Practitioner's Field Guide

AGROFORESTRY FOR CLIMATE RESILIENCE

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Practitioner's field guide

AGROFORESTRY FOR CLIMATE RESILIENCE

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PREFACE

One of the key goals of the *Vision and Strategic Plan for ASEAN Cooperation in Food, Agriculture and Forestry 2016–2025*, endorsed at the 37th Meeting of the ASEAN Ministers on Agriculture and Forestry in 2015, is ‘expansion of resilient agroforestry systems, where ecologically and economically appropriate’, expressed in an action programme under Strategic Thrust 4: To increase resilience to climate change, natural disasters and other shocks.

In line with the effort to support wide-scale adoption of resilient agroforestry systems in ASEAN Member States (AMS), three important knowledge products have been developed by World Agroforestry (ICRAF) together with RECOFTC The Center for People and Forests, ASEAN Secretariat, ASEAN Working Group on Social Forestry Secretariat and partners in the ASEAN-Swiss Partnership on Social Forestry and Climate Change.

1. *ASEAN Guidelines for Agroforestry Development*
2. *Training Manual: Agroforestry for Climate-Resilient Landscapes*
3. *Practitioner’s Field Guide: Agroforestry for Climate-Resilience*

This field guide, designed to accompany the training manual, aims to support the continuous learning and capacity building of agroforestry practitioners. It provides extension workers, farmers and other practitioners with technical guidance on designing, establishing and managing on-farm agroforestry practices that can assist with coping with the negative impacts of extreme climatic events, such as increased temperatures, extreme and erratic rainfall and prolonged droughts.

This guide is focused on different types of farmland in AMS. In each country, the guide should be adapted in accordance with the specific biophysical and socio-economic contexts of a given landscape under climate change.

ACKNOWLEDGEMENTS

This publication is the product of a collaboration between ICRAF and RECOFTC. We express special thanks to the Swiss Agency for Development and Cooperation for financial support and we extend our sincere thanks to the ASEAN Secretariat and the Secretariat of the ASEAN-Swiss Partnership on Social Forestry and Climate Change for providing us with the enabling environment to develop this guide. We are grateful for the scientists and colleagues of ICRAF in Indonesia, Viet Nam and the Philippines and RECOFTC in Bangkok who devoted their time to provide us with valuable comments and inputs. Finally, grateful thanks are given to the editors for their hard work efforts in elaborating, reviewing, editing and completing the field guide.

ABBREVIATIONS

ASEAN	Association of South-East Asian Nations
AMS	ASEAN Member States
AWG-SF	ASEAN Working Group on Social Forestry
AMAF	ASEAN Ministers on Agriculture and Forestry
ASFCC	ASEAN-Swiss Partnership on Social Forestry and Climate Change
ICRAF	World Agroforestry
IPCC	Intergovernmental Panel on Climate Change
RECOFTC	Regional Community Forestry Training Center for Asia and the Pacific
SDC	Swiss Agency for Development and Cooperation

CONTENTS

INTRODUCTION

Climate change is increasingly experienced in Southeast Asia in the form of rising temperatures, longer periods of hot weather, prolonged droughts, more powerful typhoons, and extreme rainfall. Farmers in many parts of the region are facing degradation of arable land, shortages of water, increased occurrence of pests and diseases, declines in crop and livestock productivity and loss of yields. Consequently, their income and food security have been severely threatened.

Accordingly, climate-resilient land-use practices have become a critical topic. Agroforestry — the practice of deliberately integrating trees with crops and/or animals on the same land unit to provide a range of agricultural and forestry products and environmental services — can help to increase the resilience of farmlands and whole landscapes to climatic stresses. However, lack of knowledge and technical skills to design, establish and manage agroforestry restricts practitioners from undertaking such climate-resilient practices.

PURPOSE

This guide has been developed to support the continuous learning and capacity building of agroforestry practitioners. It provides a set of technical instructions and tools for assisting farmers to design, establish and manage on-farm agroforestry practices that are resilient to climate stresses and extreme events.

TARGET USERS

This guide is for agroforestry practitioners who assist farmers to undertake agroforestry practices in the field, including (but not limited to) 1) Extension workers or rural advisors in forestry and agriculture; 2) Forestry and agricultural officers and technicians; 3) Community forestry or natural resource management staff; and 4) Development-project field staff.

It may also be useful for farmers who are interested in the design and practice of agroforestry on their farms and researchers and students who want to learn to develop climate-resilient agroforestry systems in the field.

HOW TO USE THIS GUIDE

This guide is not a ready-made 'cookbook' with recipes to be applied for any location. It is a general, basic guide for designing and practising agroforestry for climate resilience in uplands, lowlands, coastal zones and other areas. In any specific landscape and climatic context, further elaboration of the field guide is needed.

CHAPTER 1

CLIMATE CHANGE: THE PROBLEM

1.1 CLIMATE CHANGE

Climate change refers to significant changes in average weather parameters — such as temperature, wind and rain — experienced in a region over a long period of time. Increasing temperatures, erratic rainfall patterns, extended droughts, more frequent typhoons, warmer nights and hotter days are commonly associated with climate change (Figure 1.1).

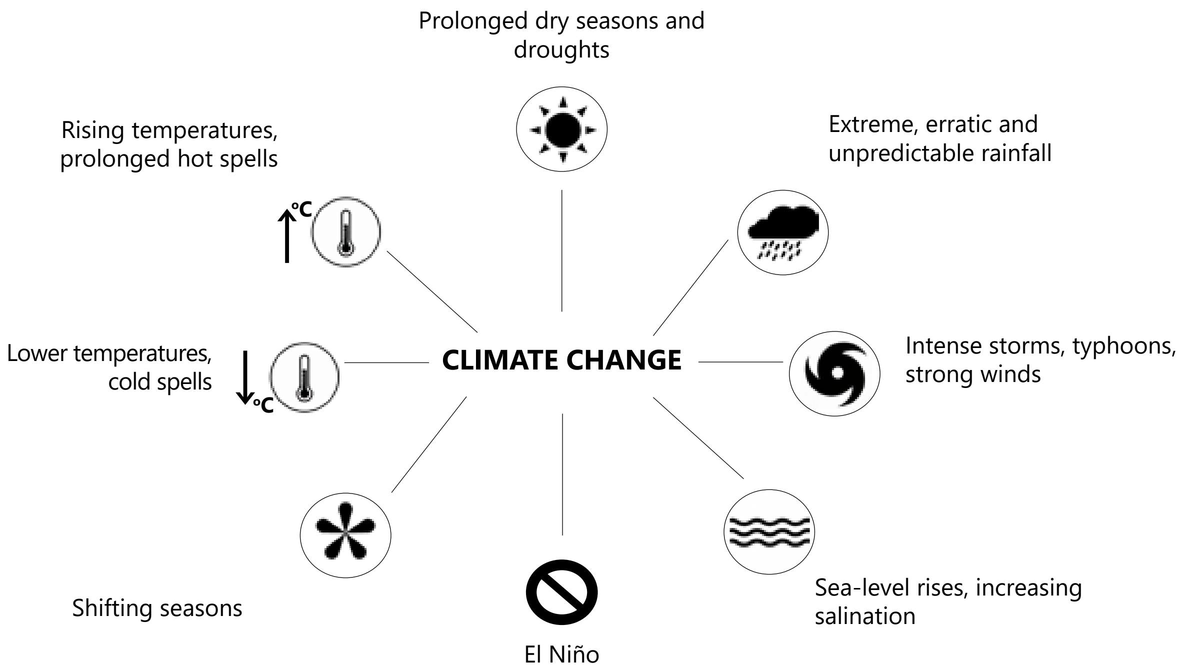


Figure 1.1 Examples of extreme events owing to climate change

1.2 IMPACTS OF CLIMATE CHANGE

Climate change is real and has had serious impacts on land, water, crop production and local livelihoods, as experienced by farmers in many locations. These impacts differ from place to place depending on the context of the specific ecological region.

Figure 1.2 Lack of water for irrigation owing to prolonged drought leading to loss of the rice harvest

There are serious impacts of climate change on land, water, trees, crops, animals and people. Some examples are listed in the table below.

Table 1.1 Impacts of changes in climate

<table>
<tr><th>Climatic issues</th><th>Water</th><th>Land</th><th>Crops and trees</th><th>Animals</th><th>Farmers</th></tr>
<tr><td>Rising temperatures</td><td rowspan="2">Decreased water availability

Lack of water for irrigation and human use</td><td rowspan="2">Hardened soils

Cracked soils

Increased wind-induced soil erosion</td><td rowspan="2">Stunted, slow growth and loss

Decreased yields</td><td rowspan="4">Increased diseases and deaths</td><td rowspan="5">Declining harvests and income

Increased debts

Food shortages

Increased malnutrition

Increased occurrence and spread of diseases</td></tr>
<tr><td>Prolonged dry seasons, droughts</td></tr>
<tr><td>Intense storms, typhoons, strong winds</td><td rowspan="2">Landslides and floods

Contaminated water</td><td rowspan="2">Increased run-off and soil erosion

Decreased soil fertility</td><td rowspan="2">Crops damaged

Growing seasons and cropping patterns changed

Decreased yields</td></tr>
<tr><td>Extreme and erratic rainfall</td></tr>
<tr><td>Sea-level rises</td><td>Saltwater intrusion

Decreased freshwater availability</td><td>Damaged shorelines

Inundation stress, increased salinity</td><td>Mangrove ecosystems threatened</td><td>Decreased areas for grazing</td></tr>
</table>

1.3 CLIMATE RESILIENCE

Resilience is ‘the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change’ (IPCC 2008).

