the air means plants can use it to increase their biomass — the major part of the plant — but not necessarily increase their yields. Rice produces less, or no, grain at higher temperatures; yields could

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Figure 3. Trees in a rice field in Lao PDR

be reduced by as much as 10% as a result of a rise in night-time temperatures by 1 °C.

5) Water scarcity: rice yields reduce by 17–40% during droughts. Climate change is predicted to increase the length and variability of droughts in rainfed rice-growing areas. Irrigated areas will also be affected if droughts are long and widespread and water sources are reduced.

6) Pests, diseases, weeds: climate change heavily influences pests and diseases. The intensity of some diseases (e.g. brown spot and blast) is increased by water shortages and irregular rainfall. More weed infestation and competition between rice and weeds are forecast to increase.

From all of this information, the conclusion is that supporting farmers to learn new skills and techniques is critically important in helping them adapt to climate change.

Integrating trees into rice-production landscapes has been shown to help reduce temperatures and improve infiltration of water into the soil, store more carbon and diversify farm production, which lowers both climate and market risks. This adds up to greater adaptability and resilience not only for individual farmers and communities but also their environments[13].

1.3 Rice-production systems in Southeast Asia

Rice, *Oryza sativa*, was domesticated from the wild grass, *Oryza rufipogon*, roughly 10,000–14,000 years ago. The two main subspecies of rice — indica (prevalent in tropical regions) and japonica (prevalent in the subtropical and temperate regions of East Asia) — are not believed to have been derived from independent domestication events. Another cultivated species, *O. glaberrima*, was domesticated much later in West Africa. Recent genetic evidence shows that all forms of Asian rice, both indica and japonica, come from a single domestication event that occurred 8200–13,500 years ago in the Pearl River Valley region of China[14].

Rice can grow in a wide range of environments (Fig. 4). Rice environments are classified based on altitude (upland or lowland) and water source (irrigated or rainfed). Rice is grown in diverse climatic zones in Southeast Asia.

Figure 4. Rice fields with trees within, and along borders, on Mindanao Island in the Philippines

Figure 5. Lowland rice landscape in Mindanao island in the Philippines

1.3.1 Rice in irrigated environments

About 75% of the world's rice production is from approximately 80 million hectares of irrigated lowland rice. About 45% of this is found largely in Indonesia, Viet Nam, the Philippines and Thailand[15]. Irrigated rice produces two or even three crops a year in humid areas. About 40% of the world's irrigation water and 30% of the world's developed freshwater resources are used for irrigated rice.

The environments of rainfed, lowland rice can be divided into (i) shallow, rainfed lowlands (field water depths fluctuate 0–0.3 m); and (ii) intermediate, rainfed lowlands (field water depths fluctuate 0.3–1.0 m).

Irrigated rice provides higher yields at an average of about 5.4 t/ha and can reach 8–10 t/ha or more with a single crop in temperate regions. In some areas, irrigated rice is also grown in rotation with other crops[16].

1.3.2 Rice in rainfed, lowland environments

Lowland rice is typically grown in river deltas and coasts. About 20% of the world's rice production is from around 60 million hectares of rainfed, lowland rice. Salinity, high uncertainty in timing, duration and intensity of rainfall are among stresses of this kind of rice environment. Fertilizers are rarely applied because of the uncertainty of harvest owing to unpredictability of rainfall. Farmers tend not to grow improved varieties. Yields can be as low as 1–2.5 t/ha[17].

1.3.3 Rice in rainfed, upland environments

Cambodia, Indonesia, Myanmar, Thailand and Viet Nam are important producers of upland rice, in extremely diverse ecosystems. For example, rice is grown in level, gently rolling or steep fields up to 2000 m in altitude with rainfall ranging 1000–4500 mm (Fig. 6). Rainfed rice in upland environments have low productivity in general, particularly at higher altitudes with steep slopes where productivity can be about 1 t/ha owing to many constraints, such as lower water- and nutrient-retention capacities of soils if their textures are coarse. Availability of water and nutrients can be reduced owing to movement of water downslope.

Figure 6. Trees with rainfed upland rice in Thailand

1.4 What is agroforestry?

Agroforestry can be defined as the inclusion of trees in farming systems and their management in rural landscapes to enhance productivity, profitability, diversity and ecosystem sustainability[18]. Put more simply, agroforestry is where trees and agriculture interact[19]. This may happen at field, farm or landscape scales, with trees occurring either as individuals, or in lines, clumps, blocks, woodlots or forests. Trees provide multiple functions and services not only for farmers but also for the environment in which they live. Agroforestry improves rural livelihoods by producing more products of higher value from trees, crops and livestock while conserving biodiversity and soil fertility[20].

There are long traditions of agroforestry in many parts of the world but it has only attracted the attention of scientists and emerged as a major part of international agricultural development since the 1970s. The word "agroforestry" in English is a combination of "agriculture" and "forestry" but there are many other names in many other languages, particularly, in Southeast Asia, such as *taungya* in Burmese, *tumpang sari* and *tembawang* in two Indonesian languages, and *nông lâm kết hợp* in Vietnamese.

Agriculture and forestry have been institutionally separated in most countries and only recently have there been attempts to bridge the gap and develop policies for agroforestry[21]. In nearly all countries, education, research, policy and action on agriculture and forestry were carried out distinct from each other, and in most countries this is still the case. Because of this historic separation between these two important land uses, agroforestry is increasingly seen as a bridge and a leader of innovation in both farming and forestry. This has mainly happened by introducing to forestry agriculture's stronger focus on humans and, at the same time, introducing forestry's greater emphasis on ecology to agriculture.

Within a single farm, trees or shrubs can be grown in hedgerows, on the boundaries of fields or in woodlots, or

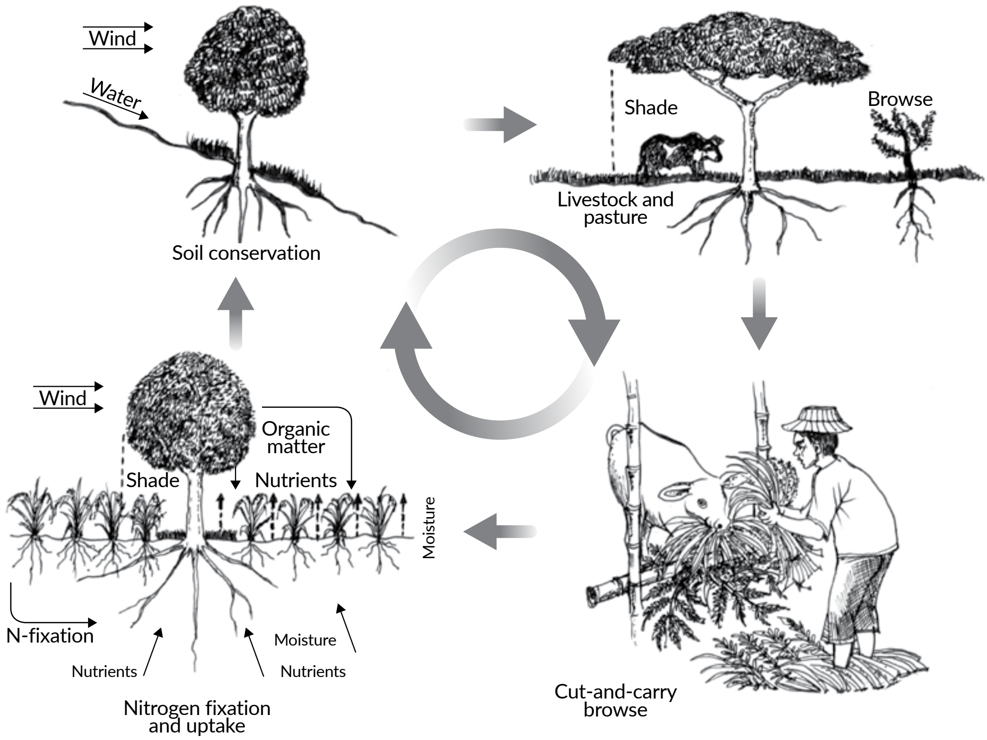


Figure 7. Nutrient cycling in agroforestry systems

Source: modified from Xu *et al.*, 2013

as single trees. Environmentally, these woodlands or individual trees provide shade for livestock, living places for predators of pests, such as birds and other insects, which reduces the need for pesticides, and recycles nutrients and organic matter for the soil that helps annual crops grow well and which not only reduces the need for fertilizers but also increase's the soil's water-holding capacity. Economically, trees provide sources of income other than those from annual crops and livestock and help make best use of land, labour and capital.

In a whole landscape, the trees and fields combined provide a range of functions that benefit entire communities: food and fuel; increasing infiltration of water into soil and generally improving the flow, and quality of, water; transferring nutrients across landscapes by livestock and preserving biodiversity that provides its own range of benefits, such as medicines and control of pests and diseases[22]; ensuring watersheds function well; and regulating micro- and meso-climates[23] (Tab. 1).

Table 1. Provisioning, regulating, supporting and cultural ecosystem services provided by trees

Type of service	Examples of ecosystem services
Provisioning (benefits from products provided by the ecosystem)	1. Food (e.g. fruit, nuts, leaves); 2. Fodder; 3. Fibres, wood, timber; 4. Fuel wood; 5. Bio-chemical matter (e.g. dyes, perfumes, medicines); 6. Gums; 7. Ornamental products
Regulating (benefits from the regulation of ecosystem processes)	1. Carbon sequestration and storage; 2. Erosion control; 3. Modifying micro-climates (e.g. through shade); 4. Water regulation (e.g. flood control) and water purification; 5. Wind breaks; 6. Biodiversity; 7. Connecting plant and animal habitats; 8. Bio-control of pests and diseases; 9. Pollinator habitats
Supporting (natural processes that maintain other ecosystem services)	1. Biological nitrogen fixation; 2. Nutrient cycling; 3. Photosynthesis; 4. Soil fertility; 5. Water cycling.
Cultural (non-material benefits obtained from ecosystems)	1. Ecotourism; 2. Visual beauty, scents and sounds; 3. Shade and meeting places; 4. Religious and customary significance.

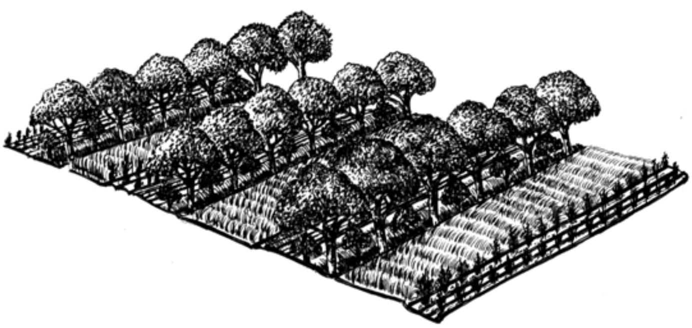
Note: The provisioning services are mainly produced on individual farms while regulating and supporting ecosystem services — such as soil and water conservation, improvement of water infiltration into soil, carbon sequestration and erosion control — become more obvious in a whole landscape. They are often produced by upland farmers and the benefits mainly enjoyed downstream. In this kind of situation, governments or businesses can consider rewarding upland farmers who grow trees that maintain healthy ecosystem services

Source: modified from Kuyah *et al*., 2016. See also FAO, 2016b

1.4.1 Types of agroforestry

There are many different agroforestry practices that farmers use to fulfil different functions. The most common way to classify agroforestry is according to use of the main components involved: the trees, crops or livestock. Different types of agroforestry practices may be integrated within a farming or livelihood systems. For example on the same farm, fodder shrub/tree hedgerows are grown along the contour lines of the slope with annual crops such as rice on the terraces, timber trees are planted on the field boundaries and trees and shrubs are growing on the grazing land.

Agroforestry can also be categorised into either simultaneous or sequential systems or practices[24]. In simultaneous agroforestry, trees and crops are grown at the same time. The arrangement of the components influences the types of interactions. Trees can be intermixed throughout the system, such as in homegardens, understorey crops, and silvopastoral systems. Trees can also be planted in zones partially separated from rice or livestock, such as in alley cropping[25] (Fig. 8). Different patterns for integration of trees on farms through agroforestry practices are illustrated in Figure 9.



Alley cropping is where trees and crops are grown together in a field (agrosilvoculture). Trees and crops are *spatially zoned*: trees grown in rows with crops in between, which allows use of machinery for tillage and harvesting

Source: modified from Xu *et al*., 2013

Figure 8. Alley cropping is one of the most familiar forms of agroforestry

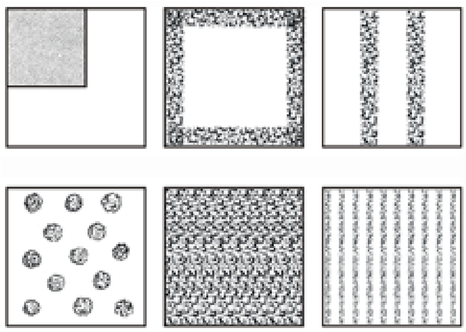


Figure 9. Different patterns for integration of trees on farms

Top from left: wood lot; boundary planting; windbreaks or hedgerows. Bottom from left: dispersed trees on fields or pasture (e.g. park lands); improved fallow (as part of rotation between years of crops); and alley cropping

Source: Xu *et al.*, 2013

In sequential agroforestry, trees and crops are shifted over time, where (i) the rice or other crops and the trees are planted at the same time but the crops phase out when the trees increase their shade levels, such as in the taungya system; and (ii) trees are used to replenish soils during the crop-free (fallow) period, such as in shifting cultivation.

1.4.2 Agroforestry in rice-production landscapes in Southeast Asia

Agricultural research and advisory services have often focused on inputs, management and performance of a main crop to increase rice yields. However, rice in Southeast Asia is part of a more complex livelihoods' system in which trees, other crops, livestock and other activities are all connected (Fig. 10). Farmers and other household members are not necessarily trying to maximize rice yields but to optimize their available resources (human, natural and financial), spread risks, achieve food and nutrition security and generate income.

Table 2. Classification of types of agroforestry

Agroforestry type	Examples
1. Trees and crops (agrosilvocultural)	1. ***Rotational***: trees and crops grown at different times in rotation or partially overlapped. The *taungya* system in Myanmar is one example where crops are grown together with young trees for the first few years. 2. ***Spatially mixed***: a. groups or individual trees growing amidst crops (trees in crop land); b. tall trees above shorter trees, shrubs and crops that are above ground-cover crops (shade trees, multi-storey planting, e.g., in plantations); mixed trees and crops in home gardens. 3. ***Spatially zoned***: a. trees grown in rows with crops in between (alley farming); b. trees grown along the borders of fields (boundary planting); c. trees grown as fences (protect crops from livestock and also used for fodder); trees grown on rice-field bunds and on terraces (protect soil from erosion and provide nutrients); d. trees as windbreaks and shelterbelts (protect crops and livestock and for fodder).
2. Trees and pasture (silvopastoral)	a. Trees and shrubs on grazing land; b. tree plantations, crops and pasture.
3. Trees and livestock (not pastoral)	a. Trees, crops and livestock on the same piece of land with either free grazing or enclosures for livestock, forming an integrated system of livestock and human food, manure and vegetable compost, building material and medicines; b. trees grown for fodder; c. trees for honey bees; d. trees with fisheries (in ponds or rice fields).
4. Forests, trees and people	a. Shifting cultivation of annual crops in forests with fallow periods in which trees grow back; b. cultivation of non-timber forest products with selective planting of suitable forest species.
5. Trees and perennial crops	a. Shade trees with perennial crops, such as coffee or cocoa; b. multi-storey tree plantations, such as coconut, rubber or timber trees with oil palm.

Source: modified from Sinclair, 1999

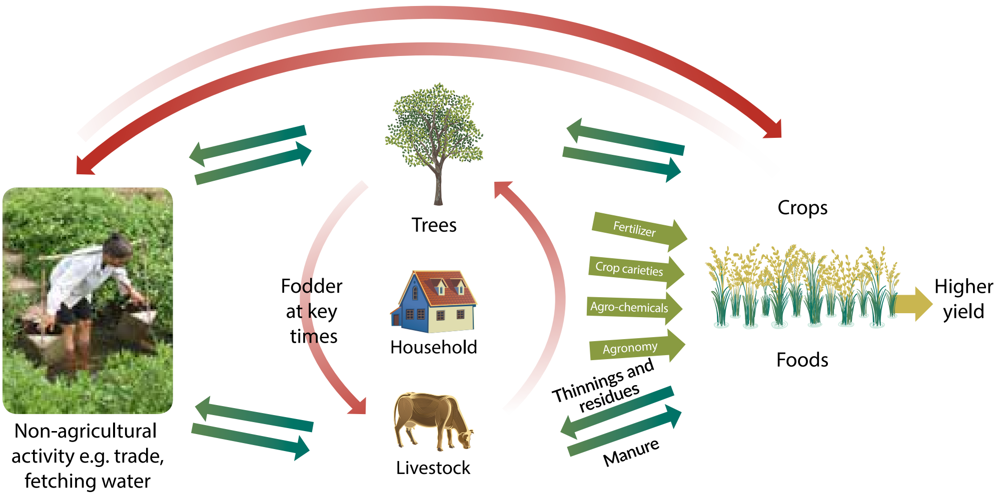


Figure 10. Rice, trees and crops working together to create diverse income sources for farmers

Source: modified from Sinclair, 2017

Farms that grow only rice are vulnerable to both climate and market shocks. Diversification through adding trees help spreads the risk. Trees are stronger and more resilient to storms, floods and droughts. They can continue to produce both food and income even immediately after a storm or flood that has destroyed a rice crop. Trees endure long droughts much better than even irrigated rice if the source of irrigation water is depleted. Farmers in Viet Nam, Indonesia, the Phillipines, Myanmar, Lao PDR, Thailand and other countries in Southeast Asia have been able to lessen these risks if they have a mix of trees and rice on their farms rather than just rice alone[26].

Consequently, the reasons for the existence of specific species of trees in, and surrounding, rice fields are both ecological and socioeconomic[27].

One ecological reason is the differing abilities of various species to survive the change of habitat involved when establishing the rice fields and subsequent cultivation. After rice fields are established, some of the forest tree species left on the floor of the field and on the bunds can survive the subsequent flooding regime of normal rice cultivation while others die out. Natural regeneration occurs on both field floors and bunds but new saplings on the floors usually cannot survive the annual flooding or else become ploughed under during cultivation. Trees surrounding rice fields are often remnant natural forests or specifically planted to provide benefits.

These latter are socioeconomic reasons for trees' existence: farmers' conscious decisions to retain or plant certain species for their economic or cultural benefits. Trees have been kept in rice fields because farmers realized that the benefits of maintaining them outweighed the disadvantages of not having them. They are retained for their potential uses and, less obviously, for their ability to improve soil fertility. Some farmers have been careful not to cut more native trees than necessary in the process of establishing their rice fields because they realized that trees fertilized the rice. It is important to note that planted trees are a long-term investment and there is usually a time lag between initial investment and return. Farmers with few resources have often needed help to bridge the time and income gaps. Loans, rewards-for-ecosystem-services schemes, subsidized inputs (seeds, seedlings, fertilizer, etc.) or help with designing integrated systems that provide both short- and medium-term returns while trees grow to maturity can help farmers be more secure investing in agroforestry.

Given the long-term nature of investment in trees, secure land tenure is a critical factor; many farmers hesitate to plant trees owing to the potential for conflict over ownership[28,29]. Clarifying rights to land and trees benefits both communities and government, reducing conflict and increasing social stability and incomes.

With increasing competition for land, agroforestry is increasingly used as an intensified buffer between agricultural and forest land so that farmers are able to obtain a diversity of products in a well-managed way that helps increase their incomes. This type of solution is becoming popular in areas with community-based forest management. Indigenous and other ethnic groups often informally manage the remaining forests throughout the region. Strengthening their rights over the land they already manage can help decrease deforestation and increase agroforestry practices.

In all parts of Southeast Asia, coordination between different government agencies and other organizations in various sectors is essential for agroforestry to be viable[30].

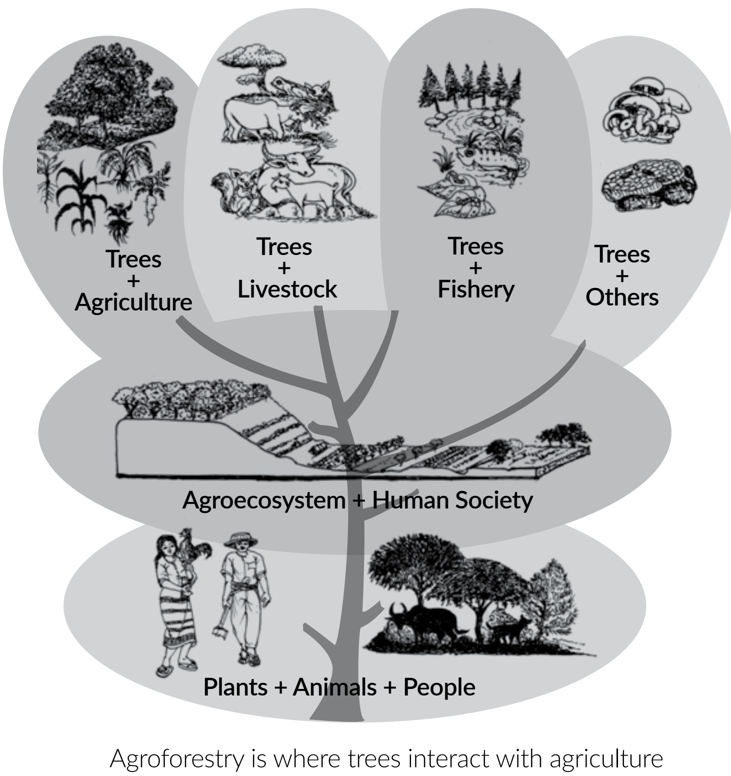


Figure 11. Agroforestry as an integrated, dynamic system

Source: modified from Xu *et al.*, 2013

The support of high-ranking government officials in agriculture, environment and forestry is often needed to create agroforestry landscapes. Agricultural agencies are focused on improving food production whereas forestry and environmental agencies want to increase tree and forest cover and ecosystem services. The gap between the agriculture and forestry sectors has to be bridged and all parties need to agree for agroforestry to be well developed in any particular area.

Agroforestry market chains are also critical for improving farmers' livelihoods yet in many parts of Southeast Asia are rudimentary and products face numerous obstacles from farm to consumer[31].

1.4.3 Benefits of agroforestry in rice-production landscapes

There are many benefits from integrating trees into rice-production landscapes.

Trees for food and medicine: trees provide many important sources of food in the form of fruit, nuts, berries, leaves, honey and fungi. Livestock often depend on fodder from trees. Although trees rarely provide most of a human diet, their role in food security is often critical. Wildlife and livestock in forests and agroforests provide important animal protein; fruit, leaves, nuts, roots and oils provided by trees are essential to many people's survival as seasonal, supplementary and emergency food. Trees are a source of vitamins and nutrients, and of herbs and spices that encourage the consumption of food.

Trees for wood fuel: trees in rice farms are increasingly used as a source of wood fuel because nearby forests, the former sources, have been converted to other purposes. Wood fuel is used primarily for cooking, charcoal production, and fires for warmth and to repel insects.

Trees for large and small timber: Large trees used for timber (beams, planks) are often hardwood species surviving from the original forest. But these have become very scarce and those still to be seen are of relatively small size. Many farmers who still own stands of such hardwood trees keep them for timber for their children in future years. Planted hardwoods are usually harvested when cash is needed for special events, such as education or weddings. Some farmers have advanced their management of planted trees to improve their quality in order to receive higher prices. ***Small timber:*** Trees are often planted to provide material for construction, tools and utensils. Fast-growing species that mature in 5-to-10 years are popular throughout Southeast Asia. Bamboo is also a fast-growing plant with multiple uses. Thorny bamboo makes excellent fencing and protection for ponds. Split bamboo has a variety of uses, is durable, and is easier to work with than wood.

Trees for fodder: Leaves, branches and other parts of a tree, such as pods and fruit, can be used as fodder. Livestock can feed either directly or be fed by the farmer.

Trees for income generation: Trees in rice landscapes provide many opportunities for farmers to generate income[32]. Gathering and processing tree products can be the main source of income or provide a supplementary income for people. The money earned in this way can be spent on food or invested in agricultural assets, such as livestock or seeds to secure future food supplies. Tree products often act as a buffer during periods of food shortage. Some people regularly gather products, such as wood fuel and rattan to store and sell when cash is needed for food. The value of food products can be increased by processing, for example, the sale of palm wine and oils is common in many parts of Southeast Asia.

Trees for conserving soil: On sloping land, trees can be grown along the contours as biological soil-conservation measures called "tree strips". The trees can be grown alone (effective only on gentle slopes of less than 8%) or with grass strips, which reduce run-off and erosion very effectively and which can be used as fodder. Tree spacing can be wider when planted along with grasses. Fruit trees can be used. On steeper slopes, trees of small sizes are suggested.

Trees for improving fallow: In both upland and lowland rice landscapes, a fallow period is often used to restore soil fertility through adding nitrogen and organic matter. If trees are used for this, it is called "sequential agroforestry". The tree should be a nitrogen-fixing species, have a relatively short lifespan and a relatively small root system, for example, *Sesbania* spp. and *Gliricidia sepium*. Simple and cheap propagation methods can be used to prepare planting stock. The trees can be planted as densely as possible to suppress weeds. If there are livestock in the area, they should be controlled (unless the trees are used as fodder). If the trees are thinned, the thinned material can be used as firewood. After the fallow period, some trees or shrubs can be left to supply propagation material for the future fallow period.

Trees as windbreaks: Some trees are more suitable than others for use as windbreaks, for example, *Acacia* spp., *Azadirachta indica*, *Parasianthes falcataria* (or *Albizia falcataria*), *Psidium guajava*, *Mangifera indica*. They can be planted along the borders of upland and lowland rice fields. They should be planted at a right angle to the prevailing wind. If the planting is designed well, the trees will not only reduce wind speed but also increase humidity and decrease loss of water from the soil.

Trees for fixing nitrogen, increasing nutrients and increasing soil stability: Trees enhance the chemical and physical properties of soils in numerous ways: (i) nitrogen input via biological nitrogen fixation; (ii) nutrient uptake by deep roots, which are then deposited as litter or biomass pruning. Root decay is also important for providing nutrients; (iii) the physical condition of soils can be improved by better aggregation (soil structure), reduced bulk density, and improved infiltration via tree organic matter input, old tree root channels, and increased macrofaunal activity; (iv) phosphorus availability can be enhanced via mycorrhizal associations; and activities of soil organism (e.g., fungi, arthropods, termites and worms) can be improved through a cooler and moister microclimate created by trees. Some trees are able to fix nitrogen from the air, providing a form of natural fertilizer when the roots, leaves or other residues decompose, releasing nitrogen into the soil. Others also provide nutrients from their litter. For example, grain and straw yields of rice have been shown to increase if small amounts of litter from *Pongamia pinnata* and *Azadirachta indica* were added to the crop under flooded conditions[33].

Trees for providing shade: Shade for livestock, people (e.g. farm workers) and crop diversification is important, especially as climates become hotter. Shade helps the soil retain moisture, which can be beneficial to rice grown during dry years and prevent desertification. With diversified crops, some might benefit from shade whereas others are sensitive to competition for light.

Trees for water regulation: Trees' deep roots improve water infiltration through the soil structure, with pores and cracks created by tree roots, earthworms and other soil animals.

Trees for bund consolidation and boundary demarcation: Trees can be grown widely spaced within rice fields or along either sides of bunds (these are also called "dikes". They are earthen constructions that separate paddy fields from each other and drier land) at wide, alternate spacing so as not to block access along the bunds. Species that are tall and slim with little shade and deep roots are likely to be preferred. Some trees are grown in many areas primarily for holding the bunds together, helping them retain their shape. In many areas of Northeastern Thailand, for example, "siaw" (*Phyllanthus polythyllus*) and "ket" (*Pandanus* spp.) hold the paddy bunds together. As soils in these areas are mostly sandy and weakly structured, they do not form long-lasting bunds without some reinforcement, such as from tree roots. Siaw is also useful for other purposes, particularly, wood fuel. Trees can be grown on the sides of rice fields in single or double rows or as boundaries to demarcate land ownership. The owners of the adjacent lands need to agree on species, spacing and management. Trees with short lifespans and trees that compete heavily for water, space and nutrients should be avoided. Adding fruit or other trees producing non-timber products will provide food, medicines and more frequent income than planting only timber trees.

Trees and straw stacks: In many rice fields, rice straw is placed in trees after threshing to be stored in the field rather than taken home. Storing the straw in trees saves both labour and wood that would be used to build a raised platform or a fence around a mound or threshing floor. This practice is particularly helpful when communal grazing is allowed, as any straw to be saved must be removed from the reach of livestock so as to provide cattle feed at a later day.

Trees as habitats: Trees in rice farms provide habitats or partial habitats for a variety of wildlife, both useful and pest species. According to many farmers, insects living in trees are not harmful to rice. Trees serve as habitats for various creatures, including insects, birds, rats, frogs and snakes. Some of these animals are used as food for humans although some are pests.

Trees for carbon storage and climate resilience: Agroforestry is better than single species at capturing and using nutrients, light and water. Agroforestry can buffer climate variability by providing permanent tree cover and a variety of ecological niches. Diversified agroforests can speed recovery after extreme weather events[34]. Climate-change mitigation include above- and belowground carbon sequestration. Crops with trees and animals integrated in agroforests can increase adaptation and mitigation. Sequential agroforestry can increase the synergy between adaptation and mitigation.

1.4.4 Some disadvantages of agroforestry in rice-production landscapes

Despite the many benefits, care must be taken when integrating trees with rice because of potential (i) competition for light, nutrients and water; (ii) hosting plant diseases and pests (as well as their natural enemies)[35]; and (iii) low compatibility with mechanization of rice production.

(i) ***Competition for light, nutrients, and water:*** Agroforestry systems need to be carefully designed so that use of light, nutrients and water is not at the expense of crop growth owing to competition. There are some potential negative effects owing to shade on rice (Tab. A1 in Appendix) and risks of hosting pests and diseases in certain tree species[36]. Owing to light competition, rice under the shade of trees can use less nutrients than normal. The effect can be seen up to 5 m from some non-nitrogen-fixing trees, for example, *Eucalyptus* hybrids. Tree roots can also compete with rice for nutrients and water. Successful agroforestry systems should have trees that use the water that would otherwise be lost from the rice field by evaporation, run-off and drainage. Trees can, nevertheless, use underground water inaccessible by rice with its shallow root system. This also applies to competition over nutrients insomuch as aboveground competition can be minimized by pruning the trees (Fig. 12). The pruning, in turn, can be beneficial to both the rice and the trees as the pruned residues of some species can be used as fodder and organic fertilizer.

Prevention and management:

(a) Trees should be planted in line with the direction of the sun's path to minimize shading.

(b) Trees should be pruned to maximize light and capture rain-water for the rice.

(c) Some fruit tree species — e.g., guava and lemon — allow enough light to reach the rice and should be prioritized for planting.

(ii) ***Diseases and pests***: Diseases and pests are more of a concern in simultaneous agroforestry systems than in sequential system because crops and trees in the same fields provide alternating hosts (of diseases and pests) and non-host plants because different trees host different diseases and pests. Providing short sequences of rotation reduces the likelihood of severe, chronic infestations. Sequential systems can be a good controlling tool in improved fallow[37] systems. (Tabs. A2 and A3 in Appendix).

(iii) ***Mechanization of rice production***: Mechanization reduces the practicality of scattered planting of trees through rice fields because they interfere with the efficiencies of the machinery. Farmers therefore might better plant trees alongside the bunds.

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Figure 12. Tree pruning for fodder and firewood and to reduce negative shading effect

Box 1. *Nypa fruticans* and rice in Central Philippines

Nipa palms (*Nypa fruticans*) growing on the coast help to shelter rice grown in the hinterland, providing an ecosystem service while also providing feed for livestock, such as fodder leaves or the sugary sap that is suitable for pigs and ducks.

The system has been developed near Legazpi, Bicol, Philippines. Planted originally by the Government in 1988 and now managed by the Energy Development Corporation, it has provided shelter in one of the worst typhoon zones in the world, enabling rice farmers to cultivate the land inland from it. At the same time, it has enhanced biodiversity and created livelihoods for farmers, who harvest mud crabs among the palms. Leaves of *Nypa fruticans* are cut and used for roofing but a potentially more profitable use is to tap the sugar-rich sap, which is produced in abundance: two or more times the yield/ha/yr of sugarcane. Palms tapped for sugar have been shown to provide an excellent alternative to maize for livestock feed, especially for ducks and pigs because they thrive on liquid-based diets. Their manure can be combined with rice straw to make biogas and rice fertilizer, adding to integration and increasing the benefits for rice production.

Source: Cano *et al*., 2016; Nguyen *et al*., 2016; Rasco, 2011; Trivino *et al*., 2016

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Figure 13. Nipa palm, *Nypa fruticans*

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Figure 14. Borders of rice fields can be narrowed or widened depending on tree species

Notes to Chapter 1

[1] ASEAN, 2016; FAO, 2015a,b

[2] Ricepedia, 2017

[3] IRRI, 2016

[4] FAOSTAT, 2016

[5] Ricepedia, 2017

[6] Nelson *et al*., 2009

[7] Nelson *et al*., 2009

[8] ADB, 2009

[9] FAO, 2010

[10] Kreft *et al*., 2015

[11] IPCC, 2014

[12] Ricepedia, 2017

[13] FAO, 2016e; Nguyen, *et al*., 2013; Öborn *et al*., 2015; Van Noordwijk *et al*., 2014

[14] Ricepedia, 2017

[15] Mutert & Fairhurst, 2002

[16] Ricepedia, 2017

[17] Ricepedia, 2017

[18] World Agroforestry Centre, 2013

[19] Sinclair, 2004; FAO, 2016a; Nair, 1993

[20] Nguyen *et al*., 2013; Rajashekhara Rao & Siddaramappa, 2008; Sae-Lee *et al*., 1992; Baggie *et al*., 2000

[21] Van Noordwijk & Lasco, 2016

[22] Pumariño *et al*., 2014; MacLean *et al*., 2003

[23] Ellison *et al*., 2017; van Noordwijk, 2014; Minang *et al*., 2015

[24] Sinclair, 1999

[25] Danso & Morgan, 2008

[26] Nguyen *et al*., 2013

[27] Grandstaff *et al*., 1986

[28] Raintree, 1985

[29] Galudra *et al*., 2013

[30] Van Noordwijk & Lasco, 2016

[31] Perdana *et al*., 2013

[32] FAO, 1992

[33] Budhar *et al*., 1991

[34] Simelton & Dam, 2015

[35] Rajashekhara Rao & Siddaramappa, 2008

[36] Schroth *et al*., 2000

[37] Schroth *et al*., 2000. “Improved fallow” in this case means planting trees that will add nutrients to the soil.

CHAPTER 02

Planning, designing, developing and managing agroforestry systems in rice-production landscapes in Southeast Asia

Prasit Wangpakapattanawong, Anantika Ratnamhin, Ingrid Öborn, James M. Roshetko, Craig Jamieson, Aulia Perdana, Elok Mulyoutami, Janudianto, Robert Finlayson, Elisabeth Simelton, Gerhard Sabastian and Agustin Mercado Jr.

Alley-cropping rice in Indonesia

CHAPTER 02

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There are many different ways to establish trees in rice-production landscapes in order to create integrated agroforestry landscapes. However, agroforestry practitioners, advisors, extensionists and researchers around the world have now agreed on more or less the same general approach, which is summarised below and then explained in more detail.

2.1 Getting started: first steps

Before setting up an agroforestry intervention, it is worth considering several principles that have been developed from our experience working with farmers, rural advisors and agricultural extension workers, governments, businesses and non-governmental organizations and which are best followed to ensure success.

2.1.1 Principles for success

(i) ***Think big***: see the landscape as a whole with its biophysical (topography, climate, land uses, vegetation cover, soil types) and socio-economic (villages, farmers' organizations, businesses, markets, government and other institutions) as components and actors. This is because even though it might seem that it is made up of several distinct elements, they all work together so that altering one part will have an impact on another. Think big over time, too. Trees take longer to grow and are big investments for most farmers. Thinking ahead some years or even a few decades will help you keep things in perspective.

(ii) ***Embrace everyone:*** see yourself as a facilitator and include in discussions about planning, design and management everyone with an interest in the landscape — female and male farmers, different ethnic groups, government agencies, traders, businesses — because you are working in an integrated system in which everyone plays a role. Each person will need to understand why changes need to be made, what impact they might have, what to prepare, what to do and when, and how to benefit before they will commit to making it work. This is particularly important in landscapes dominated by rice production because introducing new elements might create uncertainty amongst people in an already delicately balanced environment. Full and open discussions with all the people who rely on the landscape will help them understand the challenges and benefits of introducing trees.

(iii) ***Use local knowledge and wisdom***: respect the importance of local knowledge about the environment, farming practices and cultural traditions that have been developed over time. Learn with farmers and others who live and work in the landscape how to best achieve mutually agreed goals.

(iv) ***Make it new***: create knowledge with farmers and others through testing new ways of managing the landscape from individual farms through to the whole area so that everyone benefits now and in the future.

(v) ***Share***: spread what you have learned to other people in other places. This will strengthen not only your own knowledge but the whole nation's ability to enhance the income (including the stability of income) of farmers, make their farms and farming landscapes more resilient and help them better adapt to climate change.[1]

2.1.2 Forming groups

Small farms are complex systems in which farmers have to manage many different activities for both subsistence and income. Their decisions are usually rational in the context of their own agroclimatic and socioeconomic conditions and the risks with which they have to operate.

Not surprisingly, farmers often think differently about proposed innovations, such as agroforestry, than people who don't have the same experience or face the same risks.

Consequently, a thorough understanding of the underlying social, political and cultural contexts is necessary for success. The best way of learning about the unique experience and knowledge of a farmer on their farm is by creating a partnership with them. Partnerships are often best made through "rice and agroforestry" groups made up of advisors, farmers, policy makers, researchers, non-governmental organizations, businesses and anyone else with an interest.

Many such groups might already exist in your landscape but might have only a single focus, such as increasing rice yields. Given that introducing trees can add new ways of working, new people and new skills and knowledge, creating agroforestry and rice groups is the basis of a commitment to more structural and long-term engagement that will ensure success.

An important objective of such groups is to support continuous involvement in dealing with the complexity of trees in rice landscapes and in exploring, implementing and monitoring progress. Rice and agroforestry groups produce knowledge about the biophysical, technological and institutional dimensions of their particular landscape and come up with ideas about the types of trees and integrated systems that are economically, socially, culturally and politically the best for their situation.