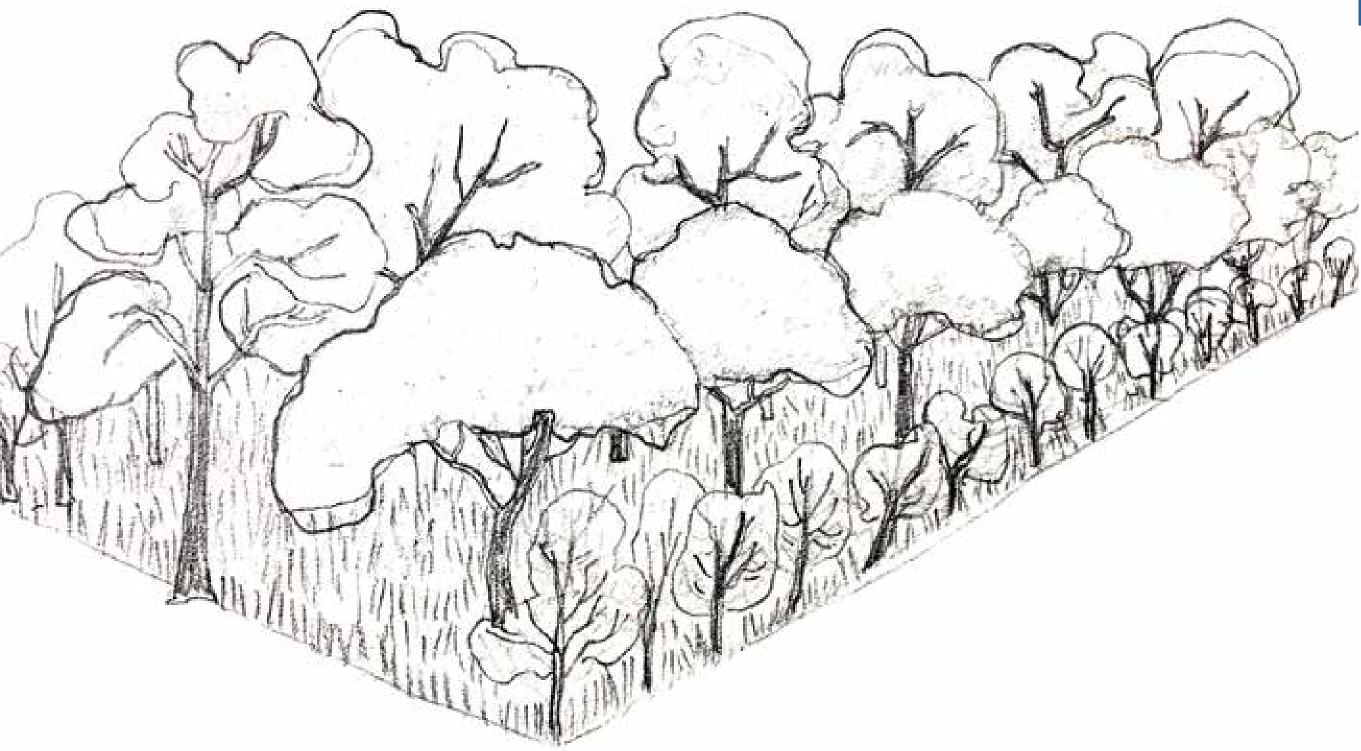
1.3.1 Attributes of resilient farming practices

- Conserve soil, soil fertility and water to ensure sustainability of production
- Diversify products and income, offering safeguards against losses owing to climatic stresses
- Maintain or increase productivity of farmland, leading to increases in yields and security of food supplies and the livelihoods of farmers
- Adapt to climate change: being able to function as well as reduce the effects of stresses
- Are adoptable: suited to local social and biophysical conditions; implementable by farmers
- Connect with other land-use practices, enhancing environmental health and the resilience of the landscape

1.3.2 Examples of climate-resilient practice

Figure 1.3 Highly productive pastures in the tropics require water and nitrogen, therefore, they are highly vulnerable to drought. Note: The figure shows an example of the impact of drought in Llanos Orientals in Colombia. Source: Altieri et al (2015)

Figure 1.4 Intensive silvopastoral systems with an overstory of shrubs and trees are resilient, allowing for continuous availability of fodder. Source: Altieri et al (2015)



CHAPTER 2

AGROFORESTRY: A SOLUTION

2.1 AGROFORESTRY

‘Agroforestry’ refers to land-use systems and technologies in which woody perennials (trees, shrubs, palms, bamboos etc) are deliberately used on the same land-management unit as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems, there are both ecological and economic interactions between different components. Agroforestry includes trees on farms and in agricultural landscapes, farming in forests and at forest margins and also tree-crop production.

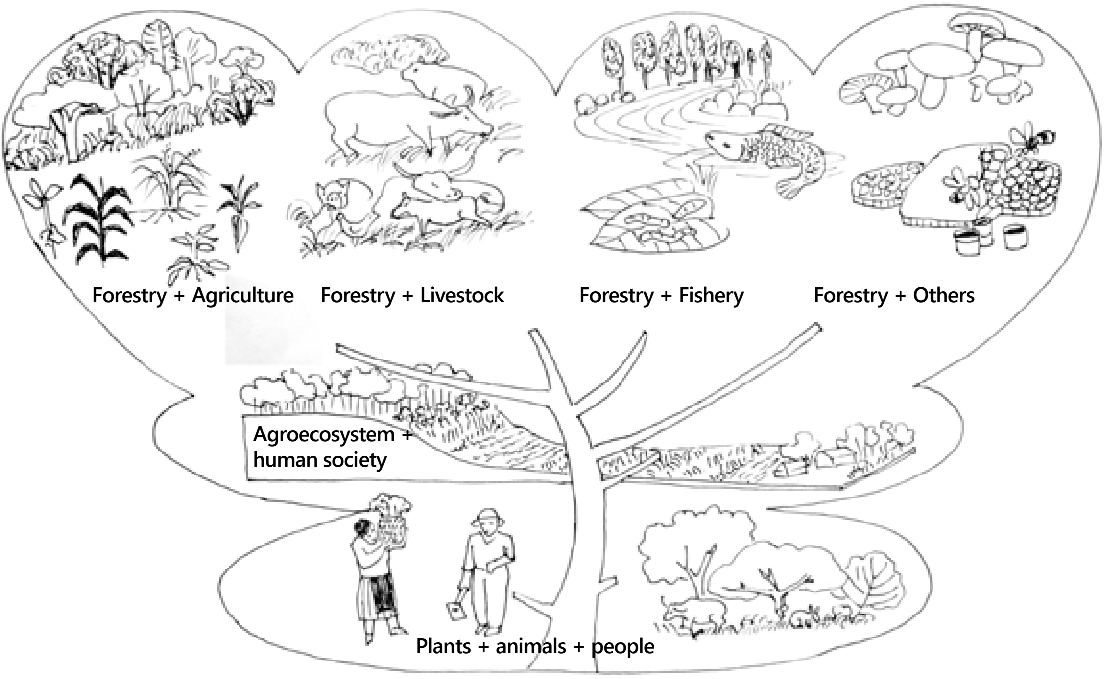


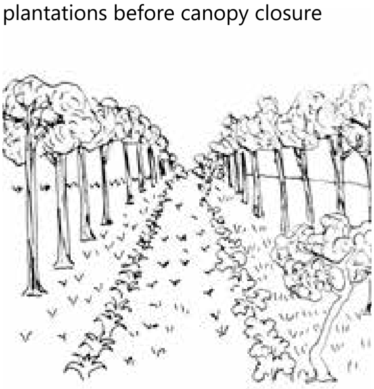
Figure 2.1 Agroforestry is an integrated, dynamic system. Source: Modified from Xu et al (2013)

There are several criteria for defining agroforestry practices.

- *Intentional:* trees, crops and/or livestock are intentionally designed, established and managed to work together and yield multiple products and benefits
- *Intensive:* agroforestry practices are created and intensively managed to maintain their productive and protective functions
- *Integrated:* the trees, crops and/or animal components are structurally and functionally combined into a single, integrated management unit
- *Interactive:* agroforestry seeks to actively manipulate the biophysical and physical interactions among the components to yield multiple harvestable products while providing numerous conservation and ecological benefits

Agroforestry practices can be classified according to functions, structure, socioeconomic purpose, and ecological criteria. The figure below provides illustration of some agroforestry practices commonly found in the region. For more information on different typologies of agroforestry practices, see Nair 1993 and Xu et al. 2013.

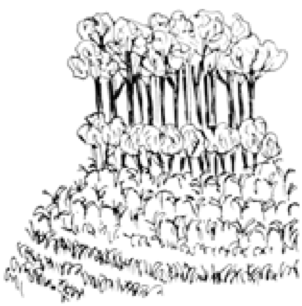
Taungya: Crops intercropped with trees for 1–3 years at the beginning of tree plantations before canopy closure



Hedgerow/alley cropping: Hedges and trees planted in parallel rows; crops are planted in the alleys between rows

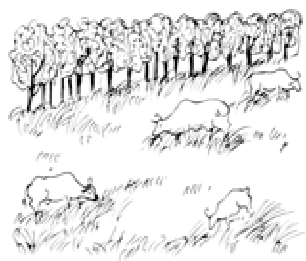
Trees/shrubs on farmland: Trees are randomly grown and distributed on farmland

Agroforestry woodlot: Trees planted on a section of farmland for production of sawlogs, fuelwood etc



Windbreak/shelterbelt: Trees are planted in rows across the direction of damaging winds to protect crops

Tree on pasture/silvopasture: Trees grown on rangelands, providing shelter for animals and supporting growth of grass



Woody hedges/boundary system: Trees planted along field boundaries or other borders, e.g. irrigation channels

Home garden: Trees, shrubs, herbaceous plants grown together close to a homestead

Aquaforestry: Aquaculture that includes trees, e.g. shrimp, fish, crab production and mangroves

Figure 2.2 Examples of agroforestry practices. Source: IIRR and FAO (1995)

2.2 AGROFORESTRY'S CONTRIBUTION TO CLIMATE RESILIENCE

Diversification of agricultural production. Agroforestry involves multiple production activities that are complementary in both economic and ecological dimensions at farm level. Agroforestry is the pathway for sustainable diversification of agricultural systems, helping to provide a variety (crop, tree and animal) of products and benefits to farmers — such as food, fodder, fuelwood — at different times of the year, thereby, reducing the risk of crop failure and food shortages or insecurity when facing climatic stressors.