As time goes on and they learn from each other and from other groups with whom they interact as part of the learning process, they also become aware of their fundamental interdependencies and the need for collaborative action to address their problems and achieve their goals.

Advisors are probably already working with a number of groups. If so, they could either introduce new members – such as staff from other government advisory agencies like forestry, natural resource management or agriculture; business people dealing with agricultural products; people from NGOs who have a special interest in governance, agriculture, forestry, markets or other special topics; staff from universities or research institutes who have expert knowledge of particular trees or systems – to deal with the greater complexities and to ensure a comprehensive understanding of the challenge and opportunities. Or new groups could be formed if none existed or were constituted in such a way that introducing new concepts, activities and people was not possible.

Usually, establishing rice and agroforestry groups will take time: it is typically not a quick or even easy process but it is the most critical and worth the effort in the long term. Advisors will likely have to visit their farming communities several times to discuss with the heads and members of villages and existing farming or community groups the reasons why they want to work together and what they hope to achieve. Advisors will need to perhaps also make new connections with staff in other government agencies and to business people and introduce them to the concept and to the groups most relevant to their area and interest. Most importantly, advisors will need a mandate from the head of their agency and other decision makers. Advisors would be wise to allow several months for this process.

2.1.3 Assessing the situation

Together with the agroforestry and rice groups, advisors need to create a common understanding about the present situation and overall landscape, both the biophysical landscape context and the institutional one.

Agroforestry usually takes more work, time and expertise to establish than monocultural crops. So, it's important to estimate the costs and benefits for farmers.

The first thing to do is to find out where agroforestry already exists, what are the markets for the products and what are the priorities of the farmers and others[2]. There are several steps involved in this.

(i) Build an effective team among the different groups and agencies involved and agree on the priority-setting approach and the interventions that might be needed for the specific landscape.

(ii) Assess farmers' needs. It's important that everyone agrees which farmers are to be involved, what they need and what are their aspirations for the future. It is critical to have the participation of the local community in what criteria should be used for involving different farmers[3].

(iii) Make an inventory of all the tree species that are being used by the farmers already. This inventory is the base from which the priority species will be selected. Indigenous and exotic species that are currently not used in the landscape but that might have potential can be added to the list.

(iv) Similar to the tree species' inventory, ask farmers to identify the types of systems using trees that already exist and those in which they are interested[4]. Almost all farming communities in Southeast Asia have traditional agroforestry systems. Adopt the local terms and definition for those systems.

(v) Define the most important products provided by the trees already. Only those species producing the products of greatest importance to farmers, which are in demand by the market and for which farmers have the right to grow, harvest and sell should be considered priorities.[5]

(vi) Select a limited number, e.g., four-to-six, tree species that have the highest expected benefits[6].

(vii) Estimate the value of production for these key species through a survey of farmers and others in the product's value chain. This step provides the quantitative information needed to set priorities among the remaining species. Synthesize previous results, to review the process and to approve the choice of the priority species.

A survey should be conducted of households, farmers' and community groups, village leaders, local governments, and government agencies, such as agriculture, forestry and planning. As many people should be included in the survey as time and budgets allow, especially those who are often unheard, such as women and minority groups, because each often has different experience and knowledge of management of natural resources. The information can be gathered by travelling through the area and noting what is seen, through using questionnaires[7] and discussions with groups and individuals and through techniques used in participatory rural appraisals, such as a transect walk, land-use and land-use change mapping and identifying preferred agroforestry species. Current management practices can also be discussed and assessed by matrix scoring. Below we provide an outline of several successful methods for gathering information that we have modified for this manual. The process is discussed in detail in the Appendix.

2.1.4 Participatory Landscape Appraisal

A Participatory Landscape Appraisal (PaLA)[8] can be used to understand the issues in the landscape, such as changes in water flows brought about by dams, rising sea levels, floods and droughts; soil erosion; pollution from pesticides and fertilizers; pests and diseases; and also which trees and crops are already grown where and what challenges and opportunities they present.

PaLA complements Rapid Rural Appraisal and Participatory Rural Appraisal[9] methods applied at household, farm and field level and combine with agroecological analysis to capture local knowledge. PaLA and related methods can be used to inform more detailed, subsequent analyses of specific issues.

We offer more detailed guidelines of how to use a set of participatory appraisal methods and tools, within the context of PaLA, in the Appendix. From them, choose those which most suit the situation and need.

2.1.5 Farmers' demonstration trial workshops

Farmers' demonstration trials[10] are explained in detail below but as part of the planning and design process a workshop can be conducted as part of the PaLA or a separate workshop conducted with leading farmers who have expressed interest in taking part in trials. The workshop is usually held in a village where there are a number of leading farmers or with one leading farmer in a village that is easier for others to visit.

The purpose of the workshop is to, first, confirm farmers' interest then build partnerships and develop work plans.

Start the workshop by reviewing the farmers' interest in trees on their rice farms and the concept of demonstration trials. A short review might be enough but be prepared to discuss the trials in detail. To makes things easier, invite other specialists (a forester or horticulturist, for example) to complement your skills during the workshop.

A visit during the workshop to a farmer who has already successfully grown trees — whether timber, fruit or mixed — on their rice farm helps inspire the others and builds their knowledge and confidence. Contact the farmer before the visit and ask them to explain their system. Advisors should point out key aspects of the agroforestry that are relevant to farmers. Farmers always benefit greatly from these visits.

2.1.6 Developing objectives

There are often many objectives that a government hopes to achieve through agroforestry, such as increasing carbon storage to help meet national targets, increasing food production to feed the growing population and to meet export goals; providing new income-generating opportunities for rural people, including marginalized and poor groups, and reducing poverty throughout the community; increasing production of bioenergy; improving the health of soils to ensure sustainability and reduce the use of fertilizers and pesticides; diversifying production to spread the risks of variations in markets and extremes of weather; and buffering natural forests to protect biodiversity and promote eco-tourism.[11]

Farmers will share some of these objectives but not all. If the focus is on diversifying rice farms so that farmers will not be totally reliant on one crop in case of drought, increasing salinization or fluctuating prices, the design of the agroforestry intervention will likely be different than if the only objective is to increase carbon storage, with co-benefits for farmers, to help meet government targets for reducing carbon emissions nationally.

Many different objectives might be applicable to any rice-production landscape, whether rainfed or irrigated, upland or lowland. To set strong and widely understood objectives for integrating trees into rice-production landscapes, advisors need to not only understand their own initial objectives but also discuss them with individual farmers and farmers' groups, other government agencies, businesses, non-governmental organizations, research institutes and other people with an interest in the landscape. Through discussion, advisors' objectives will be understood by others and will probably be modified as more information is gathered. All the possible consequences — ecological, socioeconomic and political — of trees in a rice-production landscape should be discussed and understood so that the reasons for promoting agroforestry are supported by those who will invest their time and money.

Farmers will want to know why they are being encouraged to adopt or expand agroforestry systems and practices. They will need to assess the costs and benefits of doing so. If the objectives are understood in depth, they can be

Box 2. Objectives can change with new priorities provided by farmers

Agroforestry in dryland Indonesia

On the island of Sumba in Indonesia, farmers face nine months without rain, no readily available groundwater for irrigation and rocky terrain with little soil. Much of the year they rely on food support from the government. A project introduced timber trees to produce income but many failed owing to poor management decisions about location and maintenance of the plantations. Discussions with the farmers revealed a greater interest in producing subsistence food crops for their immediate needs. Accordingly, the project adjusted its objectives and introduced agroforestry practices that integrated fruit and nut trees with maize, livestock and vegetables while at the same time increasing technical support for tree, crop and water management. The new practices were successfully established, adapted to each farmers' particular situation, despite the harsh conditions.

Left: Poorly located and maintained timber plantation. **Right:** Intercropping maize in a farmer's homegarden.

Source: World Agroforestry Centre, 2016d

explained well and advisors will be able to learn from the information gathered and modify their objectives if necessary, be easier to plan, design and implement and more likely to succeed.

2.1.7 Market and value-chain surveys and analyses

Small-scale farmers generally have weak market links and poor access to market information. Tree farming can be more profitable than rice but uncertain marketing conditions deter farmers. The existence of accessible markets for tree products is a vital criterion when planning for agroforestry in rice-production landscapes.

In summary, the following factors seem to have strong bearing on the successful development of market-oriented agroforestry: (i) secure land tenure; (ii) supportive government policies; (iii) access to, and knowledge of, the management of quality seeds and seedlings; (iv) tree management skills and information; and (v) adequate market information and links. The first two factors — land tenure and policy support — are basic enabling conditions. Developing supportive tenure and policy often requires a lot of negotiations involving local, regional and national governments as well as the private sector, community organizations and farmers' groups. A central part of such negotiations is determining just what environmental services — such as plentiful and clean water, soil fertility, air quality, landscape beauty and watershed protection — require careful regulation so that the land is not degraded further but, preferably, enhanced. Successful negotiations lead to consensus land management agreements and natural resource security for local farmers. The other three factors — quality seeds and seedlings, tree management and market links — are technical issues that can be effectively addressed at the local level by government advisory agencies, non-governmental organizations, farmers' organizations and/or individual farmers. These issues are discussed in detail below.

Value chains

Traders are the link between farmers, sawmills and manufacturers (Fig. 15). Each has an important role to play in transforming trees. A farmer is a producer. Their involvement ends after selling tree products to traders, who often also do the harvesting. The timber value chain is relatively simple[12,13].

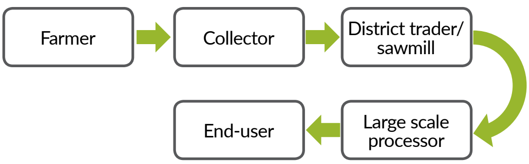

Figure 15. Example value chain for timber

For non-timber products, the value chain might not be as straightforward as for timber[14]: it could include more levels of traders because the product might be processed several times (Fig. 16). The spice value chain, for example, often involves sorting, drying, peeling, deshelling, washing, drying again, crushing or other type of processing and then packaging and sale. Rules, costs, marketing margins, and profits are embedded in each of these stages as value is added to the product.

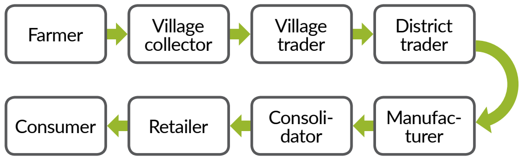

Figure 16. Example value chain for non-timber products

Non-timber products often make substantial contributions to both local and national economies[15]. This can be a powerful incentive to maintain both agroforests and natural forests.

Rural advisors can help farmers by categorizing together the things considered to be non-timber products, for example, leaves, bark, branches, flowers, fruits, seeds, saps and resins.

Most non-timber products are seasonal, so a seasonal calendar could be created that shows planting and harvest times. Including other factors, such as weather and busy farming periods, helps farmers to prepare equipment, labour and capital. A simple map showing locations of non-timber products helps farmers visualise the environment and estimate transport costs. Advisors can also assist with finding markets.

Market surveys

Market surveys are the first step in understanding existing and future demand for agroforestry products. We recommend using a rapid survey to identify and understand (i) the agroforestry species and products that hold potential for farmers (their specifications, quantities, seasonality, etc.); (ii) the market channels that are used and which hold commercial potential; (iii) the marketing problems faced by farmers and market agents; (iv) the opportunities to improve the quantity and quality of farmers' agroforestry products; and (v) market integration (through vertical price correlation and price transmission elasticity) and efficiency[16].

Figure 17. Agroforestry products on display, Mekong Delta, Viet Nam

We recommend you start with informal visits to make observations and hold discussions with farmers and others, such as other government agencies and businesses, particularly, market agents. The information from these visits and from internet and media searches is used to customize the market survey.

The survey is then conducted with farmers, market agents and other key people. The information provided by each respondent is followed through the market chain to the end consumer until information concerning the market channel is complete. The information gathered is cross-checked with direct observation and more informal discussions with respondents and different groups. The cross-checking continues until the information gathered is clear and consistent, with no new information being found.

A draft summary of the information is then shared with everyone in a formal meeting or workshop. This provides an opportunity for additional cross-checking. Any inconsistencies or gaps in the information are identified and addressed through further field investigation.

Once any remaining questions are answered a summary of farmers' marketing conditions and priorities (priority species, marketing channels and agents, farmers' market roles, marketing problems and opportunities) is finalized. At this point, work plans are developed to identify and agree on actions that farmers, market agents and others can take to improve the production and marketing of products.

2.1.8 Seeds and seedlings survey

The availability of good sources of seeds and seedlings is essential for successful agroforestry (Tab. 3). Often, seed quality is not considered when agroforestry systems are established; this can have long-term effects through marginal yields, susceptibility to diseases, or lower-quality products.

Seed sources can be established in several different ways, depending on the biological characteristics of the species and the origin of the available seeds and seedlings. The seed source is the first link in the seed production and distribution chain and greatly determines the operation of the seed system, its genetic quality and how that quality is maintained.

It's worth noting that the genetic quality of seed is determined by the quality of the seed source and the way the seed is collected (the number and relative quality of the trees from which the seed is sourced). Subsequent collection and handling (seed processing, storage and distribution) influences physiological and physical quality of the seed. Testing seed in a laboratory for its ability to germinate only measures physiological and physical (whether it is healthy or not) not genetic quality (the characteristics inherited from its parents).

We recommend conducting a rapid assessment of the local area to determine the availability of tree seeds or seedlings and existing markets for tree products (if no markets exist, creating them can take a long time and a lot of money).

Those trees that farmers have prioritized for which seeds and seedlings are available, and for which there are already strong markets for their products, are likely to be the best species on which agroforestry systems and demonstration trials should focus.

An evaluation should be made of tree nurseries, tree seed dealers, and other seed sources, such as trees that have been used as "mother" trees by farmers. Whether seedlings should be grown or bought depends on whether there are already village tree nurseries or local commercial nurseries and the time remaining before the planting season.

2.2 Designing agroforestry systems

Agroforestry in rice-production landscapes includes specific tree or shrub species and/or animals (e.g., cattle, goats, chickens, fish). If one of the objectives of establishing agroforestry is to increase food production, then trees with fruit, nuts or leaves for farmers' own consumption (as well as for livestock feed to produce food from the livestock) and/or sale can be used. If grazing animals are to be included, interactions with other components have to be considered. For example, will livestock damage young trees and will fencing be needed? what fencing material — rocks, bamboo or trees such as *Gliricidia* — is available and what labour and capital would be needed to build or plant fences? can manure be used for compost and what skills and labour would be needed to do so? can leaves, grasses and other plants be included in the system as livestock feed? are there local tree species that can be used with fish ponds to provide feed for fish and livestock and/or shade for livestock as well as other benefits, such as timber or fruit?[17]

Table 3. Sources of seeds and seedlings

Source	Description
Natural forest	Trees naturally regenerated in secondary or primary forests; these areas might be far from communities
Farmland	Trees on farms: planted or remnants of natural forests
Plantation	Trees planted in a plantation or woodlot
Seed orchards	Trees planted in a plantation or woodlot, specifically for seed production
Vegetative propagation	Grafts, stem cuttings, micro-cuttings and other plant material propagated with selected seedlings

Source: Forest and Landscape Denmark, 1983; Jaenicke, 1999; Longman, 1993a–d

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Figure 18. Farmers in Viet Nam discussing a design of agroforestry

The design of the agroforestry system must be related to the individual farmer and community's interests and livelihoods' system, types of land use (depending on biophysical features such as slope, soil type and water availability), and particular farming or cultural practices.

Other critical aspects are spatial and temporal arrangements of components to minimize competition for land, sunlight, water and nutrients between the trees and the rice.

Spatial considerations are the distances from tree rows to the rice and among trees, planted on rice bunds, in the rows. Temporal considerations are length of tree rotations, in the case of sequential agroforestry.

Rice fields are generally aggregated and occupy large (up to tens of hectares in mountainous areas) to very large areas (up to hundreds of hectares on large plains). Table 4 gives some general options for integrating trees in rice-production landscapes.

Table 4. Potential trees for rice-production landscapes in Southeast Asia

Tree species	Human food	Fodder	Timber	Fuel	Tolerant of water-logging	Nitrogen-fixing	Comments
Acacia auriculiformis (Australian wattle)		YES (Only certain livestock)		YES	YES	YES	Often used as pulpwood
Acacia mangium (Brown salwood)	YES (honey)	YES	YES	YES		YES	The pulp is easily bleached to high brightness levels, making it excellent for paper.
Albizia species		YES	YES	YES		YES	Shade
Alstonia scholaris (Devil tree)	YES (seasoning and beverage)		YES	YES			Wood for making pencils

Tree species	Human food	Fodder	Timber	Fuel	Tolerant of water-logging	Nitrogen-fixing	Comments
Altingia excels	YES (leaves raw or cooked)		YES	YES			
Annona muricata (Soursop)	YES						Fruit
Anthocephalus cadamba (Common burflower)	YES (fruit and inflorescences are edible)	YES	YES				
Artocarpus heterophyllus (Jackfruit)	YES	YES					Fruit
Azadirachta indica (Neem)	YES	YES					Vegetable, medicine, pesticide
Cajans cajan	YES	YES				YES	
Calliandra calothyrsus (Calliandra)	YES (honey)	YES (also nectar for bees)		YES		YES	Shade
Coffea species (Coffee)	YES	YES		YES			Rice has been successfully grown as a cover crop with young coffee, cocoa, citrus and rubber
Dalbergia latifolia (Rosewood)			YES	YES		YES	
Dalbergia sissoo	YES (honey)	YES (also nectar for bees)	YES	YES	Some	YES	
Durio zibethinus (Durian)	YES			YES			Fruit
Eucalyptus species			YES	YES			
Flemingia macrophylla		YES				YES	Green manure
Garcinia mangostana (Mangosteen)	YES						Fruit
Gliricidia sepium (Gliricidia)	YES (flowers as a vegetable and garnish)	YES	YES	YES	YES	YES	
Gmelina arborea (Gmelina, white teak)	YES (honey)	YES	YES	YES			
Gnetum gnemon (Gnetum)	YES	YES	YES			YES	
Leucaena leucocephala	YES	YES	YES	YES	YES	YES	Living fence. Can be invasive
Maesopsis eminii (Umbrella)	YES	YES	YES	YES			Shade
Mangifera indica (Mango)	YES	YES		YES			Fruit

Tree species	Human food	Fodder	Timber	Fuel	Tolerant of water-logging	Nitrogen-fixing	Comments
Morinda citrifolia (Noni)	YES			YES			Medicine and can grow on rocky, infertile soils
Moringa oleifera (Moringa)	YES	YES		YES			“Green” fertilizer and as medicine
Myristica fragrans (Nutmeg)	YES						Spice
Nephelium lappaceum (Rambutan)	YES						Fruit
Nipa fruticans (Nipa palm)	YES	YES		YES	YES		Alcohol and bio-ethanol for biofuel. Juice supplement for ducks in rice, duck and azolla systems.
Paraserianthes falcataria (White albizia)		YES	YES	YES		YES	
Parkia speciosa (Stink bean)	YES					YES	Bean
Persea americana (Avocado)	YES	YES					Fruit
Psidium guajava (Guava)	YES			YES			Fruit
Schima wallichii (Needlewood)		YES	YES	YES			
Sesbania grandiflora (Grandiflora)	YES	YES		YES		YES	Only casts light shade, often grown in rice fields
Sesbania sesban		YES		YES		YES	Deep roots
Shorea javanica (Damar)				YES			Resin. Gum
Swietenia macrophylla (Mahogany)			YES	YES			
Syzygium aromaticum (Clove)	YES						Spice
Tectona grandis (Teak)	YES (leaves only)	YES	YES	YES			Leaves used in cooking in some countries; dry season feed supplement for goat and sheep at low concentrations 5–25% of diet
Tephrosia candida (White tephrosia)		YES		YES		YES	Improves soil. Suitable for intercropping
Theobroma cacao (Cocoa)	YES	YES		YES			Rice has been successfully grown as cover crop with young cocoa, coffee, citrus and rubber

Source: Mulyoutami *et al*., 2014; Mulyoutami *et al*., 2015; Roshetko, 2001; Roshetko, 1998; Powell, 1997; Vityakon, 1993

Besides the points mentioned above and elsewhere in this manual, there are several other things that need to be considered when designing agroforestry.