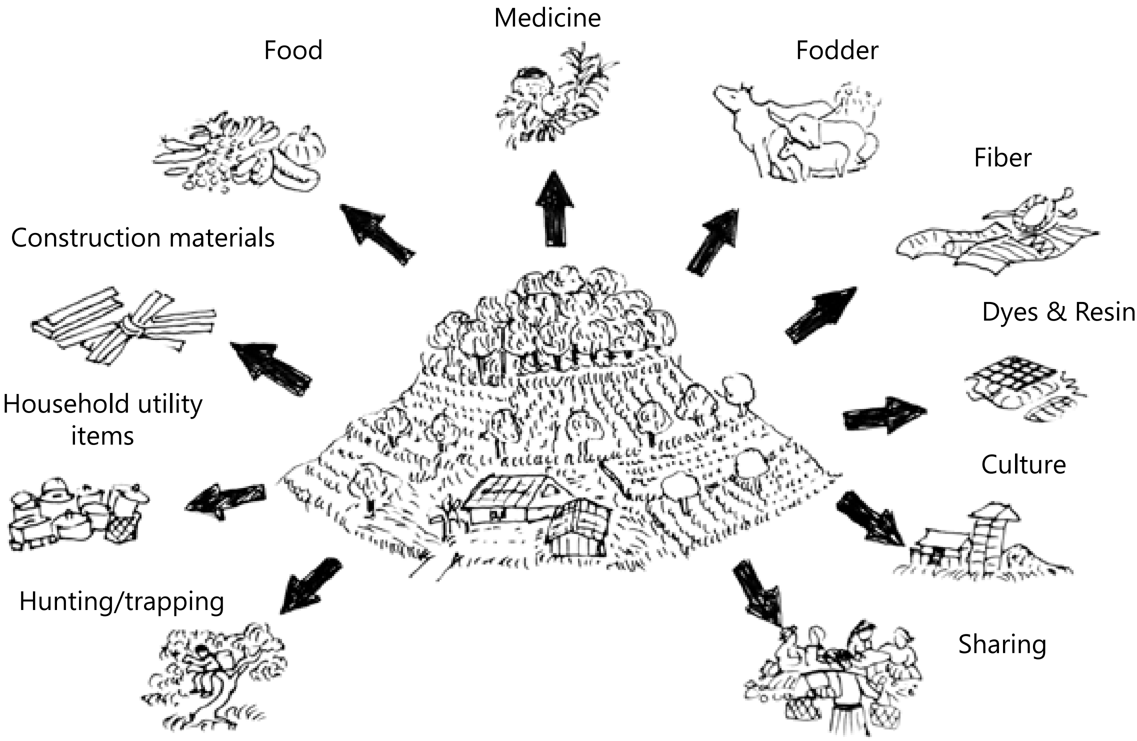


Figure 2.3 A variety of products and services are produced from agroforestry. Source: Xu et al (2013)

Nutrient cycling. Agroforestry practices are critically important for improving soil fertility. For instance, leguminous trees planted with crops can accumulate significant amounts of nitrogen in their leaves and roots, which can subsequently be available to crops.

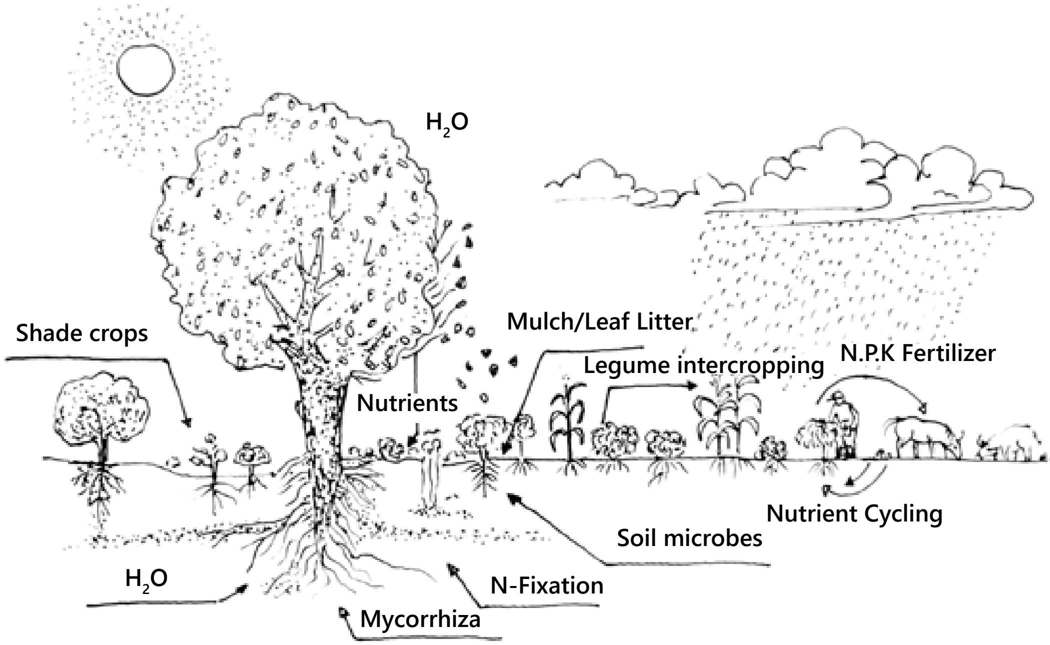


Figure 2.4 Nutrient cycles in an agroforestry system. Source: Xu et al (2013)

Control of erosion and conservation of soil. Trees in agroforestry systems can significantly reduce or even eradicate soil erosion caused by wind and water (including flooding) and prevent the run-off of sediments and pollutants (for example, chemicals) into waterways. Trees also enhance infiltration, stabilize soils and reduce the erosion of riverbanks, thereby keeping essential soil nutrients from being eroded.

Figure 2.5 Trees planted along contours as hedgerows to slow run-off, enhance water infiltration and stabilize the soil

Ameliorating microclimates. The full genetic potential of many crops and animals can only be exploited under optimal environmental conditions. In an agroforestry system, trees help reduce heat and light, bring favourable changes in microclimatic conditions through influencing radiation fluxes, air temperatures and wind speeds, which protect and improve the productivity of crops, livestock and land.

Mitigating droughts. Tree canopies lower temperatures and increase relative humidity, which lead to a lower transpiration rate. Tree litters and pruning materials act as mulch on the surface of the ground, reducing the evaporative loss of moisture. The water-storage capacity of soil is also increased owing to increased content of organic matter.

CHAPTER 3

PARTICIPATORY AGROFORESTRY DESIGN FOR CLIMATE RESILIENCE

Participatory design of agroforestry is an iterative process to ensure maximum potential for climate resilience. Each step requires monitoring and evaluation as a feedback mechanism, learning both from successes and failures in an action-learning process, similar to the plan–act–monitor–re-plan cycle.

Steps in participatory agroforestry design for climate resilience

1. Getting started
2. Understanding the field situation
3. Designing field planting

3.1 GETTING STARTED

The first step includes several activities.

- Visit the community or individual farmer to observe the biophysical and socioeconomic conditions, particularly, to gather information related to climatic issues and to check the suitability of the area for agroforestry.
- Share information about agroforestry as a set of climate-resilient practices, explaining why and what it is. This can be done through a slideshow or other methods. Organize farmers into groups to build leadership and take the initiative. Encourage the election of group leaders.
- Identify suitable areas for agroforestry, taking into consideration biophysical and socioeconomic conditions. Agree on achieving common goals and multiple outcomes, such as landscape restoration, ecological and economic benefits like food and nutritional security, employment and income, natural resources management, enhancing biodiversity and sequestering carbon.

3.2 UNDERSTANDING THE FIELD SITUATION: ASSESSMENT OF LAND-USE PRACTICES

The objective of this activity is to collect and share information on land use and management practices. Activities include an inventory of local knowledge, innovations and practices and listing useful agroforestry species (native and exotic trees). Several methods can be used.

- Transect walks
- Mapping of land use and land-use changes
- Matrix scoring of species and cultivation practices
- Ranking to identify the most promising agroforestry species for planting and the most appropriate management practices to adopt

The assessment covers biophysical parameters for soils, climate, adapted trees and crops.

- Soil parameters include soil pH, which determines acidity or alkalinity that can influence availability of soil nutrients
- Climate parameters include rainfall, temperature, humidity, occurrence of storms and droughts
- Vegetation assessment includes trees and plant species adapted in the area in relation to soil types, climate regime and elevation

Socio-economic factors include households' available land, market, labour and capital.

- Land: farm size, tenure
- Market: distance to markets
- Labour: seasonal availability, gender, family size, off-farm employment and availability of family and local labour
- Capital: household cashflows, availability and form of credit.

3.3 DESIGNING FIELD PLANTING

3.3.1 Key considerations

When designing agroforestry systems for climate resilience, the following elements should be considered.

A. Components: There are basic sets of components that can be managed by a farmer in an agroforestry system.

- **Trees**, which should be producing fodder, fruit, fuelwood, medicines and/or timber or assisting replenishment of soil fertility; and which are adapted to adverse climatic and soil conditions.
- **Crops**, particularly annual crops like grains and flowers, which are adapted to drought or waterlogging.
- **Animals,** especially those that can be used for draft power (such as buffalo) or produce meat, eggs or dairy products, which have shown the ability to adapt to a changing climate.