(i) Land ownership: if their land tenure is secure, farmers are more likely to invest in trees.

(ii) Available plot size: some agroforestry designs are not practical or feasible economically below a certain size.

(iii) Plot location: access, slope (particularly relevant in upland rice-production landscapes) and possible future changes of land use (e.g. re-designation from agricultural to forested land).

(iv) Environmental: climate, soil, drainage, sunlight and rainfall

(v) Duration: some trees can be used to address an immediate problem — e.g. soil erosion — and can be replaced later with other trees that provide different services or products.

Box 3. Diversification of rice-production systems: the fish is my farm-worker

Rice-fish cultivation, recognised by the FAO as a Globally Important Agricultural Heritage System[18], has been practised for at least two millennia across Asia from delta areas to narrow valley floors in the uplands. Wild fish entering naturally-flooded fields exist in many parts of the world. However, intentional cultivation of rice fish may have started and spread rapidly when Chinese farmers observed the benefits from discarding excess fish eggs from ponds into rice fields.

Estimates for Yen Bai Province in Northwest Viet Nam suggest that rice-fish cultivation took place in at least 5% (695 hectares) of the total area of rice fields in the province in 2012. This is likely an underestimate as often only rice is recorded in agricultural census datasmall-scale rice-fish production is not documented as aquaculture. In the south of the country in the Mekong Delta, intensive cultivation of rice fish does contribute to export income but the low-input rice fish is maintained primarily for household food security and traditional dishes.

To improve traditional practices, some local government advisory agencies offer technical support through integrated pest management programmes and farmers' field schools. The fish do not conflict with land-use plans for reaching rice targets therefore many farmers experiment on their own to gain more yields per unit of land. Further, Viet Nam's payment for forest ecosystem services' programme specifies that fish (aquaculture) require safe water (from forests and agricultural fields) for spawning and survival. Rice fish serve as an indicator of "clean water". Moreover, the fish leave the field fertile for the subsequent crop.

Recommendations for small-scale, upland, rice-fish cultivation

Ensure there are enough clean water inlets to keep water levels at 20 cm. Suitable fish species should be discussed with farmers and advisory experts, focusing on feeding preferences: weeds, insects, larvae, molluscs, etc. Farmers in Bac Kan Province in Northeast Viet Nam prefer a mix of tilapia and common carp (and no grass carp because "it eats everything", including the rice plants). The recommended stocking density is one fingerling per 2 m^2 (30 fish per kilogram) or one mature fish per 1 m^2. Certain rice varieties are more suitable than others for rice fish: in Northern Viet Nam, the local variety, *bao thai*, is commonly used with fish.

Box 3. Diversification of rice-production systems: the fish is my farm-worker (cont.)

How to avoid the two main risks: weather extremes and upstream pollution

1) Weather extremes (drought, high and cold water temperatures): A section (dyke or cylindrical shape) with deeper water levels can serve as temporary refuge, or a dyke enabling fish to swim to a pond. The refuge can be cooled by shade from trees or a trellis with seasonal vegetables. In Southern Viet Nam and the Philippines, mango trees serve this purpose in rice fields. When there are risks of cold snaps, tilapia is better kept in ponds.

2) Upstream pollution: Avoid pesticides and herbicides entering from neighbouring fields. In Bac Kan, this was done through agreement in the community about timing of spraying and how long the water would need to remain in the fields to dissolve the chemicals (with advice from advisory experts) before being let out or rerouted into other irrigation channels. In rotation, ensure that potential toxins from the previous crop do not remain in the field. For example, farmers observed that fish could not be in rotation after tobacco.

Benefits for the farmer and the environment

Rice-fish farmers enjoy multiple benefits. Fish eat weeds and their nibbling at the base of rice plants make the plant stronger and less prone to lodging. Fish are a biological pest control. Their tails hit rice plants, causing insects and larvae to fall into the water and be eaten. The fish manure and their habit of burrowing, which brings nutrient-rich substrate from the bottom, means that farmers use less or no inorganic fertilizer and pesticides yet still achieve the same yields as without fish.

Rice fish require a constant supply of water, which poses a risk for elevating methane emissions compared to rice monoculture, in particular, alternating water-and-drying techniques, which regulates methane and nitrous oxide emissions. However, effective alternating water-and-drying requires large delta fields. For small-scale, upland systems, accounting of two (rice and fish) simultaneous yields with low inputs, returns high emission efficiency (greenhouse gas emission per kilogram output per area).

Source: Simelton & Dam, 2014

SlideShare: http://www.slideshare.net/agroforestry/rice-fish-presentation-simelton-eng

Acknowledgements: FORMAS Sweden, project number 213-2010-686

Figure 19. Rice-fish landscape, Viet Nam

Table 5. Options for integration of trees into rice-production landscapes

Rice-production landscape	Functions or products from agroforestry	Potential trees	Agroforestry practice
1. ***Irrigated rice on large plains*** Trees are usually rare, mainly only found in homegardens and along road sides 2. ***Rainfed lowlands*** Trees are abundant in hedges and scattered in fields 3. ***Rainfed uplands*** Rice fields share land with trees and fallows. Trees are abundant	• Low-shade, nitrogen-fixing trees on boundaries of the fields for timber, fruit, medicine, fertilization • Windbreaks low-shade, nitrogen-fixing species on boundaries and mixed species further away from the fields for timber, fruit, medicine, fertilization • Fodder and other tree species on bunds for livestock and benefits as above • Fish, manure, pest control and nutrient transport in rice-and-fish systems • Multi-species homegardens for fruit, timber, medicine	• For boundary and windbreak planting: *Acacia* (also for fuelwood, nitrogen fixing, and pulpwood), *Eucalyptus* (also for pulpwood), teak (also for timber), various fruit species • For fodder trees[19] on bunds: *Sesbania grandiflora*, *Gliricidia sepium*, *Leucaena leucocephala*, *Calliandra calothyrsus*, *Cajans cajan*, *Flemingia macrophylla*, common burflower or "laran" (*Neolamarckia cadamba*, syn. (formerly *Anthocephalus cadamba*)), jackfruit (*Artocarpus heterophyllus*), neem or Indian lilac (*Azadirachta indica*) • For homegardens: all common homegarden species, specific to the location. Examples: coffee, guava, jackfruit, mango, teak, *Albizia*, *Gliricidia*, mahogany	• Alley cropping • Improved fallow • Planted trees in fallow • Taungya • Trees on rangeland or fields

2.2.1 Principles of planting trees in rice fields

Experiences from planting trees in rice fields that were below 1 hectare in size have been reported from Bangladesh[20]. They used several central principles to guide them, which we have adapted in the text below.

The wide spacing of the trees enhances rice production, or at least causes minimal disturbance, also ensuring that the trees formed a thin canopy and had minimum root-zone competition. Preferably, the selected species were nitrogen fixing. They also had to tolerate water logging. The wide spacing also minimized the risk of the trees being classified as "forest" by the government and consequently falling under a different set of regulations. The main species already in the fields before the experiment were *Acacia nilotica*, *A. catechu*, wild date palm (*Phoenix sylvestris*), "palmyra" (*Borassus flabellifera*), kapok (*Ceiba pentandra*) and "kadam" (*Anthocephalus cadarnba*). Certain fruit species, mainly mango (*Mangifera indica*) and jackfruit (*Artocarpus integrifolia*), were sometimes planted along the borders of the fields. All were able to tolerate the several months of waterlogged conditions.

The researchers also found that some trees reduced rice yields beneath them by 20–50% depending on the type and size of the tree, the density of its canopy (thick canopies block sunlight) and on the season and availability of irrigation. These reductions in rice yields were associated with trees that were unmanaged or managed mainly for tree products, not for maintaining or increasing rice yields.

These are important factors to consider when forming the objectives (same or better rice yields or more diverse food crops and income, for example), choosing the trees and where they're planted and how they are managed (pruned to reduce shade, for example).

2.2.2 Choosing the right trees

The main criterion for selecting trees is that they are liked by farmers. A well-known tree is better than an unknown tree but when a new species is introduced it is, of course, necessary to work with an unknown tree. A tree that is disliked by the farmers, for whatever reason, is always best avoided.

Focus groups and the ranking and scoring methods (described in the Appendix) are good ways to help farmers decide on which trees are best for their conditions.

As well as following the priority-setting process, it will help to consider these points.[21]

- The farmer's goals
- Trees that are easy to plant and manage, particularly, management that best suits the productivity of the crops and the trees being grown, e.g. maintaining or increasing rice yields, for fodder, fruit, wood or combinations of these and the potential products (e.g. fruit and nuts) and functions (e.g. nitrogen fixation)
- Suitability for the rice-production landscape, especially, having no negative effect on the rice while enhancing ecosystem services at landscape level and providing diversified income sources to the farmers.
- Characteristics of the trees or shrubs (e.g. growth rate, crown shape, and rooting pattern) that affect interactions with rice and/or animals
- Speed of growth and how soon they yield products or services, the value of the products, availability of markets, opportunities for local value addition, etc.

Farmers usually like trees that give a high net value, i.e. high values for the positive factors (high "income") and low values for the negative factors (low costs). The trees also have to be suitable for the particular conditions of the rice-production landscape.

The value for the farmer of direct and indirect production should be high. Which product or service provided by the tree is considered most important will probably vary from one area to another, from one

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Figure 20. Women's choice of trees might be different from men's

farmer to another and even within the family, e.g. a woman's preferences may sometimes be quite different from those of a man's. This is why it is best to involve both women and men in discussions about which trees to plant.

Competition with other parts of the system, especially rice, is the major cost and should be minimized. On the small plots of land common to most farms in Southeast Asia, very competitive trees might not be accepted by farmers even if they grow fast and produce valuable products.

Trees with a deep root system are usually less competitive with rice than those with many shallow roots. Shallow root systems might be better if the trees are meant to stabilize soil on rice terraces or nearby on sloping land where competition with the rice is less important. An example of a tree with shallow roots is *Sesbania sesban*; this species also fixes nitrogen.

Trees with dense shade compete with rice crops. Shading can be reduced through good design and management, such as pruning. Some trees naturally produce light shade, e.g., *Sesbania grandiflora*, *Sesbania sesban*, *Gliricidia sepium*, *Paraserianthes falcataria*, and some *Albizia* and *Eucalyptus* species. These trees might either have small or few branches, small or vertically-oriented leaves or be bare or partly bare during the rice-growing season. Other factors that determine the degree of competition are the ability to fix nitrogen and contribute that nitrogen to the soil and crops as litter. Information about factors such as these can usually be found through the Agroforestry Species Switchboard[22].

Easy methods of propagation also contribute to low costs. On-farm methods are usually cheaper than seedlings produced in central nurseries, and use of cuttings, wildings or direct seeding are the cheapest. A long life span reduces the relative cost of propagation. For instance, coppicing of trees — cutting them back to near ground level — once they are established makes it possible to harvest several times from one planting.

Interactions with animals can be positive — production of fodder and shade and receiving manure (organic matter and nutrients) — and negative: the animals destroy or eat the young trees. The negative effects can be reduced by using fences around individual trees, fencing of whole areas, and coordination among the rice and agroforestry farmers' groups and others to raise public awareness of the problems of livestock for trees.

The risks involved in agroforestry may be related either to problems with one component — e.g. the trees do not perform well — or to problems in the interaction between components, e.g. pests or diseases. Other risks might be that trees turn out to be weeds requiring more labour or that they prove to be a nuisance in some other way, e.g. are fast growing, prolific seeders or allelopathic (releasing chemicals that inhibit the seeding or growth of other plants). The risks are usually fewer with indigenous and well-known species than with exotic or unknown species.

Finally, trees are more likely to be appreciated by farmers if there are no taboos or negative beliefs associated with the particular species.[23]

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Figure 21. Trees in rice-production landscape, the Philippines

2.3 Implementing agroforestry

We have found that the key to success of any innovation in agricultural landscapes is to work closely with "champion" or "leading" farmers who have already demonstrated their commitment to trying new practices or are at least willing to volunteer part of their land for trials. These farmers are usually the key to successful, widespread adoption. Typically, once they demonstrate success, their neighbours and others from farther afield are keen to learn how it is done and adopt the practices themselves.

If PaLA or the other methods were carried out inclusively, it's likely that farmers will be interested in testing some options on their land. During the planning process, leading farmers would have been identified by their interest and willingness to participate, perhaps having already put themselves and their land forward for trials or even spontaneously planting trials themselves.

2.3.1 Farmers' demonstration trials

Farmers' demonstration trials[24] are evaluation trials designed by rural advisors and/or researchers with farmers to

- test the advantages of good seeds or seedlings;
- expand the use of trees on rice farms;
- inspire farmers to innovate; and
- serve as a future source of on-farm seed production.

It is wise to start trials with a small number of farmers. For example, at one site, only a few farmers in two villages might be involved in the first year's activities. Following the success of those trials, other farmers and a few neighbouring villages will likely also want to establish their own trials. Success breeds demand and advisors must gauge their capacity to meet demand before expanding.

After the first workshop and visit to a leading farmer, the farmers will be ready to design demonstration trials with the advisor's assistance.

The key aspects of the design are objectives, species, spacing and management. Draft designs can be completed during the first workshop or at subsequent workshops.

The objectives should be simple and clear. For example, to introduce new tree species along the bunds, test their survival and growth rates and impact on rice yields (during the first two years).

The trees included in the trial should be discussed by common and scientific names. This is because in some areas, common names for trees might vary from area to area; knowing the scientific name will help farmers if buying seeds or seedlings to ensure they are buying the right tree.

After setting farmers' priorities and assessing the sources of seeds and seedlings, it will be easier to compile a list of potential best trees. The list might include local species (which can be used as a "control" in the trial to compare with any introduced trees), new sources or varieties of local ones, and new trees not grown in the area before.

With the agreement of the farmers, other trees can be added to the list that advisors think might fit with farmers' priorities but which they might not know about or be reluctant to try for various reasons. Tree species can be timber, fruit or multiple-purpose depending on farmers' priorities and ones advisors want to test. Each of these groups has a different function. If more than one group is included in a trial, the objective should not be to directly compare their performance but to evaluate their compatibility.

It is wise to start with trees that serve both a household use and meet a market demand.[25]

Designing the trials

In the beginning, particularly with farmers who have limited experience with growing trees, the objectives and design of the trials should be kept simple. One standard design and set of objectives will be enough for all the participating farmers.

Tree spacing and management

The spacing and management of trees greatly effect success. Farmers with limited experience with trees will require strong guidance. If necessary, other technical experts can be called in to help answer their questions and assist with the design. But always remember that the trials are intended to address farmers' needs. Listening to farmers' concerns and using their advice when creating the design will lead to them respecting the finished design and working hard to ensure it succeeds.[26]

Experts can also help because sometimes farmers' designs are not technically sound. For example, many farmers want to plant trees close together and not thin them as they grow. They initially ignore the fact that trees need additional space as they grow larger. In such a case, politely explain the limits of their design and suggest alternatives. If necessary, bringing in an outside expert can sometimes help persuade them because the expert might have greater knowledge and examples to explain to them. But usually most farmers will appreciate advisors' comments and quickly understand the reasons. It is best not to dictate a management regime but rather provide a range of options that farmers can adapt to their conditions.

If the trial features trees planted in the rice fields, during the first 1–3 years farmers will continue to benefit from their rice yields and the trees will benefit from the fertilizers and weed control done for the rice.

Researchers in Bangladesh tested an ultimately successful design with farmers that followed several principles[27].

- Wide spacing: minimum tree-to-tree distance of 8 m
- Location mainly along bunds and within a field only when it is more than 16 m wide
- Plant beside and not on bunds to avoid interference with use of the bund as a pathway
- Plant on alternate sides of the bunds to share the benefits and the costs equally between owners of adjacent fields
- Each plot includes three species of tree; nine trees of each species
- Plant to minimize occurring side by side
- A typical plot to consist of 27 trees, covering about 2000 m², which can be composed of several small fields belonging to one or more farmers
- Tree seedlings are planted at the time of planting the main rice crop, to provide initial protection from grazing
- Regular root pruning (cutting back long roots to encourage new roots closer to the trunk and to discourage top growth) and top pruning (removing higher up, spreading branches to encourage taller, slimmer growth) as required.

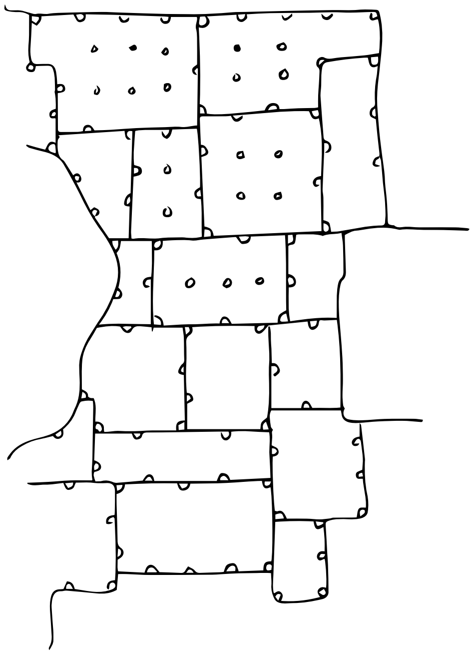

Figure 22. A sample design tested in Bangladesh

Source: Hocking and Islam, 1994

If the trial is of agroforestry adjacent to a rice field, then a simple design could have the objective of comparing the growth and survival of five timber species planted in two blocks of 25 trees at spacing of 2 x 4 m (total area around 2000 m²). Such a design will give the farmers the information they need and is likely to succeed.

As the farmers gain experience, more complicated designs will likely be developed, such as alternate rows of short- and long-rotation timber trees or various intensities of branch pruning. More complicated designs require more management and monitoring by advisors and other specialists. Advisors must be ready to provide this monitoring and advice.

2.3.2 Roles and support: how farmers and advisors can work together

From the start, it is important to be clear about roles and levels of support. Generally, farmers and advisors design and establish the trials together. Farmers are responsible for managing the trials with advice from the advisors. However, if farmers want to alter the management plan — even remove the trees — they must be free to do so.

Both farmers and advisors monitor and evaluate the trials because each might have different objectives and criteria. Advisors should clearly state that the trees are farmers' property. Neither an advisor nor anyone else has any claim to the trees and nor are advisors responsible for buying the tree products.

Discuss the respective roles and responsibilities of farmers and advisors with everyone and document the agreement. It is a good idea to post the agreement on the wall of the village head's office or other place often visited by the farmers involved in the trials.

Appropriate support includes the cost of workshops, visits and training; technical information, such as manuals, leaflets and guidance videos; seeds and seedlings (in the first year of a trial, it might be easier to buy rather than grow seedlings); nursery material; and agricultural inputs, such as fertilizers and pesticides, in case of infestations. Avoid giving money. Experience indicates money attracts the wrong type of people, raises unrealistic expectations, hampers self-motivation and dilutes the focus of the activity.[28]

Asking farmers to provide some type of in-kind matching support strengthens the partnership and demonstrates their commitment.