B. Tree root and canopy structure. This refers to how the roots and canopies of trees are layered and spread. The roots of trees and crops should have a combination of spreading roots for soil binding, which reduces soil erosion during intense rainfall, and deeply penetrating roots for soil anchorage, which provide better water infiltration during intense rainfall, thus, avoiding landslides and liquefaction. Appropriate canopy structures are 1) conical crown; 2) flat-topped, spreading crown; 3) tall bole and small, dense crown; and 4) narrow columnar crown. Canopy shapes that should be avoided are 1) rounded crown with dense canopy; 2) wide conical crown; and 3) wide columnar crown.

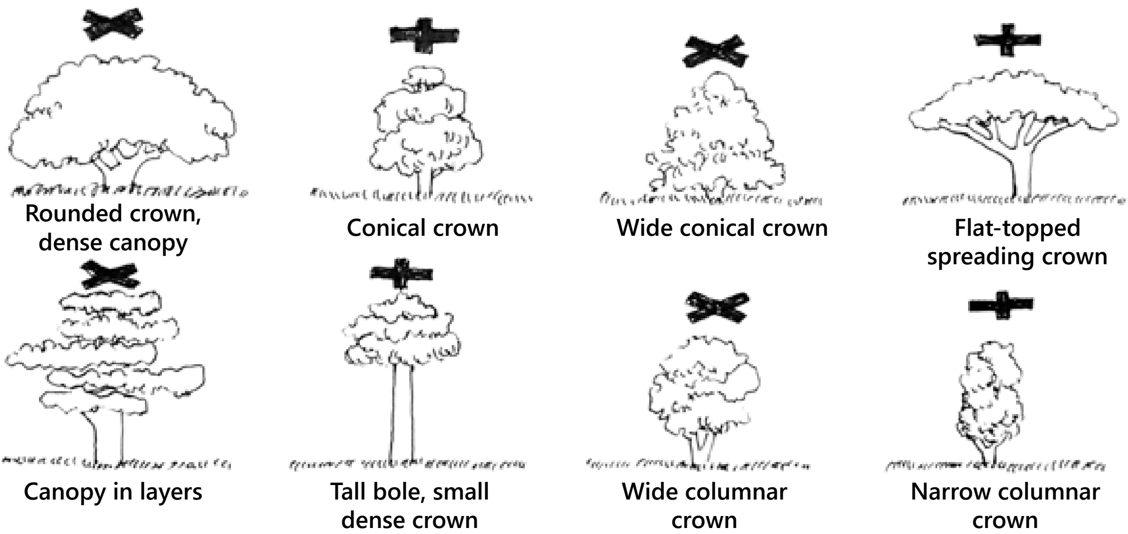


Figure 3.1 Canopy structures of trees suitable for agroforestry. Source: Mercado et al (2018)

C. Arrangement: Two kinds of arrangement are considered in any agroforestry system.

- **Spatial arrangement** refers to how plant components are physically arranged. This can be dense mixed stands, which are common features of home gardens, or sparsely mixed stands.
- **Temporal arrangement** refers to the pattern of shifting cultivation on a single piece of land. An example of this is using land for cropping for two-to-four years followed by over a decade of fallow when woody species are planted.

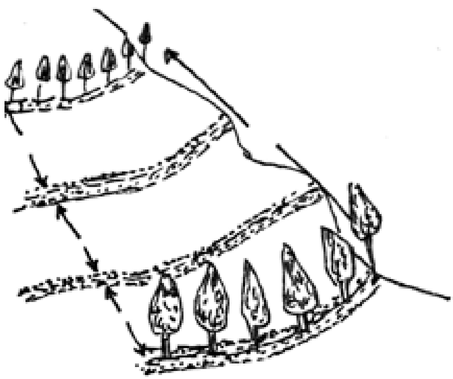
D. Management or function: This refers to the process in which inputs are introduced, managed and converted into outputs over a certain period to attain desired goals. Examples are propagation, weed control, fertilization, control of pests and diseases.

E. State or interaction: This refers to how the components of an agroforestry system interact with each other. The interactions may be positive, such as complementation or supplementation, or negative, such as competition or allelopathy.

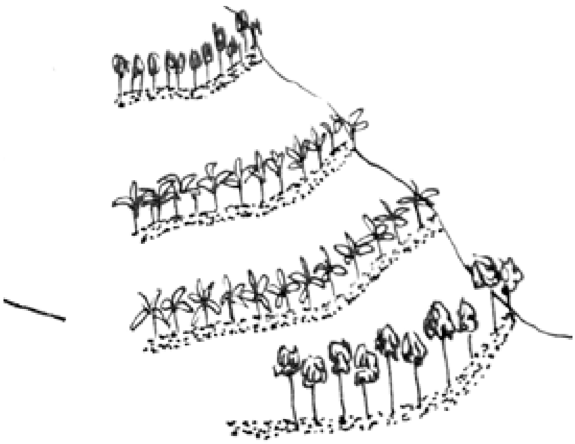
F. Hierarchy. This refers to the order of needs and priorities of farmers. Farmers may decide to have an annual cropping or perennial system. Selection of tree species, spatial and temporal arrangements are typically influenced by the farmer's decision to undertake annual cropping or perennial system.

Upland rice – Mango – Forage grass system
Photo: World Agroforestry/Do Van Hung

Teak – Plum – Coffee – Soybeans – Forage grass
Photo: World Agroforestry/Pham Huu Thuong



Schematic diagram of single tree-line agroforestry system



Schematic diagram of double tree-line agroforestry system

Figure 3.2 Examples of tree and crop arrangements in an alley-cropping agroforestry system on sloping land, based on a hierarchy of products and priorities. Source: Mercado et al (2016)

3.3.2 Selecting tree species

There are several factors to be considered in the selection of tree species.

- Knowledge about management of tree species
- Commercial value or local use of the trees
- Growth rate
- Availability of quality, certified germplasm
- Resistance to pests and diseases
- Less competitive for associated crops

- Small and open canopy
- Good root distribution

Selection may be conducted following the steps below.

A. Identify preferred species

Different species respond differently to extreme climate events and have varying resistance to pests and diseases. Selecting species that have different responses to extreme climate events will reduce the risks to the farmer's livelihood.

- Select locally grown species that have differing responses to specific climate events
- Select species that have differing susceptibility to pests and diseases

Table 3.1 Example of different species with specific responses under coffee agroforestry systems in Ogan Komering Ulu Selatan District, South Sumatra, Indonesia

Low production during droughts	Low production during heavy rainfall
Vegetables Coconut Bird's-eye chili Ginger Rubber	Clove Fruit (avocado, lansium, durian, parkia, mango-steen, archidendron) Bird's-eye chili Robusta coffee Rubber Pepper

Select preferred species based on biophysical suitability, market potential, and farmers' needs and interest.

Preferred species	Biophysical suitability	Market potential	Farmers' needs and interest

B. Classify the preferred species based on vulnerability to extreme climate events (adaptive capacity, sensitivity and exposure).

Identify the most frequent extreme climate events in the area. This information will be used to decide the role of agroforestry and, ultimately, to identify tree species that can adapt to the area's changing climate.

Species	Production response to extreme climate events				Response to market potential
	Heavy rain-fall	Drought	Strong wind	High temperature	

C. Select a combination of species that are resistant to extreme climate events and price fluctuations. Examples of combinations follow.

From 100% of total number of species:

- 20% of total number of species (and number of individual trees) are resistant to heavy rainfall
- 20% of total number of species (and number of individual trees) are resistant to drought
- 20% of total number of species (and number of individual trees) are resistant to high temperature
- 20% of total number of species (and number of individual trees) are resistant to strong winds
- 20% of total number of species (and number of individual trees) are resistant to price fluctuation

Trees and livestock farming have been reported to be less vulnerable to fluctuating weather conditions than rain-fed crops. Maintaining livestock is important in the event of crop losses.

3.3.3 Arrangement of species for climate-resilient agroforestry

The combination and arrangement of species in an agroforestry system should be based on the farmer's objectives, the biophysical characteristics of the site and the farmer's socio-economic conditions.

To achieve resilience, a system should combine species with various adaptation capacities to extreme climatic and soil conditions, pests and diseases, and market shocks.

There are different spatial arrangements of system components in agroforestry, which could be intentional or unintentional. For example, in a parkland type of agroforestry, trees are just allowed to grow, or planted sporadically in the field. Examples of intentional spatial tree arrangements are shown below.

- Trees along boundaries. The distance of the trees from other species needs to be considered (Figure 3.4).
- The double-row (Figure 3.5) and single-row (Figure 3.6) arrangements are common.
- Short-term agricultural plants intercropped between trees (Figure 3.7) or at the centre of the farm (Figure 3.8).

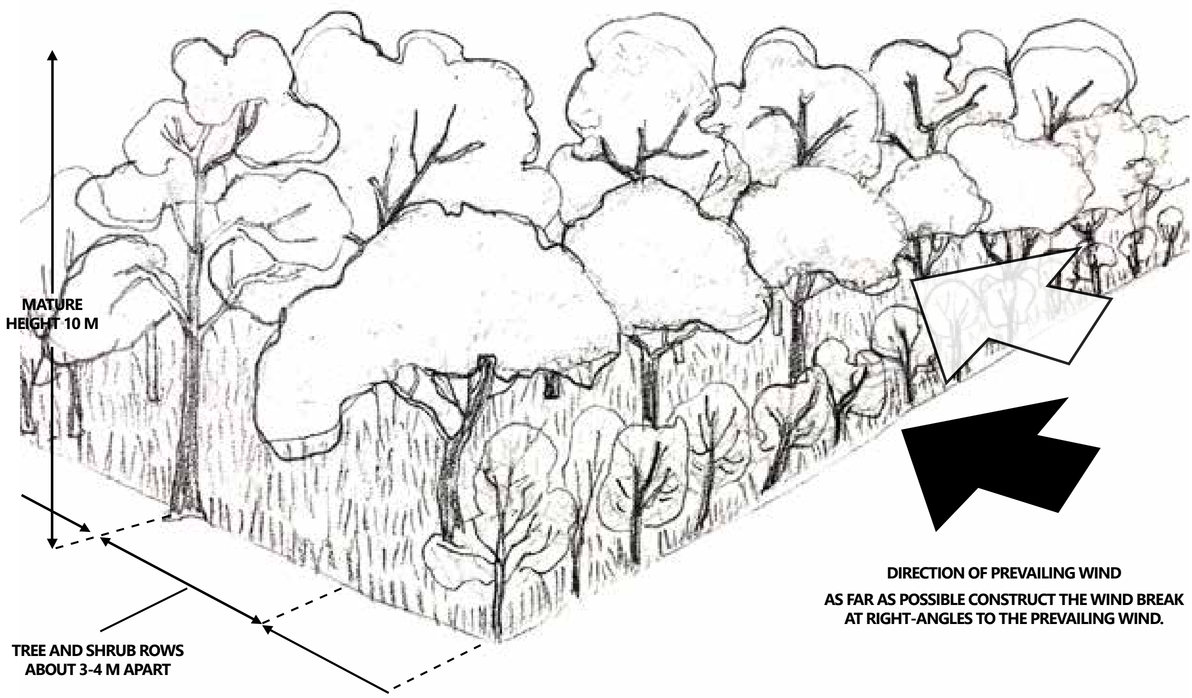


Figure 3.3 Arrangement of tree species in an agroforestry system deployed as a windbreak. Source: Tengnas (1994)

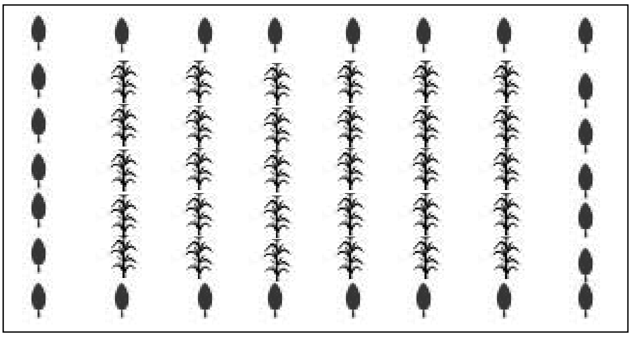


Figure 3.4 Trees along boundaries

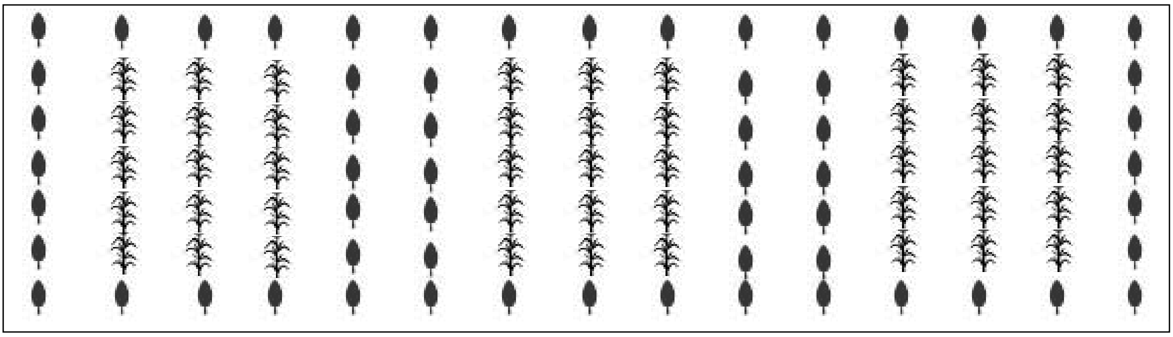


Figure 3.5 Double-row arrangement

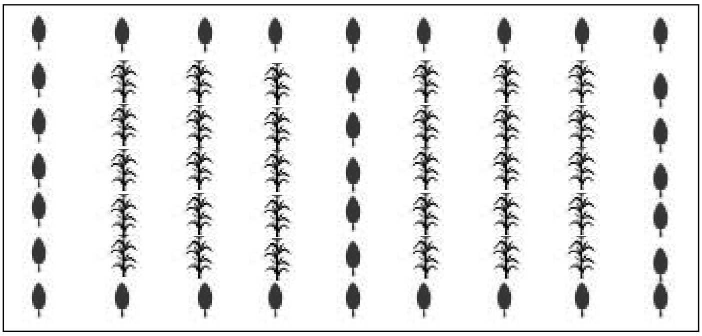


Figure 3.6 Single-row arrangement

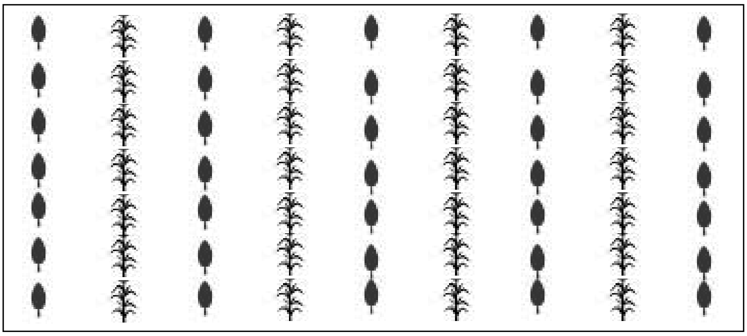


Figure 3.7 Agricultural plants intercropped between trees

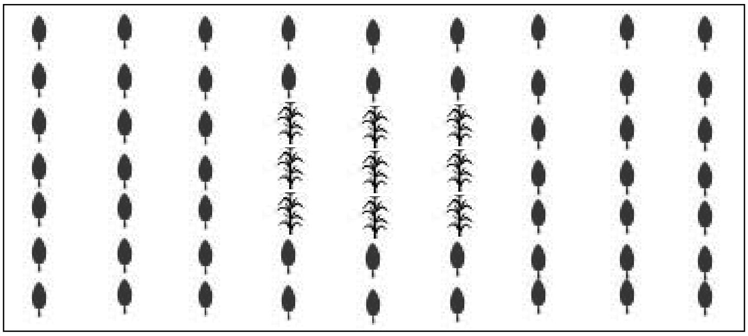
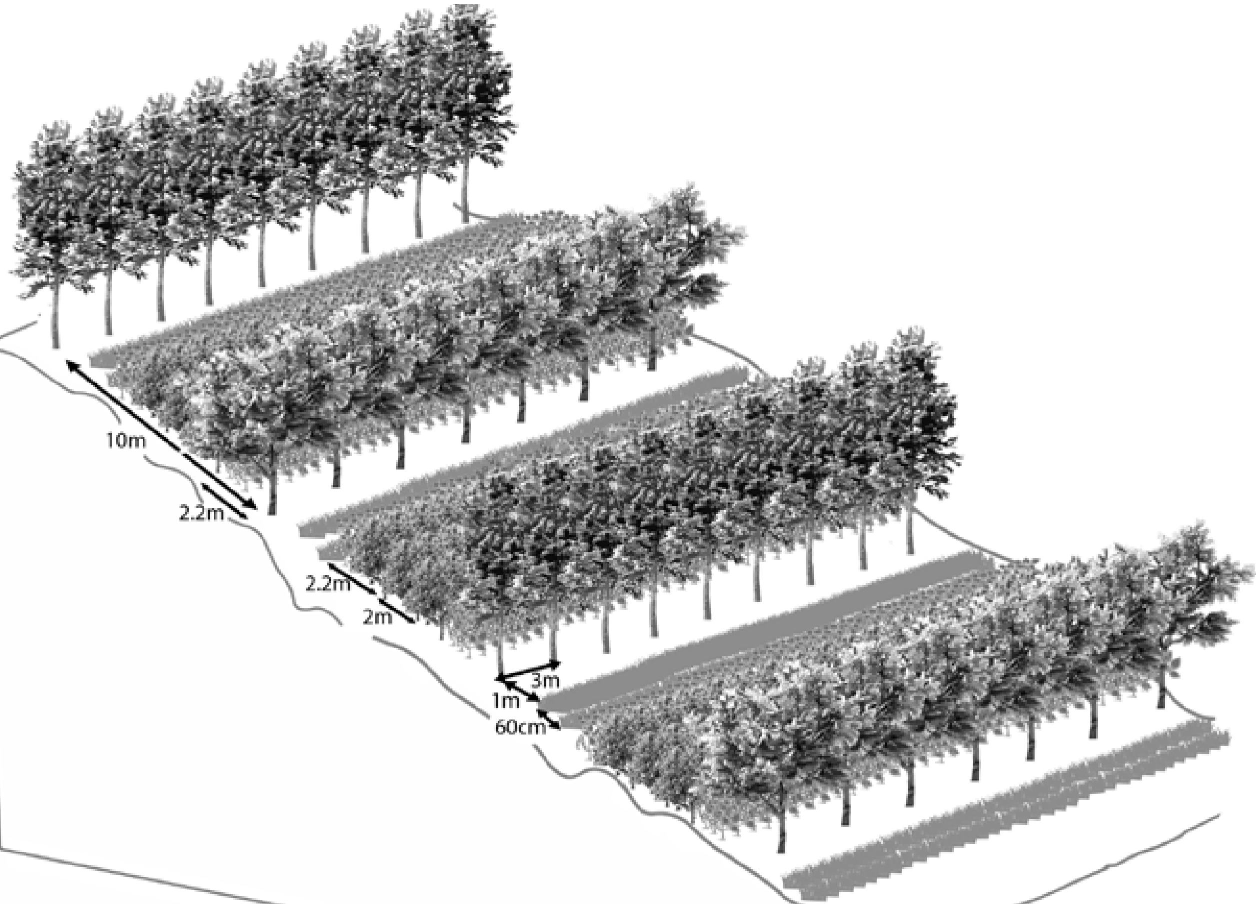


Figure 3.8 Agricultural plants at the centre of the farm



CHAPTER 4

AGROFORESTRY ESTABLISHMENT AND MANAGEMENT FOR CLIMATE RESILIENCE

Climate resilience as well as the success of an agroforestry system are very much dependent on proper establishment and management. After designing the desired agroforestry system, farmers should be ready to implement in the field. However, there are a number of key practices that need to be done with care, such as selecting quality seedlings, preparing the land, spacing and planting trees and crops, maintaining, pruning, thinning, controlling pests and diseases, and deploying methods against specific climatic threats.