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Figure 23. A rural advisor in Viet Nam examining a graft during a monitoring visit with other advisors, farmers and researchers

2.3.4 Collecting seeds and seedlings

If good-quality seeds cannot be easily bought in the area they can be collected from "mother" trees in the fields or forests. The mother trees should grow in similar agro-ecological conditions as where the seeds will be planted. The mother trees should be in a good condition and demonstrate good traits related to the products or services the farmers want. Straight and vigorous trees will very likely provide seeds that will generate trees of the same traits.[29]

The intended purpose of the trees will determine which mother trees to select. For example:

(i) trees or shrubs with dense or thorny branches are good for living fences;

(ii) trees with dense foliage and/or pods that livestock like to eat are good for fodder;

(iii) trees with good quantities of healthy fruit (if increasing incomes are part of the objectives, then preferably the fruit from the mother tree should be at a standard that meets market specifications) are good for fruit production.

To maintain biodiversity and to ensure genetic variation, seeds should be collected from as many mother trees as possible (at least 30). Fruit or pods should be collected when they are ripe but before they fall to the ground or as soon after they fall as possible.

Seeds can then be extracted by either (i) threshing; (ii) de-pulping by soaking in water; or (iii) extraction by hand.

Before sowing, some seeds might need to be treated with either (i) hot water; (ii) cold water; or (iii) mechanically. Advisors should check not only the Agroforestry Species Switchboard[30] or other scientific sources but also with farmers who have already successfully used a particular method with specific trees.

Seeds can then be planted directly or germinated as seedlings in a nursery. Some trees suitable for direct sowing are *Acacia*, *Gmelina arborea*, mango (*Mangifera indica*) and guava (*Psidium guajava*).

Wildings, which are seedlings that have naturally regenerated in fields or forests, can be collected while they are still young and replanted during the wet season. The replanting should be done in the same year as collection. Some species suitable for wilding collection are mango and guava.

Table 6. Numbers of tree species in the Agroforestree Database of importance to farmers in Southeast Asia for food and nutrition

Function	Number of tree species of importance to Southeast Asia	Number of tree species indigenous to Southeast Asia
Human food (fruits, nuts, etc. for direct consumption)	225	49
Animal fodder (important for dairy, meat production, etc.)	191	47
Soil improvement (important for staple crops)	154	45
Fuel (provision of charcoal, fuelwood, etc., for cooking)	249	47

Source: modified from Kindt *et al.*, 2006

2.3.5 Establishing nurseries

There are many types of tree nurseries operated by farmers, larger private businesses and government agencies.

Farmers' tree nurseries that produce high-quality seeds and seedlings are a critical part of ensuring not only the success of farmers' demonstration trials but also the longer-term sustainability of the agroforestry programme.

Individual- and family-run nurseries can often produce from 50 to several thousand seedlings per season; group or community nurseries as many as 10,000; and large-scale commercial or government nurseries 100,000 or more[31].

How to establish a nursery

There are several steps to follow in order to successfully establish and manage a tree nursery[32].

(i) Choose a suitable location for the nursery

a. Near the farm house for ease of maintenance

b. Near a road for ease of access to transport

c. Near a reliable water source

d. Protected from livestock and possible natural disasters, such as landslides or floods

Box 4. Assessing seed need and supply

ICRAF has developed a simple method for assessing the supply of, and demand for, quality seeds and seedlings for trees, the capacity of local nurseries, and the effectiveness of support for developing local nurseries.

Called NotJustAnyTree, the method involves several steps. It focuses on farmers' nurseries not larger private businesses or government nurseries. These latter two must, however, also be included so you can understand the extent and quality of supply.

First, conduct a survey of tree nurseries to understand the species and types of species they produce; the quality of their seedlings (origins of the seeds, budwood and other material; how the seedlings are propagated; and the size and age of seedlings). It can be useful to collect and compare any surveys that have already been done of suppliers who operate at local, national or even international levels (often relevant if your area is near a national border). Assess how easy it is for farmers to access the suppliers; travelling many days to collect seedlings will increase the risk of damage during transportation.

Second, assess the quantity of seedlings produced by each nursery; the average number of seedlings per sale; the business capacity of each nursery; and their relation to other parts of the tree-seed sector (other nurseries and seed and seedling suppliers, government agencies, the private sector, customers etc. A gap analysis that starts with potential demand can identify opportunities for new species to enter into the nurseries.

Third, estimate future demand for seedlings from farmers, government agencies, development projects and the private sector and evaluate the nurseries' ability to meet that demand.

Finally, in conjunction with the third step, conduct a needs assessment of the farmers nurseries' human resources and infrastructure to identify any training and equipment needed to improve their operations to meet demand, including estimating the cost.

Source: Roshetko *et al*., 2013

e. On flat land with good drainage and not rocky

(ii) Prepare the site

a. Clear and level the ground

b. Build fencing

(iii) Make seed beds (also known as “media”) from equal parts of soil, sand and manure (goat manure is recommended). The bed can either be directly on the ground or added to any type of containers, such as unused plastic bags, plastic water bottles, bamboo, empty cans, unused pipes or “polybags” (a factory-made, black, plastic bag of varying sizes, usually available in agricultural supply shops).

Figure 24. Polybags are the most commonly used nursery container

(iv) Find mother trees that provide good-quality seeds. The mother trees should meet several criteria.

a. Well-shaped, healthy trees with desired physical form that are free of pests and diseases

b. Mature

c. Resistant to extreme weather

d. Fruiting consistently at appropriate times

e. Produce abundant fruit of good quality

(v) Prepare the seeds[33]

a. Decide how many seeds are needed

This can be determined by using a specific formula:

$$V = \frac{A}{B \times C \times D}$$

V = number of kilogram needed; A = number of seedlings produced; B = percentage of seedlings that survive; C = the percentage of viable seed; D = number of seeds per kilogram

b. Collect and sort the seeds[34]

Seed collection should follow certain criteria.

1. Collect from at least 30 mother trees

2. Fallen seeds can be collected as long as they are not damaged by animals, weather or exposure

3. Certified seed sources are recommended as the best for collection. That is, those that have been evaluated against a set of criteria and “certified” to meet those criteria. This is often the function of a “tree seed unit” in the government. Forestry companies may also have a seed-source certification

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Figure 25. Building a seed nursery shade house

programme on land they manage. The process for collecting seed from "certified seed sources" or "natural forests" is the same.

c. Treat before sowing
   1. The seeds must first be cleaned and any damaged or diseased ones removed
   2. If they will be directly planted, they do not need to be dried. In general, the seeds of fruit trees can be planted directly
   3. If they are to be stored for some time, they need to be dried for 1–3 days.
   4. Fungicide should be applied to protect the seeds from attack by fungi.

(vi) Plant the seeds either directly into the seed bed on the ground or in the containers. The beds should be free of weeds.

(vii) To reduce the risk of the seeds drying, build a protective shade house over the seed bed or bags using bamboo, poles or other local material. The roof and walls can be of shade net (available from agricultural supply shops) or palm or other types of leaves. Ensure light can enter but is filtered by the protective material.[35]

(viii) Water and weed the seedbed daily.

(ix) For most seeds, germination will occur within 1–3 weeks.

(x) Once the seeds have grown into seedlings, they can be "weaned" or transplanted from the sowing beds or containers into larger containers or an acclimatization chamber (if using a non-mist propagator, for example). This involves several steps.
   a. The day before weaning, heavily water the old and new beds
   b. Wean in a shady place, such as the nursery
   c. Prepare planting holes that are large enough to take the seedlings' roots

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Figure 26. A simple protective structure in Thailand

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Figure 27. Farmers at work in their tree nursery in Indonesia

d. Select the healthy and strong seedlings and remove the diseased or deformed
e. Lift the seedlings from the base of their stems and carefully place into the holes in the new containers
f. Water the seedlings well

(xi) There are several steps involved in planting seedlings into the field.

a. Reduce watering. About a month before the seedlings will be transplanted to the field, reduce watering. While specifics will vary by local conditions, general recommendations are to reduce watering by half for 1–2 weeks then reduce watering by half again for the remaining period before transplanting.
b. Reduce shading. If the seedlings have been produced under shade, reduce shading about a month before transplanting to the field. Again, specifics vary by local conditions. General recommendations are to reduce shading by half for 1–2 weeks then expose seedlings to full sunlight for the remaining period before transplanting. If seedlings were produced in a shelter, move the seedlings from the shelter about a month before transplanting to the field and provide partial shading for 1–2 weeks then expose seedlings to full sunlight for the remaining period before transplanting.
c. Monitor seedling health. Do not reduce watering or shading to the point that seedlings die.
d. Other factors. In areas with windy conditions, exposing seedlings to greater levels of wind is also recommended to prepare the seedlings for transplanting to the field. Again, the process should be gradual, accomplished in steps. Transplanting to the field should correspond to the onset of the rainy season. If the rains are late, delay transplanting.

Box 5. Vegetative propagation: top and side grafting

Vegetative propagation[36] is often used in nurseries to grow high-quality seedlings. It is a form of asexual reproduction of a plant. Only one plant is involved and the offspring is the result of one parent. The new plant is genetically identical to the parent.

Using material from proven, high-quality mother trees, farmers can cultivate seedlings that have the qualities of the mother tree but without having to grow from seeds, that quickly bear fruit, and which require material and equipment that are readily available and cheap.

The most common, and easiest, techniques are top and side grafting.

Top grafting

Top grafting is a way of attaching a cutting from a better-quality tree onto the stem of a seedling (young trees can also be top grafted).

(i) You will need hand pruners (pruning shears or secateurs), a sharp knife, soft plastic strips and small, narrow, transparent plastic bags.

(ii) In the nursery, choose a vigorous, healthy seedling of the same species as the cutting you want to graft.

(iii) Prepare a cutting about 10 cm long, preferably with buds, from the mother tree.

(iv) About 10–15 cm from the base of the seedling, cut off the top part.

(v) Cut a v-shaped slit in the top of the seedling's stem.

(vi) Cut a v-shaped wedge about 1 cm long into the base of the cutting from the mother tree.

(vii) Insert the wedged end of the cutting into the slit in the seedling's stem.

(viii) Tie the two parts together with a soft plastic strip.

(ix) Place a plastic bag over the two parts and tie at the bottom with a soft plastic strip.

(x) Place the seedling in the nursery, away from wind and playing children, and water and weed daily.

After three weeks, if the grafted cutting is still green, it's likely the graft has been a success.

The seedlings should not be planted in the field until they are around six months to a year old, depending on the species and conditions in the field. You should discuss the correct timing with specialists and the farmers.

Side grafting

Side grafting is similar to top grafting but is more often carried out on a young tree than a seedling. It's commonly used to graft different varieties of the same species onto a single tree so that they will produce different types of fruit, for example, several different varieties of mango.

(i) Choose a vigorous, healthy sapling.

(ii) Prepare a cutting about 10 cm long, preferably with buds, from the mother tree.

(iii) On the side of the sapling, cut a v-shaped slice into the stem.

(iv) Cut a v-shaped wedge about 1 cm long into the base of the cutting.

(v) Tie the cutting and the stem of the sapling together with a soft plastic strip that fully covers the cuts.

Figure 28. Steps in top grafting

Top row from left: Removing a top cutting to be grafted to better rootstock; cutting a wedge into the top cutting; cutting a slot into the better rootstock. Bottom row from left: Inserting the top cutting into the rootstock; tying the cutting to the rootstock with a plastic strip; covering the graft with a plastic bag; tying the plastic bag with a plastic strip

Figure 29. Steps in side grafting

From left: Preparing the cutting to be grafted; a wedge cut into the tree; the cutting inserted into the wedge; a bag placed over the graft; the bag tied

Box 6. Growing seedlings with a non-mist propagator

An effective way to grow cuttings is in a medium in a protected space. A simple-to-make propagator[37] can be used for all types of trees that are not easy to cultivate well when seeded, transplanted, grafted or through other means. The propagator keeps moisture in the air and soil without the need for installing pumps, pipes and misting heads.

There are three things to prepare: (i) the propagator; (ii) the seedling media; and (iii) a space in which the seedlings can acclimatize.

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Figure 30. A propagator frame

(i) The propagator is a frame made from bamboo, timber or plastic piping, 1 x 2 x 1 m (or can be smaller: 1 x 1 x 1 m) with the walls and lid made of semi-transparent plastic. The bottom is lined with thicker plastic or carpet or other watertight material. It is designed to keep water available at the bottom of the media and to stop water flowing to the surface of the media so that, indirectly, the humidity in the propagator and at the surface of the seedling media is maintained. The top is inclined at a tilt facing east. The propagator must be placed in a shady area, such as under a tree or a shade net

(ii) The seedling media: Inside the propagator arrange wooden boxes 25–30 cm high. Layer each box, first with stones of around 2 x 3 cm size, 10–15 cm deep. On top of the stones, lay sand, fine soil or sawdust that has decomposed, or a mixture of sand and sawdust, about 15 cm deep. Inside the box, install a PVC pipe of 2.5–5 cm diameter, from just above the bottom stones to the rim of the box, for filling and measuring the water level. Add water if the water level in the pipe has dropped.

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Figure 31. Seedling media boxes

Left: with bottom stones. Right: prepared

Box 6. Growing seedlings with a non-mist propagator (cont.)

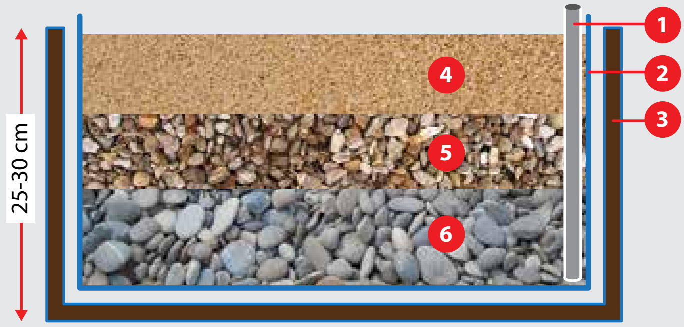

Figure 32. Cross-section of boxes

Note: 1. PVC pipe 1.5–2 cm diameter; 2. Seed-bed wall 2 x 30 cm; 3. Plastic layer between the wooden boxes; 4. Media such as sand, fine soil or decomposed sawdust; 5. Small or broken stones; 2–3 cm size; 6. Larger stones greater than 3 cm

Source: Purnomosidhi *et al.*, 2016

(iii) The acclimatization chamber is a plastic-covered frame 1 x 2 x 2 m or as big as needed, which is used to separate and manage seedlings that have rooted from the cuttings in the propagator. Putting the rooted seedlings into the frame allows them to adapt before being planted in the field. The seedlings in the acclimatization chamber must be regularly watered and organic fertilizer applied.

Figure 33. Acclimatization chamber

Growing seedlings in the propagator

There are four things that need to be considered when preparing tree cuttings: (i) when to collect; (ii) choice of part; (iii) making the cut; and (iv) accelerating the growth of the seedlings and their maintenance.

(i) When to collect: fresh cuttings are crucial to success. The best time for taking cuttings is in the morning before sunrise, i.e. before the stomata in the leaves have opened so that evapotranspiration and photosynthesis haven't started. If you must take a cutting after sunrise, take more plant material than is needed, such as a whole branch. To maintain the freshness of the cuttings, they should immediately be put into a container of water.

Box 6. Growing seedlings with a non-mist propagator (cont.)

(ii) Choice of part: Select parts with leaf buds that have already opened fully, branches or new shoots (if from a seedling in a nursery) or branches that grow straight (called an "autotroph") and not sideways ("plagiotroph"). Choosing autotrophs will result in seedlings with roots growing straight down rather than spread wide and cause competition problems with rice and other plants.

In the Philippines, autotrophs are chosen for propagation of timber trees such as *Albizia chinensis* and *Eucalyptus urophylla*. However, for fruit trees — such as durian, sugar apple and cocoa — farmers prefer plagiotroph with a slope of 30–45° because the resulting trees have a lot of horizontal, fruit-bearing branches.

(iv) Making the cut: choose woody shoots growing approximately 5–10 cm below the top, youngest branch. The characteristics of suitable woody shoots are supple, with a dark-green stem, and leaves that have fully opened. Before planting a cutting in the propagator, cut it back so that only 1–2 leaves remain so as to stimulate root growth, and reduce photosynthesis and evapotranspiration. Keep the cut end at an angle so as to improve water flow.

(v) Accelerating growth and maintenance: Before placing the cuttings in the propagator, the bottom of the cutting can be covered with growth hormones to accelerate growth of the roots. Growtone or Rootone are common rooting hormones that are available in agricultural supply shops. The most important factor in cutting management is to maintain the water level in the media boxes, which can be seen from the level in the pipe. If the level is lower than the surface, water should be added. Water the cuttings with a low-concentration leaf fertilizer to help them take root. All plastic surfaces need to be cleaned of water vapour every day.

(vi) Seedlings should not be planted in the field until they are around six months to a year old, depending on the species and conditions in the field. You should discuss the correct timing with specialists and farmers.

2.4 Maintenance, harvesting, post-harvest, monitoring, evaluating and sharing

Trees need to be maintained to ensure they function effectively. Regular management includes (i) protecting seedlings and saplings; (ii) weed control; (iii) pest control; (iv) fertilization; (v) irrigation or watering, if necessary; (vi) thinning; (vii) pruning; (viii) coppicing; (ix) harvesting; (x) post-harvesting; and (xi) monitoring and evaluation.

2.4.1 Protecting seedlings and saplings

Seedlings need to be protected in a nursery or when growing in the field unless they have grown from natural regeneration (and the farmer wants to keep them). Protection in a nursery has been discussed above. Seedlings and saplings in the field need to be protected from livestock with a fence of some kind either around individual trees or the planted area. A fence can consist of bamboo sticks placed in the ground and bent over the seedling or sapling or, in the case of an agroforest adjacent to a rice field, be a living fence of *Gliricidia* or other fast-growing species or made of rocks or even wire and poles, depending on what is easily and cheaply available.

2.4.2 Weed control

Both seedlings in nurseries and saplings in fields need to be regularly weeded to reduce competition for nutrients, light and moisture.

2.4.3 Pest control

Different trees are attacked by different insects and birds. Specialists and farmers often know which pests are likely to attack each tree species and how to control them. Trees planted in rice fields will likely benefit from any pesticides applied to the rice though this should not be assumed and testing might be required.

2.4.4 Fertilization

Trees, like any crop, benefit from the addition of extra nutrients. Trees planted in rice fields will benefit from any fertilizer applied to the rice. Trees planted outside rice fields can have organic fertilizer, such as compost, added to their planting holes. Different trees will likely require additional fertilization at different times, especially fruit trees. This should be discussed with specialists and farmers to choose the right fertilization regime.

2.4.5 Irrigation or watering

Trees can be planted in rice fields to coincide with the flooding. Because different trees have different responses to waterlogging, the best timing should be discussed with specialists and farmers. Trees planted in areas that are not irrigated should be planted to coincide with the wet season but, again, the specific needs of each species should be discussed first with specialists and farmers. In areas with long dry seasons, bucket or drip irrigation might be beneficial during the early stages of growth to ensure survival.

2.4.6 Thinning

Some trees can be planted densely and then thinned at a later age, removing the slower-growing, poorer-quality trees to allow the better-quality trees to grow to maturity. The trees that have been removed can be used for other purposes, such as fencing, building or fuel wood. The particular needs of each tree in relation to planting distance should be discussed at the design stage with both specialists and farmers. For example, some species coppice after cutting. The coppice will need to be cut again but can be used as fuel wood, animal fodder or other purposes depending on the species.