4.1 ESTABLISHING AGROFORESTRY

4.1.1 Selecting quality seedlings

Trees usually require 3–5 years before starting to yield. If seedlings of poor quality are planted, the survival rate could be very low. Farmers would then have wasted 5 years, receiving poor quality and quantity of yields.

- **Select quality sources of seeds or seedlings** (registered or known quality). The mother trees should be known for their high production potential, tolerance to extreme biophysical and climate conditions (for example, have gone through at least two harvest cycles with good yields of quality products), resistance to pests and diseases, and normal or superior physical attributes.
- **Good performance of seeds or seedlings.** They must have good size and colour, free from pests and diseases, strong leaf turgidity, good and sturdy root development.

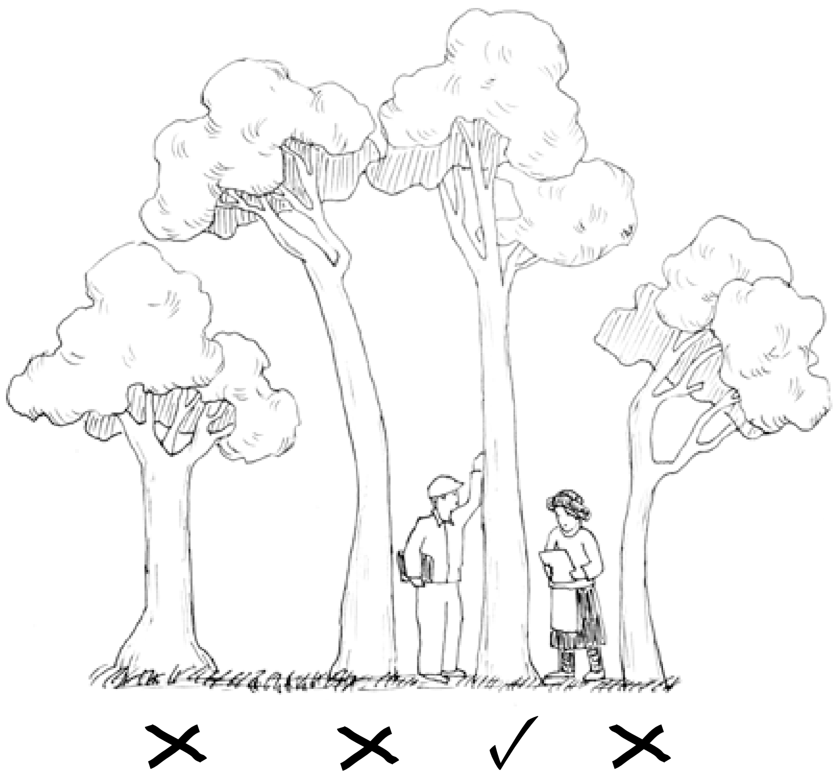


Figure 4.1 Healthy mother trees with the best characteristics should be selected for propagation of superior seeds or seedlings. Source: Martini et al (2017)

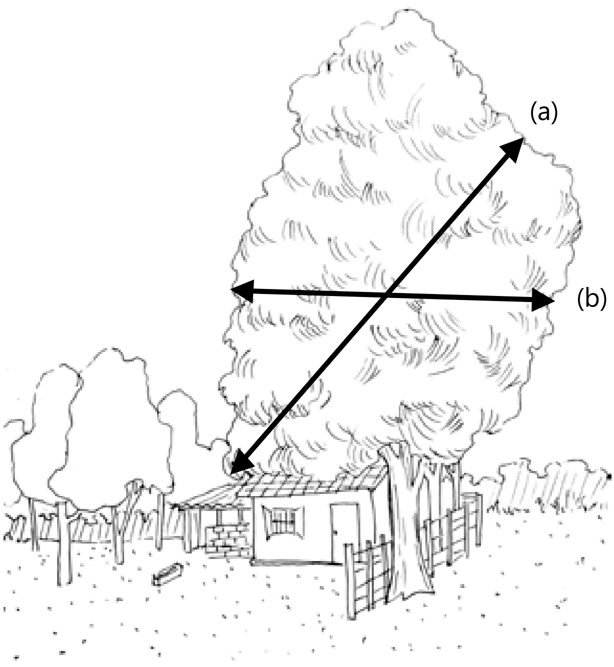
4.1.2 Preparing the land

The land must be prepared properly. It should be free from weeds before planting. This can be done through ploughing and harrowing until it is pulverized. Do not plough or till the soil when wet because the soil structure will be destroyed, making clay soil more compact. To completely eliminate weeds, ploughing should be done during the dry season or at least several months before the wet season.

Correct spacing between individual trees is essential. Sufficient spacing reduces competition for light, water and nutrients between and among individual plants; otherwise growth will be inhibited. Spacing in agroforestry systems needs to be regulated both horizontally between plants and vertically between their canopies.

Horizontal spacing is the distance between individual plants in a system. Information on standard dimensions for horizontal spacing can be obtained from extension officers or research institutes. When there is no known standard spacing, it can be estimated using the steps below.

- Find mature, productive trees of the species that grow in a relatively open area.
- To estimate the spacing distance between individuals of the same species: measure the crown width in a diagonal direction (a). Repeat the crown-width measurement in a horizontal direction (b) (Figure 4.2, left). The spacing dimension between trees of the same species will be (a) in length and (b) width or vice versa.
- For different species: Spacing distance is half of the average canopy width of species A (x) + half of average canopy width of species B (y) (Figure 4.2, right).



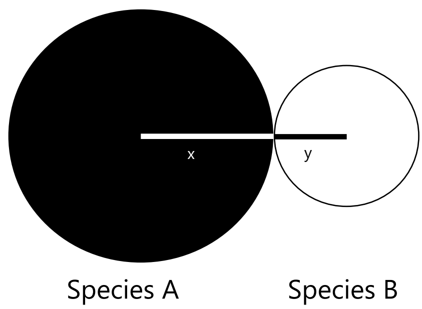


Figure 4.2 Estimating spacing distance for individuals of the same species (left); and individuals of different species (right). Source: Martini et al (2017)

Vertical spacing is the distance between the canopies of understorey and upperstorey plants. The spacing will greatly depend on the light tolerance of the understorey species and the farmer's long-term objective. For example, coffee requires 75% sunlight; young trees need at least 2 m vertical distance between the coffee canopy with its shade trees and at least 5 m for mature trees (Figure 4.3). Some farmers aim to continuously plant crops in between rows of trees while others may want to shift into perennial systems. These aims will influence the spacing of trees.

Young plants (below 4 years-old)

Productive plants (above 4 years-old)

Figure 4.3 Vertical spacing of coffee agroforestry systems

4.1.3 Planting

Make sure that the planting holes for trees are dug in sufficient time before planting to allow sunlight to disinfect the holes from fungus, bacteria and other disease-causing microorganisms. If the soil is heavy clay, dig 50 x 50 x 50 cm. The poorer the soil, the bigger the holes should be. Loamy black soil can be smaller: up to 30 x 30 x 30 cm. For heavy clay and poor soils, mix thoroughly with two sacks of rice hulls, sawdust or sand to one sack of animal manure. Fresh manure or compost should not be used because it produces gas during decomposition that may damage the roots. Fresh organic fertilizer needs to be placed in the holes one month before planting to avoid fungal and bacterial attacks and nutrient immobilization from decomposing organic matters.

The best time to plant is during the wet season or at least three months before the dry season, to allow the roots to develop and the plant to adapt to the changing environment.

- Harden the seedlings before planting to minimize mortality and stunted growth.
- Do not water the seedlings one day prior to planting. Do not subject the plant to water stress, manifested by wilting leaves and shoots.
- Apply fertilizer with more phosphorous to enhance growth and deeper root penetration for better anchorage.
- Fill the hole with a 30 cm thick mixture of topsoil, manure and rice hulls (or sawdust or sand) for clayey soils. For sandy loam soils, add only manure or compost.
- Hold the seedling by its container not its trunk, to avoid damaging the roots.
- Remove the seedling container 1 cm from the bottom. In the event that the ball of soil breaks, remove all the leaves to minimize evapotranspiration.
- Position the seedling in the middle of the planting hole. Add soil around the base.
- Completely remove the container. The roots must be free to grow wider and deeper for deeper anchorage and to make the plant resistant to drought.

- Before planting, put a 1.2–1.5 m stake beside the seedling. Tie the seedling to the stake after planting to train the trunk to grow straight.
- On sloping land, fill the hole with the planting medium 2.5–5 cm from the surface. On flat land or areas subject to waterlogging, elevate the base by 30 cm.
- Water immediately after planting.

Figure 4.4 Hole size for tree seedlings (right) and placing the seedling in the hole (left)

4.2 AGROFORESTRY MAINTENANCE AND PROTECTION

4.2.1 Maintenance

A. Fertilizing

- Integrated application of a combination of chemical and organic fertilizers is recommended for optimal production. Table 4.1 shows the advantages and disadvantages of chemical and organic fertilizers.
- Organic fertilizers can be applied at the beginning of the wet season and the end of the dry season; chemical fertilizers are best applied at the start of the wet season.
- To support sustainable production of organic fertilizer, keep livestock as sources of both liquid and solid fertilizers and plant fodder crops, such as *Arachis pintoi* and *Gliricidia*.

Table 4.1 Advantages and disadvantages of chemical and organic fertilizers

	Chemical fertilizers	Organic fertilizers
Advantages	• Nutrients are quickly absorbed by plants. • Provide standard dosage of particular nutrients.	• Improve soil fertility and structure. • Cheap and easily available.
Disadvantages	• Expensive and limited stock. • Excessive dosage is dangerous: can kill the plants and destroy soil fertility. • There are many fakes on the market.	• Nutrients are slowly absorbed by plants. • Information on the standard dosage of particular nutrients is limited.

Figure 4.5 Integrated production: tree fodder for livestock that produce manure for fertilizer

B. Pruning

The general objectives of pruning are to 1) form the tree crown (formative); 2) eliminate plant parts that are infected by pests and diseases (protective); 3) eliminate unproductive shoots or branches; and 4) improve air circulation (productive). Pruning can be divided into several parts.

- Pruning of young plants to improve growth and production (formative).
- Pruning of productive trees is done a minimum of once a year to 1) stimulate the process of flower sprouting and pollination; 2) provide branches for fruit for the next harvest; and 3) ease in harvesting (productive).
- Pruning of shade trees is necessary to increase light penetration to crops growing beneath. This improves production, for example, of pepper, coffee and cocoa.

Figure 4.6 Before (left) and after (right) pruning. Source: Martini et al (2017)

C. Thinning

Thinning removes unproductive trees and abnormal fruit.

- Tree thinning removes unproductive trees to reduce competition for water, light and nutrients. Thinning is done if the crown between individual trees overlaps owing to spacing distances that are too close. Remove trees that have low growth rates and abnormal shapes.
- Fruit thinning is usually done to enhance quality by limiting the number of fruits per branch. This allows the remaining fruit to receive sufficient nutrition for growth. When thinning, farmers need to estimate the optimal number of fruits that can be supported by the branch and receive adequate nutrition from the tree. For example, to grow one durian fruit requires at least 100 leaves. Smaller sized and abnormally shaped fruits should be removed.

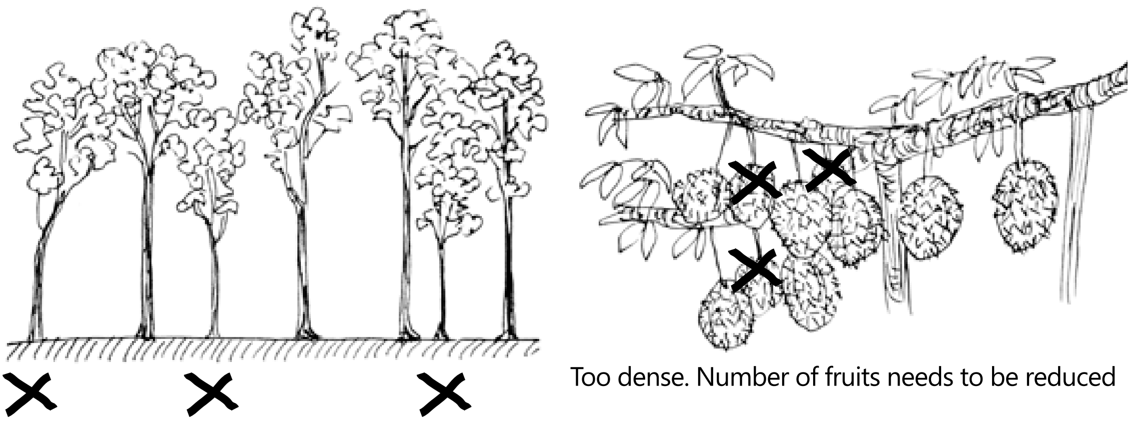


Figure 4.7 Thinning for increased growth (left); and for better quality fruit (right). Source: Martini et al (2017)

4.2.2 Protective practices

The trees and crops should be protected against fire, wind, scorching sunlight, stray animals and pests and diseases.

- **Fire** is a serious threat during dry seasons. Risk of fire can be reduced through regular weeding or brush cutting, composting litterfall and establishment of firebreaks.
- **Wind damage** can be prevented through establishment of windbreaks or temporary stakes to avoid trees rubbing each other during times of strong winds.
- **Shade plants** are needed to protect young trees from scorching sun, particularly, during dry seasons. Some plants require permanent shade—such as coffee, black pepper and cocoa—which can be provided by leguminous trees, such as *Gliricidia sepium, Leucaena* spp, *Cassia siamea*.
- **Stray animals** can damage young trees. This can be prevented by fencing either using live fences or barbed wire. Live fences of leguminous trees can also provide fodder for livestock.
- **Pests and diseases.** Healthy plants are able to outgrow pests and diseases. Using hardy species and quality seedlings are the keys to reducing the risk of damage.

Figure 4.8 Rubber as nurse trees of cocoa and coffee in Claveria, the Philippines. Photo: World Agroforestry/Agustin Mercado Jr

4.3 AGROFORESTRY MANAGEMENT FOR CLIMATE RESILIENCE

In a climate-resilient landscape, four management techniques are recommended to mitigate the effects of extreme climatic events on production: 1) improving soil organic matters; 2) maintaining soil moisture to reduce impact of prolonged droughts; 3) preventing soil erosion owing to heavy rainfall; 4) reducing fruiting failure owing to strong winds; and 5) controlling pests and diseases.

4.3.1 Maintaining soil moisture

Soil moisture can be maintained through the application of organic fertilizers and mulch, managing cover crops, and regular irrigation if the soil is too dry.

- Integrated application of chemical and organic fertilizers is recommended for optimal production. Organic fertilizers should be applied at the end of the wet season and the end of the dry season; chemical fertilizers should be applied at the start of the wet season.
- Mulch maintains soil moisture during drought, acting as a lid that keeps moisture in the soil. Recommended mulch thickness is 10–15 cm of rice straw, grass or leaf litter.

The ‘rorak’ technique (Figure 4.9) can be used to maintain soil moisture and stimulate the growth of new roots. The technique features a pit dug under the tree canopy with the objective to rejuvenate roots. Usually the pit size is 75–100 cm in length, 30–40 cm in depth and 40–60 cm in width. The distance of the pit to the tree trunk is 60–100 cm. The pit is filled with organic fertilizer that maintains soil humidity near the roots. The pits should be prepared and filled at the end of the wet season at least 2–3 months before the dry season. The number of rorak pits per hectare should be 50% of the total number of trees. The rorak pits should be maintained annually.

Figure 4.9 The rorak technique is used to maintain soil moisture in agroforestry especially when prolonged drought is anticipated

4.3.2 Preventing soil erosion and waterlogging owing to heavy rainfall

The application of planting techniques that conserve soil and water can reduce the effects of erosion and waterlogging. Establishing 'natural vegetative strips' (NVS) on slopes and along drainage canals on flat land is effective in controlling soil erosion. This technique uses contour hedgerows to minimize labour input and reduce competition between crops, grasses and trees. The strips are established by marking contour lines along a field, leaving them unploughed during land preparation. The retained vegetation will form a natural terrace and organic matters will accumulate along the contour. Native grasses and weeds will soon form stable hedgerows with natural front-facing terraces. The system can be enhanced with trees planted above them (Figure 4.10).

Figure 4.10 NVS with fruit trees above the strips. Photo: World Agroforestry/Mai Phuong Nguyen

NVS on flat land

To avoid flooding or waterlogging on flat land, drainage canals should be established as shown in Figure 4.11.

Figure 4.11 Drainage canals reduce the chances of flooding or waterlogging on flat land

4.3.3 Reducing fruiting failure owing to strong winds

In some areas, strong winds can cause fruiting failure of agroforestry species such as coffee and cocoa. To mitigate the effects of strong winds, windbreak trees can be planted around the plot or between several tree rows for larger fields. They should not be too dense, however, because completely blocking the wind can cause turbulence over adjacent crops (Figure 4.12). If the windbreak is too dense, branches of some of the trees should be pruned.

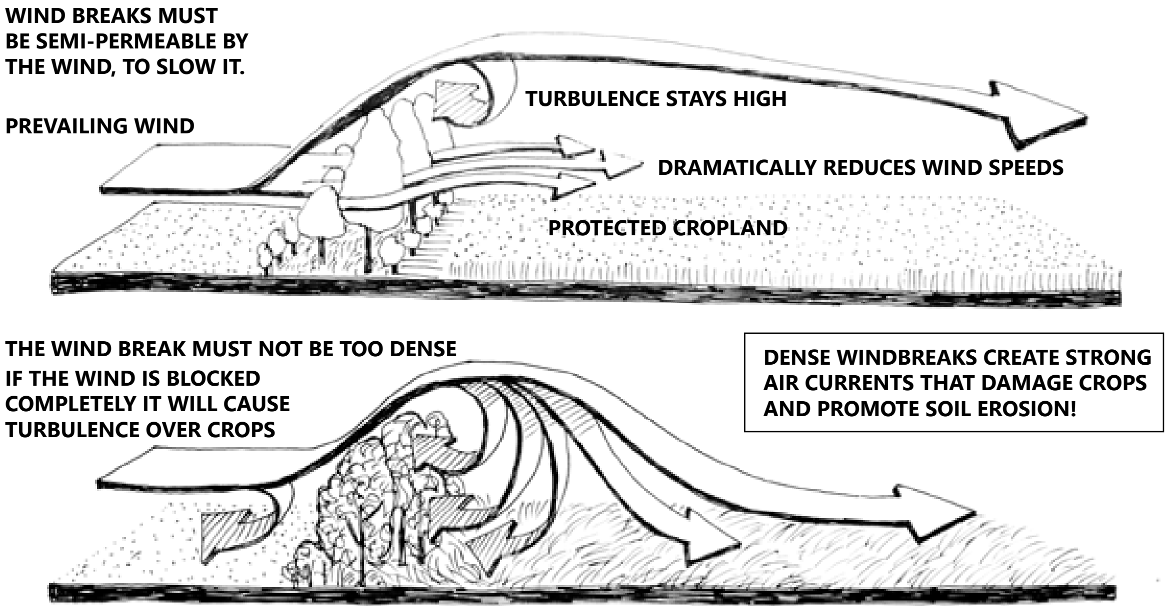


Figure 4.12 Technique for establishing windbreaks in agroforestry systems. Source: Tengnas (1994)