2.4.7 Pruning

Removing non-productive branches encourages nutrients and growth in the trunk and principal branches and reduces the risk of the tree falling over. Again, each tree has special requirements for pruning, which should be discussed with specialists and farmers.

Generally, for timber trees, removing branches that diverge from the main trunk and threaten to create a V shape or branches that grow horizontally will encourage the tree to grow straight, which increases the value of the timber at harvest. For fruit trees, horizontal, fruit-bearing branches are usually preferred.

Figure 34. Stages of tree pruning

From left: Selecting a small branch to cut using a pruner; cutting the small branch; cutting a larger branch using a saw

Pruning is best done in stages. First, when the sapling reaches human height, regardless of its age. Using hand pruners (for smaller branches) or a saw (for larger ones) rather than a machete reduces the risk of damage to the tree by keeping the wound small; larger wounds attract diseases and pests more easily. Cut the branch close to the trunk and at an angle so that rain will not easily enter the wound.[38] Covering the wound with paint or even a marker pen can lessen the risk of water, disease or insect damage.

Second, particularly for timber trees, when the tree is well above human height, pruning can be done with a pole saw and pruner (a combined set is often available in agricultural supply shops) attached to a long pole.

Third, small, unwanted branches can be removed at any time of a tree's life.

2.4.8 Coppicing

Some trees regenerate quickly and successfully when cut back almost to ground level. Discuss with specialists and farmers which trees are suitable for this technique.

2.4.9 Harvesting

Timber trees can usually be harvested at 5 to 30 years of age, depending on the species, stocking and the farmer's needs. Teak, for example, will be most valuable when mature at 30 or more years-old but most farmers will harvest when the tree is much younger to meet cash needs. *Albizia chinensis* can be harvested at around 5–10 years, making it a popular crop for farmers. Harvesting is often carried out by traders themselves, which reduces time and labour costs for farmers but also reduces price premiums. An option would be that farmers cooperate to harvest and market their timber. Fruit and nut trees vary in harvest times but most fruit annually. Growing a mix of timber and fruit trees in an agroforestry landscape helps farmers maintain cash flow throughout the year and over decades.

2.4.10 Post-harvesting

For fruit and nut trees, post-harvest work can include application of fertilizer, pruning and processing of the fruit either for fresh-fruit sale (such as grading and packaging to meet market specifications) or creation of other products, such as dried fruit, teas, alcoholic drinks, pastes or preserves. Collaboration among farmers will help reduce costs, strengthen bargaining power and add value to their products that will increase their incomes.

Post-harvest processing of timber trees that increases income includes processing logs into planks to suit market demand, something that is best done cooperatively or in collaboration with a local sawmill. Again, collaboration among farmers is usually beneficial.

Please note that with timber trees, harvesting an entire area can create environmental problems, such as erosion and sedimentation. In the design stage these risks at post-harvest stage can be reduced. For example, a mix of trees planted at different times and in different areas, which can be harvested at different times and intensities, will help reduce damage to soil. Such design will also help with post-harvest replanting, reducing the amount of seedlings to be sourced and planted at any one time. Care should be taken to ensure that the complexity of management doesn't become too great.

2.4.11 Monitoring and evaluation

Monitoring and evaluation are important for improving the performance of farmers' agroforestry practices in rice-production landscapes, including the types of agroforestry, the amount and type of vegetation cover, species, products, markets, income generated, food and nutrition provided, and as well as for the advisory service and the rice and agroforestry programme itself. This information is crucial for developing successful rice and agroforestry production and businesses and in communication with policy makers and others about the progress, problems and enabling conditions required for success. Only if advisors can quantify the beneficial effects both on farmers' livelihoods and their communities and also on sustainable management of natural resources across whole landscapes will they be able to prove the success of the programme.

There are four basic concepts involved in monitoring and evaluation. The example we provide here is for monitoring and evaluating rural advisory services. It can be adapted to other uses.

(i) ***Capacity of the advisory service*** is the control that the agency has over physical, financial and human resources. Strong capacity enables rural advisors to serve farmers effectively. Outreach, intensity of the service, technical competence, and physical and financial resources are reflected in the concept of "capacity". The performance of advisors depends directly on their capacity. The performance of an advisory service can be measured through its effectiveness and efficiency.

(ii) ***Effective performance*** is the "degree to which goals are attained". Specific goals — such as social (e.g., farmers' welfare) and economic (e.g., increased incomes) — are often those of advisors. The goals with special significance are operational goals (e.g., physical and financial targets) because their achievement makes other goals possible.

(iii) ***Efficient performance*** is usually measured by the rate at which farmers adopt the new practices. Varying degrees of complexity of adoption rates can be considered depending on the specific conditions in a landscape.

Figure 35. Agroforestry farmers' field school, Indonesia

(iv) ***Impact*** can be measured by a simple indicator, for example, rice and agroforestry yields per hectare, or simple productivity indices can be constructed. Such indicators provide ultimate tests for the success of advisory programmes.

Points (i)–(iii) are indicators for monitoring the process — to check the progress of the rice and agroforestry programme — while point (iv) indicates the evaluation score that shows what impact is being experienced by the farmers.

2.4.12 Sharing information

Farmers who have learned to integrate trees into their farms in rice-production landscapes have developed a large amount of specialist knowledge that can be shared with others to increase productivity, incomes and resilience to climate change. Group meetings and farmer-to-farmer visits, along with various tools — such as posters, photos and field demonstrations — can be used to spread experience and knowledge. The participatory development of agroforestry should be continued by, for example, expanding good agroforestry practices, incorporating new knowledge and/or new species, testing innovative methods, and conducting agroforestry experiments. Details of the methods are presented in Chapter 3.

Notes to Chapter 2

[1] Modified from Martin & Sherman, 1992

[2] Joshi *et al.*, 2013

[3] Roshetko *et al.*, 2005

[4] Joshi *et al.*, 2013

[5] Franzel *et al.*, 1996

[6] Roshetko *et al.*, 2005; Franzel, 1996

[7] Franzel, 2004

[8] Hoang *et al.*, 2013

[9] FAO, 1996

[10] Roshetko *et al.*, 2016; Roshetko *et al.*, 2005

[11] Franzel *et al.*, 1996

[12] Perdana *et al.*, 2012

[13] Perdana & Roshetko, 2015

[14] Perdana & Roshetko, 2013

[15] Perdana & Roshetko, 2013

[16] Perdana *et al.*, 2013

[17] Roshetko *et al.*, 2007; Hoang *et al.*, 2012; Hoang *et al.*, 2015 ; Hocking & Islam, 1998, 1995; Kosaka *et al.*, 2006

[18] FAO, 2017a

[19] Roshetko & Gutteridge, 1996

[20] Hocking & Islam, 1994

[21] Franzel *et al.*, 1996; Martini *et al.*, 2013; Pramono *et al.*, 2011

[22] Kindt *et al.*, 2016

[23] Franzel *et al.*, 1996 ; Martini *et al.*, 2013

[24] Roshetko *et al.*, 2016; Roshetko *et al.*, 2005

[25] Hocking & Islam, 1994; Kindt *et al.*, 2016

[26] Hocking & Islam, 1994; Roshetko *et al.*, 2005

[27] Hocking & Islam, 1994

[28] Roshetko *et al.*, 2005

[29] Kindt *et al.*, 2006 ; Mulawarman *et al.*, 2003; Schmidt, 2000

[30] Kindt *et al.*, 2006

[31] Nyoka *et al.*, 2015

[32] Institute of Agroforestry, 1998; Jaenicke, 1999; Roshetko *et al.*, 2012; Roshetko *et al.*, 2013a; Wightman, 1999; World Agroforestry Centre, 2016a

[33] Mulawarman *et al.*, 2003

[34] Jaenicke, 1999; Kindt *et al.*, 2006; Mulawarman *et al.*, 2003; Schmidt, 2000; Wightman, 1999

[35] World Agroforestry Centre, 2016

[36] Prastowo *et al.*, 2006; Purnomosidhi *et al.*, 2002

[37] Purnomosidhi *et al.*, 2016

[38] World Agroforestry Centre, 2016e

CHAPTER 03

Sharing knowledge

Prasit Wangpakapattanawong, Elok Mulyoutami, Riyandoko, Endri Martini,
Gerhard Sabastian, Aulia Perdana and James M. Roshetko

Farmers at an indoor training session in Indonesia

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CHAPTER 03

Sharing knowledge

Prasit Wangpakapattanawong, Elok Mulyoutami, Riyandoko, Endri Martini, Gerhard Sabastian, Aulia Perdana and James M. Roshetko

Agricultural and rural advisory services and other community facilitators are the link between researchers and farmers. Advisory services can help transfer knowledge to and from farmers and researchers. There can be many channels of communications between them. For example, by gathering in farmers' groups to learn together, establishing tree nurseries or forming innovation platforms for adding value and better marketing of products. This chapter discusses some of the ways to learn together and spread knowledge, and advisors' role in them.[i]

3.1 Rural advisory services

There are many kind of advisory agents who can give advice on how to develop good agroforestry practices in rice-production landscapes. Advisors might come from a government agency, non-governmental organization or private business, but no matter from where, they will be working closely together with farmers to develop practices that will improve production, incomes and the environment.

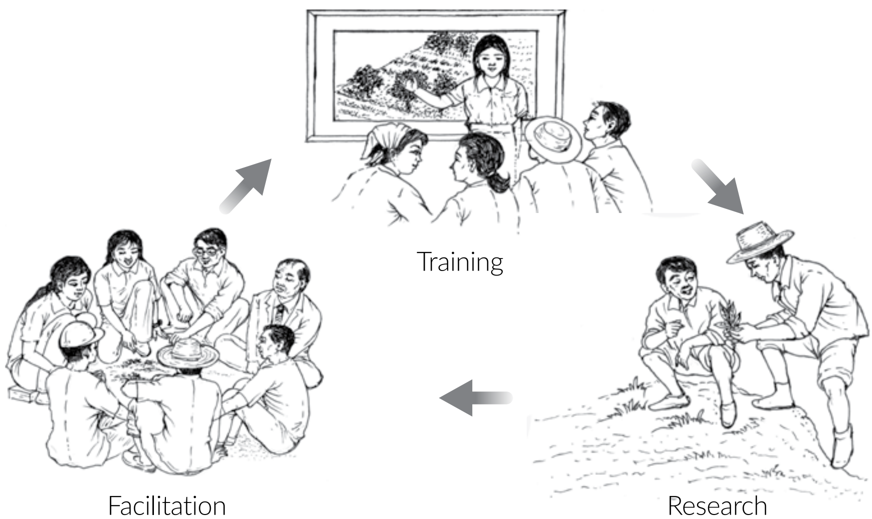

Figure 36. Advisory, or extension, services

Source: modified from Xu *et al.*, 2013

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Figure 37. An advisor and farmers sharing information

Agricultural advisors play extremely important roles in improving farmers' knowledge and skills and translating research into action. Consequently, it's essential that advisors thoroughly understand farmers' issues and be able to explain them to researchers, policy and decision makers, non-governmental organizations and businesses. This means that the advisor needs to have high-level and varied communication skills.[ii]

However, owing to many factors — e.g. limited resources, limited understanding of the national or local languages, and poor infrastructure — it might be very difficult for some advisors to work effectively with farmers.

To help overcome these challenges, we have found that farmer-to-farmer extension and farmer leaders are often very effective ways to provide advisory services in communities. One of the best ways to develop leading farmers into local advisors is through shared learning, of which there are a number of proven techniques, described below.[iii]

3.1.1 The role of advisory services

Rural advisory services are an informal education system for improving the livelihoods of farmers and their communities. The core activities are education and training. Rural advice is mostly thought of as integrating local knowledge and skills with new ones derived from study or research into an overall framework of discussion, cooperation and joint learning and sharing between farmers and the advisory organization.

For advisors, communication is two way in the sense that advisors teach and demonstrate research knowledge or technology to farmers and then communicate feedback from farmers to researchers. This is especially crucial when technologies are new. In addition, agroforestry technologies are often complex and site specific and require particular attention in rice-production landscapes. It can take a long time to reach this most-desirable state.

Evaluations should be carried out by advisors and farmers together through various steps, discussed below.

(i) ***Observation***: Advisors can observe the farmers' activities, for example, how different combinations of trees and crops are performing (selection of species, seeds and seedlings; appropriate spacing of trees; pruning; fertilization; yields, etc.), which management practices are preferred by farmers, and the presence of pests and diseases.

(ii) ***Listening and/or interviews***: Careful listening can be a great tool for understanding the issues. Listening is also a very good way to demonstrate that the interviewer is really interested. Interviews can help gather the ideas of farmers about progress, problems and recommendations.

(iii) ***Record keeping***: It is crucial for advisors to take notes regularly on direct observations and information gathered by listening and interviewing. Advisors should always keep extensive notes, preferably typed, so that they can refer to them as time passes and memory fades and in case they leave the programme or service so the information is available to the replacement.

3.1.2 Farmers' groups as advisors

Farmers' groups[iv] are an effective means of reaching large numbers of farmers.

The farmers' advisory group approach increases the motivation of farmers to improve the productivity and profitability of their rice and agroforestry systems, strengthening their capacity to seize market opportunities.

Initial training is given to farmers' groups to

(i) analyse the biophysical and socioeconomic conditions of the landscape, its problems and opportunities;

(ii) identify technical options for improving productivity, adding value to the products and strengthening market links while finding ways to resolve challenges and remove obstacles; and

(iii) set work plans that include more intensive follow-up with the group. This can include making a schedule and estimated budget and, if needed, ideas on how to access the capital required to get started, e.g., such as establishing a group tree nursery.

The approach should be flexible and dynamic, adjusting to local conditions. Furthermore, it must be informal, practical, impact-oriented and focused on the priorities identified by the farmers. To avoid wasting resources and time, the structure and process should be simple and straightforward.

Training workshops for leading farmers should focus on management of priority species, developing and maintaining rice and agroforestry systems, problems encountered along the way, access to planting material and other inputs, links to markets and/or other priorities. Common topics include seedling propagation and nursery management, management of rice-agroforestry systems, pests and diseases, farmer–market links, and farmer-operated commercial nurseries and other enterprises. Training should be participatory, well planned and well implemented. After initial discussions, develop a training curriculum that is then reviewed by the farmers and adjusted as necessary.

In the training, advisors should give background information and then facilitate discussions. A larger group should be divided into working groups so the farmers can share and compile their experience and knowledge on previously agreed topics or new ones that arise in discussion. The working groups then report to the whole group. Practical sessions where farmers can practise new skills should be included in the training, helping to further build their technical capacity.

Most importantly, the training exposes farmer leaders to new ideas and helps them recognize the depth of their own knowledge and capacity to improve not only their own farms but also their community. The training is very valuable in motivating farmers and helping them identify priorities. Developing work plans should be an integral part of each training event.

Following the training workshops, advisors can help the farmers to (i) share what they learned in the training with other farmers; and (ii) review, revise and implement their work plans drafted at the workshops. Follow-up technical assistance can be done through farmers' meetings, mini-training sessions and field implementation, such as nursery construction or establishment of a demonstration trial. The activities should be indicated in the work plans and be mutually supportive and integrated so that the objectives and topics of each are relevant to those of earlier activities.

These follow-up activities create a continuous flow of contact between the farmers' groups and rural advisors. Activities are implemented through three main channels: (i) advisors facilitating and monitoring progress towards achievement of groups' objectives on a periodic (monthly, bi-weekly, weekly) basis; (ii) advisors and other specialists (including market agents) providing specific technical assistance as requested by the groups; and (iii) farmer-to-farmer and farmers' group-to-farmers' group technical assistance on an informal basis, with facilitation by advisors as necessary.

Activity (i) above ensures frequent contact with farmers' groups, helping them to concentrate on their objectives and plans, monitor progress and, if necessary, change their objectives. Combined with activity (ii), farmers are able to develop their organizational capacity and there are opportunities to coordinate activities between groups. This is important early in a programme.

But experience indicates that the greatest impact is achieved through activity (iii): farmer-to-farmer and farmers' group-to-farmers' group technical assistance.

3.1.3 Farmer specialists

Farmer specialists[v] are farmers who intimately understand the conditions and concerns of fellow farmers. Their language and communication style is readily understood by other farmers. More comfortable under such conditions, farmers are more likely to ask questions and share their own experience when farmer specialists lead sessions. Active participation leads to greater learning and sharing of knowledge. Rural advisors provide technical assistance but their main role should be to facilitate the process of spreading knowledge widely through the farmer specialists. A key function of advisors is to identify the farmer specialists, leading to the creation of a strong network of farmers, farmers' groups, technical specialists and institutions, including market people.

This can lead to spontaneous farmer-to-farmer advice and adoption of technologies. This is probably the single greatest impact of the approach.

3.2 Specific ways of transferring knowledge and technologies

3.2.1 Farmers' demonstration trials

This approach has been discussed in detail above. There are several basic principles worth revisiting here.

(i) ***Work together***. On-farm demonstration trials are done by individual farmers and groups with facilitation by advisors, researchers and specialists together.

(ii) ***Share***. The learning should be two-way. Local contexts should be understood, including the problems farmers encounter, the village's political structure, market prospects, and knowledge gaps in technical skills.

(iii) ***Strengthen "champion" farmers***. Relationships with "champion" or leading farmers should be made and strengthened. They should not only have demonstrated a commitment to increasing their knowledge and applying it on their farms but also have shown an interest in the environment and sustainability.

(iv) ***Use private land.*** Demonstration sites should be located on private farms.

(v) ***Train trainers***. Several workshops in villages should be conducted to "train the trainers". Some outside specialists can be invited to workshops from local government, private businesses etc depending on the topics and local situation.

(vi) ***Find more resources***. Farmers should be assisted to find more technical and financial resources.

3.2.2 Farmers' self-managed plots as knowledge centres

As well as farmers' demonstration trials, plots established and managed by farmers is another effective way of spreading knowledge[vi].

A farmer who has successfully developed a rice and agroforestry system can more easily demonstrate to other farmers the advantages and disadvantages. Best practices generated by a farmer's own experience are more likely to be adopted by farmers new to the practices. Once self-managed plots show success, neighbouring farmers will be keen to observe and imitate the practices in their own plots

3.2.3 Farmers' field schools

A farmers' field school[vii] is a group learning process where farmers enhance their knowledge and analytical skills through observation and experiential learning conducted over a season or over the full cycle of crop and tree production, including harvesting the first products, preparing them for the market and selling them.

The school is facilitated by rural advisors or farmer specialists. The school should emphasize group observation, discussion, analysis, presentation, collective decision making and action. Not only new technology and techniques should be shared but also how to identify local potential, identify problems, and make decisions about the best technology to use. Farmers' demonstration trials can be a good place to conduct a farmers' field school.

There are several principles involved in the schools.

(i) ***Discovery learning***: Farmers and advisors observe and learn from field work by doing practical activities. The advisors should not act as teachers but as facilitators encouraging the farmers to think, test, observe, analyse and discover answers to problems.

(ii) ***Equity, no hierarchy***: Everyone should participate equally as unique experts.

(iii) ***Self-defined curriculum***: The topics studied in the school should be designed to suit the needs of all the group members.

(iv) ***Participatory monitoring and evaluation*** with a specific plan to measure the achievements.

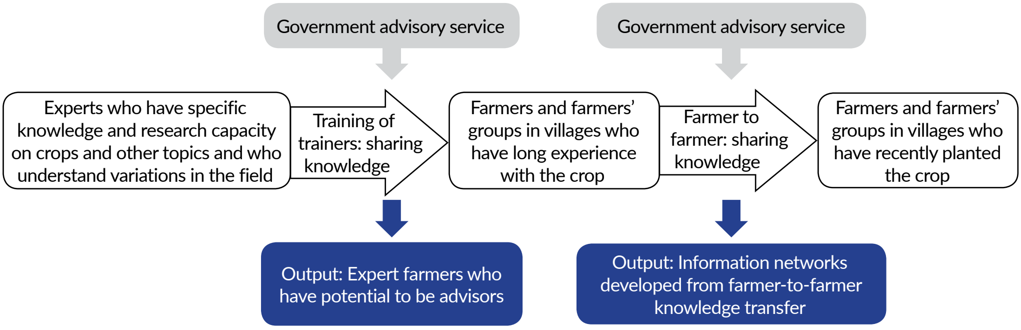

Figure 38. Concept of the Agroforestry Farmer's Field School

Source: Martini *et al.*, 2016c

The concept of an agroforestry farmers' field school is described in Figure 38. Box 7 describes experience in Sulawesi, Indonesia, where the farmers' field school focused on five main agroforestry commodities prioritized by farmers: pepper, clove, coffee, cocoa and durian.

Box 7. Agroforestry farmers' field schools in Indonesia

Recent work in Sulawesi, Indonesia has shown that farmer-to-farmer advisory approaches can help spread agroforestry innovations. In Indonesia, knowledge of agroforestry is mostly transferred informally between farmers because government advisory services mainly focus on agricultural and commodity crops.

The Agroforestry and Forestry in Sulawesi project focused on improving farmers' livelihoods through agroforestry and forestry. The project used various advisory approaches to improve production from agroforestry systems in Sulawesi. One particularly successful approach was the Agroforestry Farmers' Field Schools[viii]. These combined researcher-to-farmer and farmer-to-farmer advisory approaches, field visits and farmers' demonstration trials (the latter were monitored every 3 months). Bi-weekly visits were conducted to monitor the results of the schools.

The schools were implemented in the first year (April 2013 to March 2014), with a focus on five main agroforestry commodities prioritized by farmers: pepper, clove, coffee, cocoa and durian. Experts from Indonesian national research institutes were engaged to provide advice. One year after the programme began, an evaluation was conducted through interviews with randomly-selected school participants from four districts in South and Southeast Sulawesi provinces, with a total of 263 respondents (12% of total school participants). Results showed that 97% of the respondents gained benefits, in particular, new and reliable knowledge was perceived as the most important aspect motivating farmers to attend. Further, 14% of respondents had generated more income from testing new techniques. The amount of money depended on the type of knowledge tested. Fertilizing and pruning of trees were important techniques that yielded cash benefits for farmers within a year. The evaluation concluded that after the schools' activities ended, a minimum of one year of facilitation would be required to assist participants to effectively test and adapt the new knowledge learned.

Source: Martini *et al.*, 2016c

3.2.4 Visits and study tours

Visits to other farmers (often called "farmers' cross-visits") to study their experience with integrating trees into rice-production landscapes is very important for broadening knowledge and building confidence in the new technologies and systems. Farmers can see the evidence of successful application, which might not be available in their district or at the beginning of a demonstration trial or field school. Learning from other successful farmers inspires and motivates farmers to apply the knowledge on their own farms and in their own communities. Visits need to be planned well in advance to ensure both hosts and visitors are prepared and the tour takes place at a mutually convenient time. Because levels of application of new technologies vary widely between districts even within the same country, farmers can learn a lot from others elsewhere. Tours to neighbouring countries to meet farmers who have much more experience of rice and agroforestry systems in biophysical conditions similar to their own can be especially valuable. Well-trained, experienced interpreters are a critical part of such visits.[ix]

3.2.5 "Rice and agroforestry" groups

These groups consist of farmers and other people with specialized interests in agroforestry in rice-production landscapes.

Ideally, a rice and agroforestry group will be an equitable partnership between the farmers, rural advisor, researchers, other officers from other agencies, and private businesses, particularly, market people.

The group should meet regularly and support each other in their activities. Because of its specialized nature, an advisor should facilitate this group and make links to other individuals and groups with interests in rice and agroforestry.

Sometimes groups formed around developing a specific type of enterprise is called an "innovation platform"[x]. The platforms build on everyone's experience and expertise along the value chain, bring the farmers and producers together to learn from each other, and even find capital to start some processing and create a large enough volume of products suitable for marketing. This will be further explained in the next section.

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Figure 39. Farmers in a shared learning group in Indonesia

3.3 Development into farmers' enterprises

Conducting market studies and developing the role of farmer specialists and farmers' advisory groups builds farmers' awareness of market conditions, enhances their technical skills, and forms and strengthens more farmers' groups[xi].

This process often leads to the development of farmers' enterprises, which can be broadly defined as any venture, project or activity that contributes to farmers' livelihoods or incomes.

To encourage this process, our experience is that initial efforts should focus on several main activities.

(i) ***Improve the system***. Improving the quality and quantity of farm products through intensification or expansion of their rice and agroforestry system.

(ii) ***Improve post-harvesting***. Improving the quality and value of the products through sorting, grading and packaging.

(iii) ***Improve processing***. Transforming products from a raw to semi-processed state.

(iv) ***Increase market access***. Learning about markets (demand for, and specifications of, each product) and improving access to them, such as identifying how various products get to markets, developing links with market agents and how to access different types of credit (e.g., micro-credit).

The last three activities are likely to be new for most farmers but are usually well within their capacity if they are given encouragement and support. Undertaking these activities will require more inputs from farmers: labour, time, capital, skills and planning. This is a significant investment for farmers but will be rewarded with higher incomes. The key to success is a well planned and executed market study and expansion of farmers' enterprises based on the opportunities identified in the study.

Any of the four activities above will be more efficient if carried out by a group of farmers united in purpose. Group members can share experience, knowledge, resources and responsibilities of the enterprise for mutual benefit. It is an appropriate next step for the farmers' group to assume a marketing role through involvement with market agents. This process should start small, gradually expanding as the capacity of the farmers, rural advisors and the market agents grows.

In most cases, individual farmers or groups can form businesses or associations that focus on (i) transportation, wholesaling and other mid-channel activities; and (ii) processing raw materials and manufacturing finished goods[xii].

However, such activities require a profoundly different set of resources, information, skills, planning and capital than are available to most individual farmers or groups. They also involve a lot of financial risk. Operating these types of enterprises is not an easy progression and should be carefully evaluated before being pursued. Our experience shows that their development is dependent on an outside champion or local leader who is connected and knowledgeable regarding the operation of the enterprise and/or able to carry the financial risk.

Therefore, we suggest that farmers' groups focus on (i) improving their capacity to supply reliable quantities of high-quality products; (ii) establishing permanent and profitable market links; and (iii) developing sufficient entrepreneurial capacity to assure financial success before considering investment in off-farm enterprises. In other words, farmers' groups should first master the four activities listed above before consider forming larger and more complicated enterprises.[xiii]

3.4 How to find new information and keep learning

Advisors will likely have much greater access to information on rice and agroforestry systems available through their own agency or through contacts with others, including national and international organizations, such as ICRAF and the FAO, both of which might also have offices in your capital city or even field offices if they are conducting projects.

Such specialised information is often in English and might need to be translated or interpreted into national or local languages to be most effective. Organizations are sometimes able to provide this service in collaboration with the advisory agency. Internet searches are an invaluable tool for finding information and should be frequently done to keep up to date with the latest research and developments in rice and agroforestry systems. Advisors can also find information about conferences, seminars and workshops that will help expand their knowledge and skills. The FAO maintains a database of such events at http://www.fao.org/asiapacific/events/en/.

Conventional media such as television, radio, newspapers and trade magazines also provide valuable information and should be frequently viewed to keep up to date, especially with local and national developments.

3.4.1 More information from ICRAF and FAO

FAO and ICRAF, amongst other organizations, have material available to support rural advisors.

For information from ICRAF, go to https://www.worldagroforestry.org/ras/ for details of farmer-to-farmer extension, rural resource centres and rural institutions, community nurseries and agroforestry farmer field schools, civil society campaigns, radio and social network analysis and successful agroforestry extension programs.

For information from FAO, go to http://www.fao.org for details of tailoring rural advisory services for family farms, Gender and Rural Advisory Services Assessment Tool (GRAST), rural advisory services and climate, building knowledge systems in agriculture, the new extensionist position paper and Global Forum for Rural Advisory Services (GFRAS).

Also see the References and Further Reading section below.

Notes to Chapter 3

[i] Martini *et al.*, 2016a,b; Staiger-Rivas *et al.*, 2010; Taylor & Beniest, 2003

[ii] Simelton *et al.*, 2013

[iii] World Agroforestry Centre, 2016c

[iv] Martini *et al.*, 2016a,b ; Chipeta *et al.*, 2016

[v] Franzel *et al.*, 2015; Martini *et al.*, 2016a,b; World Agroforestry Centre, 2016c

[vi] Franzel *et al.*, 2015

[vii] FAO, 2015a,b; FAO, 2016c,d; FAO, 2011; http://www.fao.org/farmer-field-schools/en/

[viii] Roshetko, 2015

[ix] Martini *et al.*, 2016a,b; World Agroforestry Centre, 2016b

[x] Dror *et al.*, 2016

[xi] Roshetko *et al.*, 2007

[xii] Perdana *et al.*, 2013

[xiii] David & Oliver, 2002

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Appendix

Appendix

A1. Objectives of PaLA

(i) Understand what farmers think about the relationship between their farming practices and how the landscape functions.

(ii) Understand why farmers have chosen particular ways of farming (e.g., construction and management of paddy fields, why do they like a certain type of agroforestry or tree) and how these decisions are linked to outside influences, such as government policies, market demands and changes in weather patterns.

(iii) Understand the flows of water, sediment, nutrients and organisms and how these provide essential functions in the landscape, their relationship with farming practices and environmental services and how this mosaic forms a functioning whole.

(iv) Raise awareness among farmers, government officers, business people and staff of non-governmental organizations of the wider landscape issues and how they affect ecological and administrative limits.

A1.1 Implementing PaLA

We recommend that PaLA is conducted in close liaison with all the people interested in the landscape, as mentioned above. It is an excellent way for everyone to learn and share information.

The methods used in PaLA are derived from several decades of experience throughout Southeast Asia and other parts of the world; they have been adapted for this manual.

Bear in mind that many of these methods might only be appropriate if there is already commitment from government agencies and heads of villages and farming groups. If this is not the case, the less formal methods, such as semi-informal interviews with farmers who have demonstrated an interest in innovations and group discussions with existing farmers' groups might be more appropriate. All the methods do not need to be used but only those that suit local conditions, capacity and resources and help meet the objectives. However, the more thorough the collection and analyses of the information is, the more likely success will be.

(i) Form an interdisciplinary **survey group** made up of colleagues as well as farmers, business people and others drawn from the agroforestry and rice groups and elsewhere. The group will lead the PaLA process. The concepts behind PaLA and the steps that need to be taken to implement it should be understood and agreed on by the group. Their first activity will be to plan the step-by-step process outlined here, adapting it for the specific landscape in which they work. It will take some time to bring together the group and carry out its initial planning. Especially with farmers, before each method below is used, test it first exactly as it is planned to be done. Remember to ask follow-up questions of why and how etc and ask if anything has been missed. Any or all of the methods below can be used that most suit local conditions.

(ii) Identify **ecological and administrative domains** with clear boundaries through indoor sessions and field observations. This includes reviewing existing maps and reports on biophysical, ecological, socioeconomic and policy areas. Relevant documents include topographical, land-use, soil and administrative maps. An internet search can also uncover hidden gems of information that are relevant for understanding the landscape.

Sometimes, contradictory information will be identified that can be highlighted for further work by those with the authority to do so. This can take the form of government officers understanding that different agencies' boundaries, authority, responsibilities, budget and objectives can overlap or even contradict one another. Steps then need to be taken to resolve the issues.

Establishing a separate cross-agency working group as a formal government mechanism that includes representatives of farmers' groups, research institutes and businesses has been proven to be an effective vehicle for reviewing policies and other administrative matters in many countries in Southeast Asia.

(iii) Conduct a **survey** of a sample of the people interested in the landscape using questionnaires[i], single interviews and group discussions. The selected set of people should be broadly representative. Selection criteria should include the locations of their fields (e.g., close or far away from water sources; on particular soil types; near increasingly saline areas; on higher ground), different income levels, females and males, social status, age, experience and education. The criteria should be based on the objectives. It is important to discuss both the objectives and the selection criteria at the start of the PaLA process and report them when the results are presented. If the informants are chosen widely and well, the results will be stronger and the process itself will serve as a promotional exercise for the objectives.

(iv) Make **village maps** or 3D models that identify the land-use patterns and the main landscape points. This can be done through semi-structured interviews with male and female groups. The model should show the local names of the different areas, the distribution of different land-use plots, and the main features of the landscape, such as rivers, streams, high and low ground, roads and market places. To make the map, start by searching for an Internet map (or other digital map) available for the area, print it in large format and take it to the village as the starting point for the discussion that will develop the village map. If no digital map is available, a map can be made by following this simple procedure: clear a large piece of open ground or, if indoors, use a big sheet of paper and use available material as markers, e.g. sticks, stones, leaves, chalk.

a) Next, either on the hand-drawn or digital printout, ask the farmers to mark out the village area and the key features of the landscape mentioned above and discuss, for example

i. The present situation

ii. The past situation

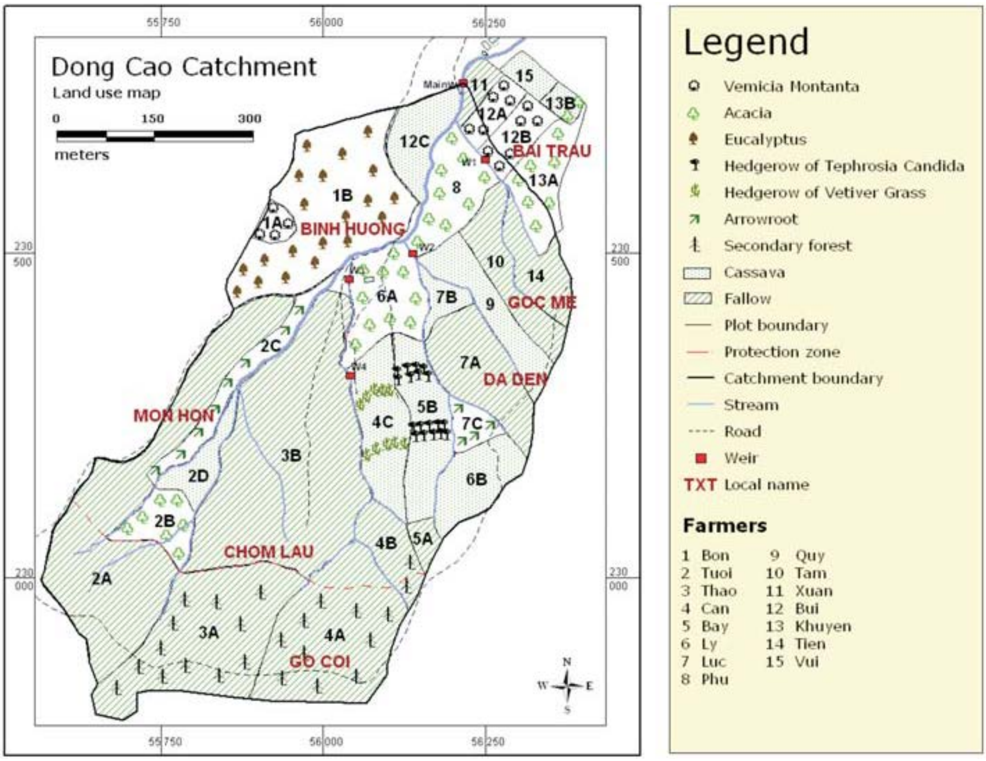

Figure A1. Example of a village map

Source: Fagerstrom *et al.*, 2005

iii. The future if things don't change

iv. The future they would prefer

(v) Go on a **transect walk** with farmers to understand the soil, plant, water, land use, land ownership, slope, social and cultural interactions in the area. A transect is a straight line that goes through a particular area that has features mostly common throughout the landscape (from the village margin to the village centre, from the top of the hill down to the stream, etc.).

a) Select a transect with the farmers using a survey map or online map (prepared in advance if there is no network coverage in the village)

b) Select the farmers who have fields or other activities along the transect and ask them to join the walk

c) Ask the farmers to show their plots along the transect. Walk, for example, from the foot to the top of a hill or between a paddy field and treed or other agricultural areas. Walk with the farmers and note what is seen. Try to obtain as much information as possible. Ask many "why?" and open-ended questions

d) Each plot that belongs to one farmer and has a homogenous land form and type of land use (e.g. paddy rice, maize field on sloping land or a mixed tree

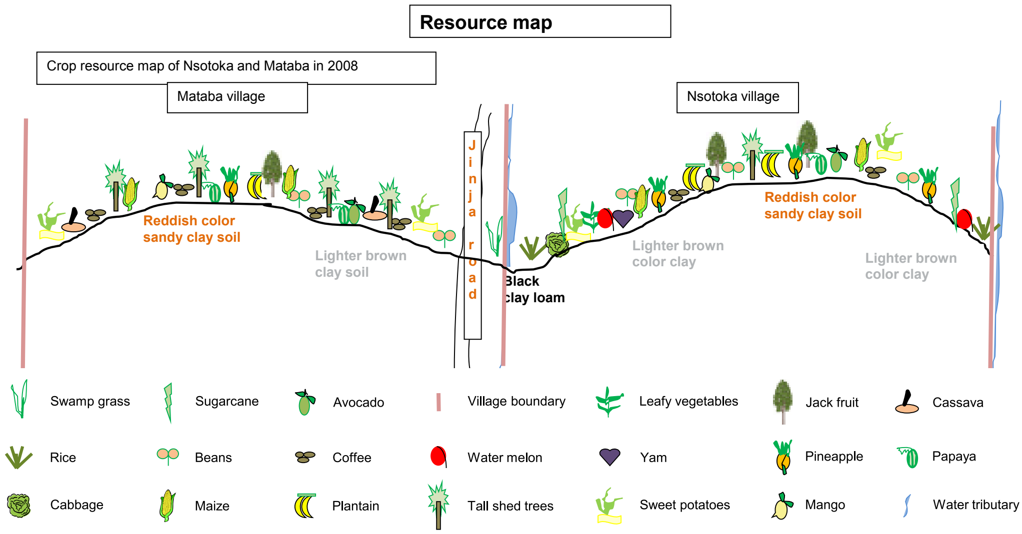

Figure A2. A resource map of two villages was drawn based on observations from a transect walk

Source: Raj, 2009

garden), will form one section of the transect.

e) Describe each section, noting its borders, who owns it, any constraints such as caveats or conflict, how the land is used, the type of soil, the types of vegetation, the amount and flow of water, buffers and filters (see Box A1), the impact of humans, the length of the slope (if any) and other points of interest as you walk. Let the farmers on the walk see what is being written and drawn, to stimulate more discussion and openness.

f) One or more transects can be walked depending on the terrain and issues. The transect/s should cover most of the land-use types found in the area.

(vi) Draw up a **timeline** for each land-use type along the transect/s and/or for the fields. The timeline can be used to understand land-use changes over time. Seasonal calendars (see below) can also be created if the farmers are interested in changing their land use, e.g., planting trees and implementing some agroforestry practices.

(vii) Make a **village timeline** to understand the history and predict the future of the community and stimulate discussion of why and how the present situation came about and particular problems arose. The timeline can start as far back as people remember, include the present and also indicate possible futures. Bring together a group, usually of older members of the community but preferably with members with a range of ages and experience. Be prepared and know some general history of the place. Identify any sensitive issues that might arise and prepare the responses carefully in consultation

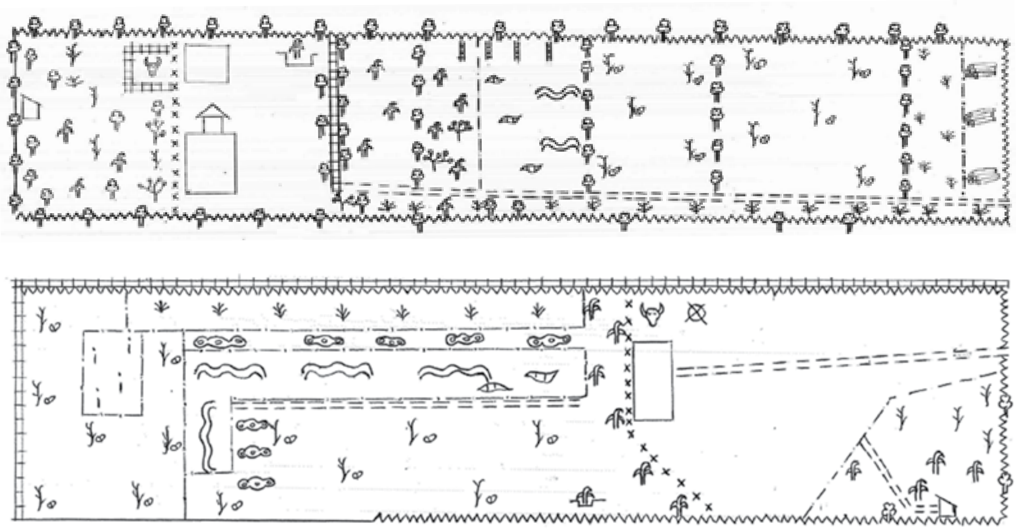

Figure A3. Farm sketches with (top) crops, livestock and many trees; and (bottom) with crops, livestock and few trees

Source: Swedish University of Agricultural Sciences/Y. Nyberg

with others who know the history better. Ask some easy historical questions first and allow plenty of time for discussion. Ask who lived in the area first, where they might have come from, the types of vegetation and land uses, any natural phenomenon such as floods or droughts, and any other significant events in the community's history. To get community perceptions of trending changes in the local environmental, economic, social or institutional patterns, ask how things have been changing. What is getting better or worse? What might the future look like? Are there alternative futures? Use pictures, writing or symbols to record the discussion for analysis.

(viii) Make **farm sketches** with the farmers to identify the resources on their farms and where different crops are grown and livestock kept. Then make a **seasonal calendar** with the farmers to understand seasonal changes (e.g. gender-specific workloads, diseases, income, expenditure, seasons and agriculture activities for all major crops.

a) Draw the year as a line or circle and explain the purpose

b) Start with something easy, like the wet seasons

c) Ask for the specific start and end times

d) If gaps appear, ask for the reason or activity at that time. On rice farms, there might be several seasons, crops other than rice, harvesting times etc

(ix) Make a **daily activity clock** of the different kinds of activities carried out in one day in order to see where new activities generated by introducing agroforestry could fit. This is useful for looking at relative workloads for the different groups in

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Comments
27.3' SC, maize, SP, Sorghum, Cassava	7.3' maize, SP, Sorghum, Cassava					2.9' Cassava, maize			4' SP	7' SP, Maize	7.4' SP, Green grams Cow peas	6.2' /month Pension, Rent
55' Hptl, Domestic (+5'), Farm	84.5' School fees, farm	6' Farm	7' Farm	95' Building, School fees, Farm	7' farm	15' school fees	8.5' farm, domestic(+3')	35.5 school fees, farm	5.5' Farm	1' Domestics (+1')	15' Luxery/ Domestics	5'/mth domestics, 1'/ mth church
1	1	3	3	4*	4*	3	2	3	4*	4*	1	* Better food situation-> better health situation
2	3	4, ploughing, weeding	5, ploughing, weeding	5, ploughing, weeding	4	5, harvest	2	3	5, ploughing	5, ploughing	1	5&4=32 h/day, 3=24 h/day, 2=8 h/day, 1=0
SP	Cassava, Nuts (Sale)				SP (Hh)	Maize, Sorgum, beans (mainly Hh)	Maize, Sorgum, beans (mainly Hh)	Cassawa, beans (Hh)	Cassawa, beans (Hh)	Maize, Sorghum		Crop to harvest
River	River	River	Water hole (WH)	WH	WH	River	River	WH	WH	WH	River	Water source
More diseases (foot&mouth), 1-1.5 l milk/day			3-5 l milk/ day									weekdays grazing in the farmyard, weekends off --farm. Dry season less milk.
	Fertilizer (CaN)			Weeding by hand		Weeding by hand and ox				Burn and harvest		
			Weeding by hand, fertilizer, Roundup									
	Weeding by hand				Harvest	Chopping and trash lining and weeding						
			3 water	5 water						3 water		
1, 2 times	2, 5-6 times	3, 2 times/ week	4-5, daily	5, daily, heavy	4	2, 4-5 times, windy	2, 5-6 times	2-3, drizzle	2-3, drizzle	2, 3-4 times, weekly	1	Rainfall

Figure A4. Example of a seasonal calendar

Source: Swedish University of Agricultural Sciences/I. Lindell & G.M. Kroon

a community; compare the working hours, activities, tasks, leisure time and sleep periods; compare with different times in a year; and compare male and female groups.

a) Sit in pairs in which one is the facilitator and the other is the farmer or householder

b) For five minutes, the facilitator asks questions of the other person about their daily activities, creating a pie diagram for:

   i. a working day and

   ii. a holiday

c) Then the facilitator and farmer or householder change roles and do the exercise again

d) Then they both discuss their diagrams for two minutes

(x) Make a **who's who diagram** to learn about the important groups and institutions, links and conflicts in the area.

a) With focus groups (see below), identify the different groups in the area

b) Draw circles of different sizes to indicate their importance: the bigger the circle, the more important the group

c) Position the circles in relation to each other according to the frequency of interaction: groups that rarely interact will be further away from each other; those that interact frequently and

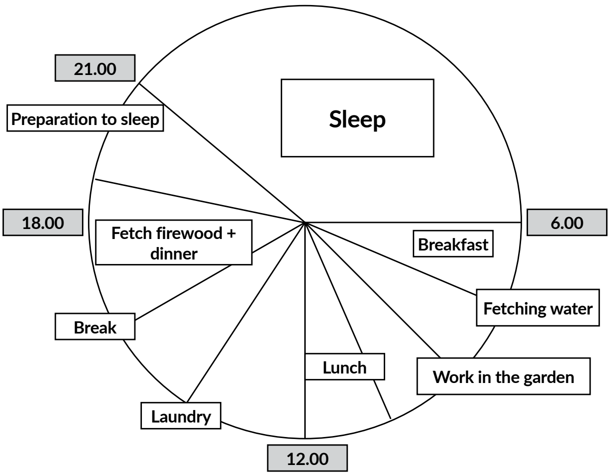

Figure A5. Example of a daily activity clock for female farmer

Source: Swedish University of Agricultural Sciences/V. Guaman

share membership will overlap

d) Discuss the reasons for the differences in sizes and distances

(xi) Hold **focus group discussions** to gather a variety of views on a topic from a specific, well-defined population. Restrict the group to 5–10 participants based on purpose, e.g. women, men, mixed genders, younger, older, mixed ages, type of farm or wealth. Explain clearly the purpose of the discussion and that nothing is wrong to say, that people have different views that will be respected in the group. Make sure there is a facilitator or chairperson. Use the local language or a language comfortable for all. Ensure a proven and accurate interpreter is present if needed. Make sure everyone understands the purpose and content of the discussion. Have several questions ready for the same issue. Avoid leading questions. Ask many "why" and open-ended questions (why, who, what, when, how, where?). Ensure that everyone has a chance to speak. Keep the discussion on topic. Take notes (or ask the group to choose a note-taker), use flip charts or whiteboard if available so everybody can see what is being noted but also use a recorder because it is impossible to take notes on all that is said. Keep the discussion to around 2 hours. Certainly don't go any longer than 4 hours. Keep to a time plan that includes a break for refreshments. Observe the group. Rank and score (see below) the various options, preferences etc listed by the group.

(xii) **Ranking and scoring** is used to understand the main preferences, priorities, needs, constraints or problems of a person or a group on a certain subject, in this case, the use of trees in rice-production landscapes. The process is simple.

First, either rank a number of options listed or draw a matrix and carry out the ranking:

a) Develop a **list** of options (needs, constraints and opportunities) through brainstorming with the group. Ask them to rank the options based on the preferences and aspirations of the group (e.g., income generating, providing food and nutrition, saving labour, etc.).

b) The options can also be arranged in a matrix before ranking by drawing a box table on paper or on the ground using a stick. Form a question and then mark the issues raised on both the top and side of the matrix. The issues can be those identified in the exercises above or come from the group drawn specifically for this

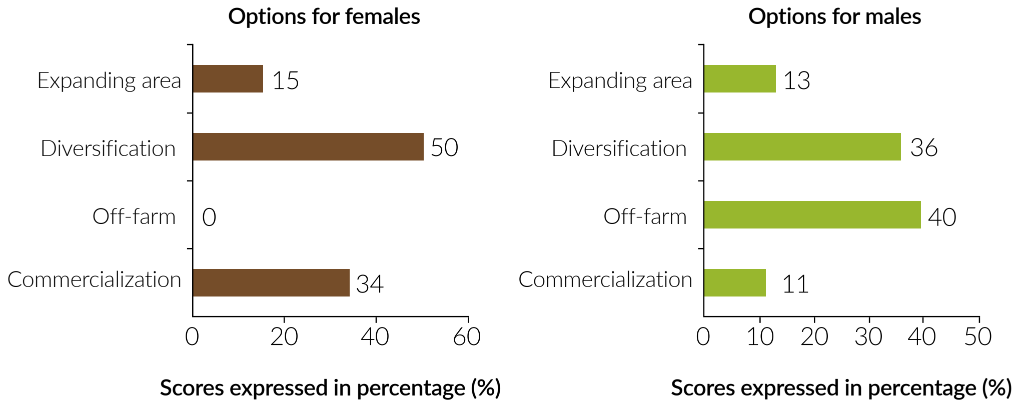

Figure A6. Scoring of options for future development of agriculture in a village

Note: Results from focus group discussions on community aspirations with female and male farmers

Source: Swedish University of Agricultural Sciences/I. Okeyo

exercise. In the case of trees in rice-production landscapes, a question to be ranked and scored might be, "What stops you from including trees in your rice farm?" and the reasons might be "lack of knowledge about which trees are best", "lack of good-quality seeds and seedlings", "shading the rice and reducing yields", "trees harbour pests like birds and insects" and "no space to grow trees". Make sure all the possible issues are listed.

c) With the group, identify their preferences and priorities and add them to the matrix using coloured paper, markers or things in the field, such as fruit, stones or sticks.

d) Ask them their reasons for their ranking, using many "why" and open-ended questions and take notes.

e) Second, for scoring, for each issue, let the group or each person score them according to which is more important or has greatest potential. Vote using beans, stones or other readily available things. If voting individually, ensure all participants have the same number of votes (e.g. 20)

(xiii) Conduct **individual interviews**. Select interviewees based on the purpose of the interviews and what is wanted to be known, their gender, age, type of farm, area in which they live or work, wealth, etc. Use open-ended questions, using "what", "when", "why", "who". For example, "What do you think about trees on rice farms?" or "What do you think about fruit trees on your rice farm?" Avoid questions that lead the interviewee towards answer (leading questions NOT be used are "Do you think it's good to have trees on your rice farm" or "Wouldn't you make more money if you had fruit trees on your rice farm?"). If you are preparing questions that will be translated, discuss them carefully with the translator or interpreter to ensure there are no errors or possibilities for misunderstanding. There are several types of interview.

a) Formal and Structured: these interviews use a questionnaire[ii] and are primarily one way, that is, the interviewer doesn't discuss the issues with the interviewee. The interviewer asks the questions and records the answers. If they interviewee seems to have misunderstood the question or said very little, the interviewer might rephrase it or ask for more information.

b) Informal, Semi-structured and In-depth. These types are two-way communication in a relaxed manner using a checklist of topics. Typically, the same question is asked in several different ways to avoid misunderstandings and elicit full and complex answers. Answer of question 1 will often lead to questions 2 and 3 in a form that is more like a dialogue. Start with some easy questions and note the interviewee's body language to check for ease and openness.

(xiv) **Compile all the data** from the various methods into a presentation suitable for farmers and other interested people. This usually will take some time and involve the whole survey team to ensure that all information is captured.

(xv) **Analyse the data with the survey group.** The sketch transects, maps, timelines, ranking and scoring, interview results and any other results from whichever methods used should be discussed by the group and all findings compared and cross-checked in order to create a complete picture of the landscape's patterns, issues and potential solutions.

(xvi) **Report the survey findings** to the farmers, government agencies, business, non-governmental organizations and others who were involved in the process or who have an interest, to receive their feedback and to agree on the next step. Presentation of the findings will require return visits to the villages from which the information was gathered to ensure that the farmers are continuously involved in the process and are able to not only add or adjust information but also learn about the opinions of other farmers and the situation in other villages and those of government agencies, businesses and non-governmental organizations. Presentations should also be made to the participating government agencies and other partners to ensure that everyone is aware of the issues and preferred options. In all cases, ask for feedback and modify the information accordingly.

Box A1. Buffers and filters

The concepts of "buffers" and "filters" in a landscape, as used here, are related. Buffers reduce variability, filters (selectively) reduce transmission. The technical definitions of "buffer" are based on variance reduction: rainfall is highly variable (being zero much of the time and having high values a couple of hours per year); stream flow is buffered, although still variable: if it was the same amount every day, buffering would be 100%. The concept of buffering applies to anything that varies and where variation matters: prices, rainfall, temperature, politics, human health in the face of diseases, crop health in the face of pests, soils' water content etc. Buffering cannot, however, shift the means over a longer time period. Filters can. Filters separate particles from their carrier, as a paper or metal coffee filter does. Landscape filters can intercept some of the soil particles in the overland flow of water by allowing them to settle. Filters intercept monetary (or budget) flows, preventing funds from reaching downstream people. Filters lead to selective transmission of information. In the context of PaLA, the buffers and filters relate mostly to water flows and erosion and sedimentation processes. The strips of land along rivers, or in other strategic positions in a landscape, that have a filter function can be called "filters" themselves. The term "buffer" is often used as shortening for "buffer zone", an area in between intensive agriculture and conservation of natural habitat and associated biodiversity. The buffer zone buffers human influence on wildlife and wildlife influence on humans.

Table A1. Overview of shade effects on pests and diseases

Causal factor	Desirable effects	Undesirable effects
Reduced UV radiation	Reduced sporulation and spore release of fungi	Protection of pathogens from lethal UV radiation
Reduced temperature	Reduced activity of sun-loving herbivorous insects	More favourable temperature for microbial growth, increased activity of shade-loving herbivorous insects, reduced activity of many hymenopteran parasitoids
Reduced temperature fluctuations	Reduced dew formation on plant surfaces, which reduces humidity that is conducive to some diseases	
Reduced air movements	Less dissemination of spores and propagules	Prolonged leaf and fruit wetness favouring microbial growth and infection
Increased atmospheric humidity, slower drying of plant surfaces	Increased efficiency of entomopathogenic fungi	Increased release of fungal spores, spore germination and microbial growth
Interception of rainfall	Reduced spore dissemination by splash effects under small-leaved trees	Coalescence of raindrops and increased splash dispersal of spores under large leaves
Mechanical effects	Protection of crops from damage by hail storms which could create entry points for infection	Increased damage from falling branches, etc.
Associated biodiversity of shade trees	Trees harbour natural enemies and antagonists of crop pests; non-host plants as dispersal barriers for pests, diseases, and their vectors	Trees serve as alternative hosts or provide physical protection to crop pests, diseases and their vectors
Increased soil organic matter content and nutrient availability	Enhance antagonist potential of soil microorganisms against pests and diseases which will protect crop vigour and improve nutritional status of certain tree crops under shade	Competition between crops and shade trees for water and nutrient reduces crop vigour
Reduce susceptibility of crops to pests and diseases	Reduced stress from excessive temperature, radiation and transpirational demand; avoidance of excessive vigour favouring some biotrophic infections	Etiolated and weak plants under excessive shade

Source: Schroth *et al.*, 2000

Table A2. Some important pests and diseases that affect taxonomically related crop and tree species

Pest or disease	Principal groups of affected plant species	Affected plant species from other families
Insects		
Bruchids	Many herbaceous and woody legumes	
Rhynchophorus palmarum	Many cultivated and wild palm species	Papaya, sugarcane
Erinny sello	Manioc and rubber trees	Papaya
Sahlbergella and other mirids	Cocoa	
Conopomorpha cramerella	Cocoa	Rambutan
Hypsipyla spp.	*Meliaceae* (many timber trees)	
Viruses		
Cocoa swollen shoot virus (vector: many insects)	Cocoa	
Fungi		
Moniliophthora roreri (moniliasis = frosty pod)	Cocoa	
Crinipelli sperniciosa (Witch's broom)	Cocoa	
Nematodes		
Bursaphelenchus cocophilus	Red ring disease of coconut and other palm species	
Phytoplasma		
Lethal yellowing	Coconut and other palm species	*Pandanus utilis*

Note: "Related group" refers to taxonomically related crop and tree species. Affected plant species from other families are also indicated

Table A3. Some important pests and diseases that affect taxonomically unrelated crop and tree species

Pest or disease	Affected crop species	Affected timber and service tree species
Insects and mites		
Helopeltis clavifer	Cocoa	*Eucalyptus deglupta*
Planococcus citri	Cocoa, Citrus	*Leucaena leucocephala* *Erythrina*, *Tephrosia*
Cratosomus flavofasciatus	Citrus	
Scirtothripsa wemdii	Orange (*Citrus sinensis*)	
Viruses		
Peanut bud necrosis (vectors: thrips)	More than 370 plant species from more than 50 families	Many legumes
Fungi		
Phythophthora cinnamomi	More than 1000 species and varieties of plants, e.g. avocado and pineapple	*Eucalyptus* spp.
Pellocularia koleroga	Many species, e.g. coffee, mango and orange	*Acacia mangium*
Sclerotium coffeicola	Many species, e.g. coffee and mango	
Colletotrichum gloeosporioides	Cassava	*Gliricidia sepium*
Mycena citricolor (South American leafspot or cock's eye disease of coffee)	More than 150 species, e.g. coffee, citrus and mango	Several native and introduced forest trees
Many soil-borne fungi, e.g. *Armillaria*, *Fomes*, *Ganoderma*, *Rosellinia* and *Verticillium*	Many cultivated and wild tree species	Many cultivated and wild tree species
Nematodes		
Meloidogyne incognita *M. javanica*		*Sesbania* spp. *Acacia* spp.
Radopholus similis	Approximately 100 species, e.g. banana	*Sesbania* spp.

1 Franzel, 2004
2 Franzel, 2004

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