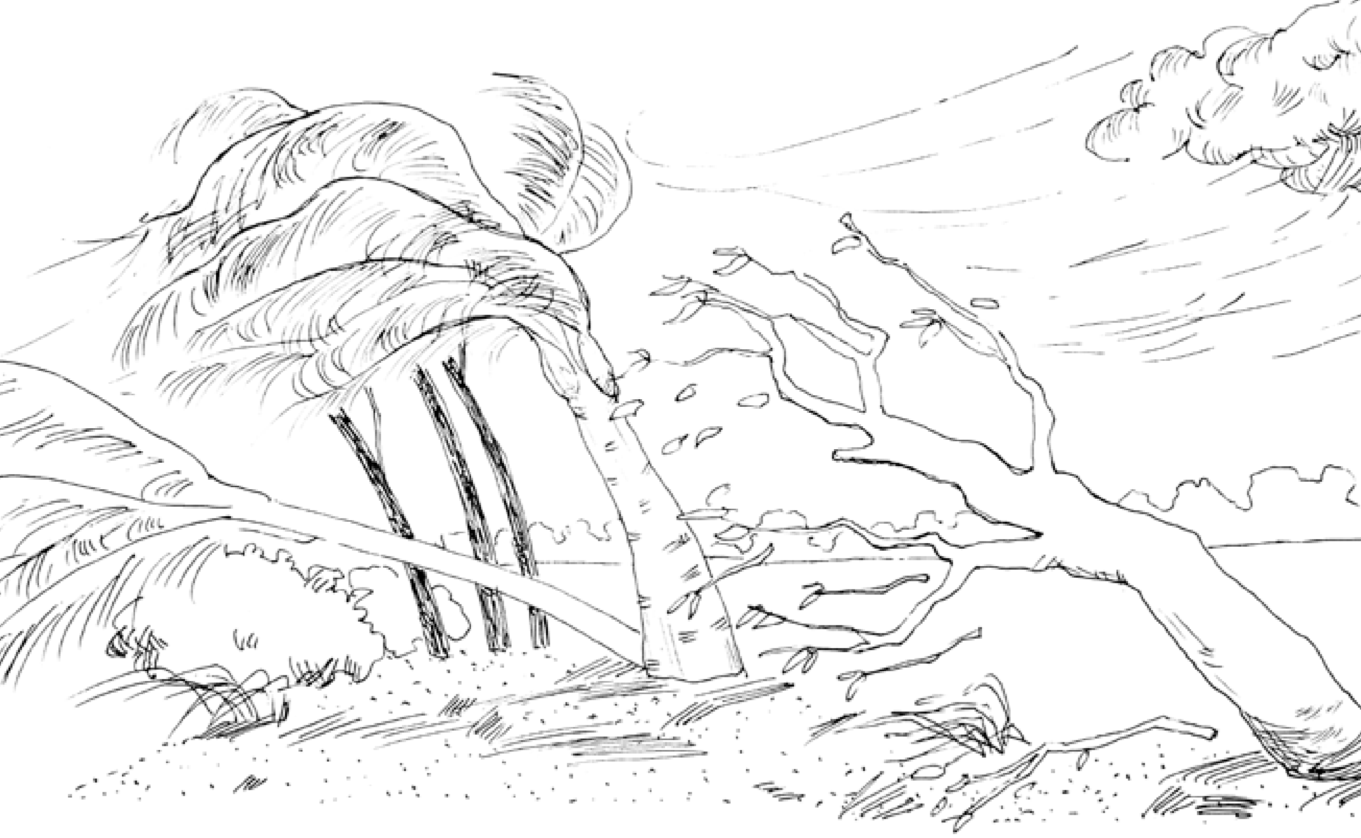
4.3.4 Controlling pests and diseases

Pests are animals that attack crops or livestock, inhibiting growth and decreasing yields. Diseases are plants, fungi, bacteria or viruses that attack crops or livestock, also inhibiting growth and decreasing yields.

Extreme climate events may stimulate outbreaks of pests and diseases. Providing sufficient nutrition for the crops or livestock and maintaining sanitation on the farm can reduce the risk of severe damage.

Identifying and increasing populations of the natural enemies of pests or diseases can assist in the prevention of severe outbreaks.

Planting cover crops with white or yellow flowers can increase the number of insects that can be natural enemies.



CHAPTER 5

ASSESSING RESILIENCE TO CLIMATE CHANGE

5.1 STEPS TO ASSESS THE CLIMATE RESILIENCE OF AGROFORESTRY PRACTICES

The following are several steps in assessing reslience of agroforestry practices:

Step 1: Decide who will be involved

- This most important first step can be best carried out through group meetings in the community. This helps to ensure everyone's perspectives are understood and their issues and wisdom incorporated.
- The assessment team may consist of community members, farmers who are undertaking agroforestry and other interested groups.

Step 2: Clarify objectives and scope

- Several questions need to be discussed: 1) Why do we need an assessment? 2) What do we need to achieve (from the assessment)? 3) What is the intended use of the assessment? 4) How much is the budget of the assessment?
- The discussions can be held in small group or whole village meetings.

Step 3: Identify criteria and indicators

Based on the objectives, criteria and indicators need to be developed for each objective. Criteria and indicators are tools used to guide, monitor and assess the resilience of agroforestry practices to climatic issues in a given context (See 5.2 for more information).

- Criteria define essential attributes against which resilience is assessed with due consideration to different (ecological, socio-economic) aspects of the agroforestry practice in question. Each criterion related to a key attribute of resilience is a standard for assessment and may be described by one or more indicators.
- Indicators are parameters that correspond to a particular criterion. They are signs that measure resilience. When measured they help to demonstrate or indicate the resilience status of the agroforestry practice in question.

Step 4: Determine methods and collect the data

Depending on the indicators that have been selected, several qualitative and quantitative methods could be identified for collecting data, for example, document and secondary data reviews, questionnaires, surveys and interviews (See 5.3 for discussion on methods for assessing resilience of agroforestry practices at farm level).

Step 5: Develop the questions for the assessment

Based on the indicators, the assessment questions will be developed to generate responses from applying agroforestry practices for climate resilience. The questions should be agreed through group discussion and ranked in order of importance if there are many questions.

Step 6: Consolidate and analyze the collected data and information

In this step, the collected data and information is analyzed and synthesized to see if there are patterns or trends in climatic resilience that emerge (See 5.4 for people to be consulted).

Step 7: Interpret findings, provide feedback and recommendations

This step is the process of providing recommendations about how to strengthen implementation of the agroforestry practices well as making any adjustments and offering incentives for improvement.

Step 8: Communicate findings

This step provides insights to everyone involved in the assessment to help decide how to use the results to strengthen the agroforestry practices and their wider adoption (see also 5.4).

5.2 CRITERIA AND INDICATORS FOR ASSESSING RESILIENCE OF AGROFORESTRY PRACTICES

A set of criteria and indicators should be employed for an assessment (see below). The selected indicators should be SMART: Simple – Measurable – Achievable – Replicable – Time-bound.

Table 5.1 Examples of criteria and indicators for resilient agroforestry practices

Criterion	Indicator	Measure
Conservation	Reduction in soil erosion Increase in soil fertility Water availability in dry seasons	Amount of soil loss per ha per year Soil organic matters/nutrient content Amount of water for crops and humans
Productivity	Increase in crop/livestock yields Increase in productivity of farmland	Yields of crops, livestock harvested per land unit per year Land equivalent ratio
Diversity	Existence of various species Existence of tree, crop, livestock products at different times Existence of various income sources	Number of tree/crop/animal species Different tree, crop, livestock products produced throughout the year Incomes from trees, crops, livestock
Adaptability	Change in microclimate Frequency of disease/pest (outbreak) Damage/loss of trees, crops, animals owing to climatic stress Recovery periods after stresses	Temperatures, humidity over a period Incidence of diseases/pests in a period Damage/mortality rate of trees, crops, animals Time (e.g. months) needed to recover
Adoption	Increase in awareness of the introduced agroforestry practices Increase in potential undertaking of agroforestry	Number/percentage of households aware of agroforestry practices Number/percentage of households willing to undertake agroforestry practices

5.3 METHODS FOR ASSESSING RESILIENCE OF AGROFORESTRY PRACTICES ON FARMS

Several quantitative and qualitative methods can be defined and employed for assessing the resilience of the implemented agroforestry practices. These include but are not limited to surveys, biophysical measurements (quantitative methods), key informant interviews, group discussions, direct observations and case studies (qualitative methods).

For each method, certain tools could be used, for example, structured and semi-structured questionnaires, instruments like soil traps to measure soil erosion, Participatory Rural Appraisal (PRA), and case studies.

Various assessment methods

Survey: commonly used to assess outcomes of the agroforestry practices with target groups. For recording physical measurements, a standardized form may be used, while for socio-economic data, a structured questionnaire can be used to record data from interviews with individual respondents.

Biophysical measurements: measurements of physical change over time, for example, crop yields, soil erosion, water table depths and availability. This may require instruments installed on-site, for example, a soil-trap installed on the lower part of a slope to measure soil erosion.

Key informant interviews: focused interviews in which key informants, few in number and purposively selected owing to their particular knowledge and position, are interviewed. This usually makes use of semi-structured or structured questionnaires.

Focus-group discussions: conducted with groups of selected people who are familiar with pertinent issues using various PRA tools. This is useful for assessing changes and their causes and for identifying areas that need improvement.

Direct observation: involves structured observation of phenomena in the field. This can be used to understand the context and explain results of evaluation and should always be used in conjunction with other methods.

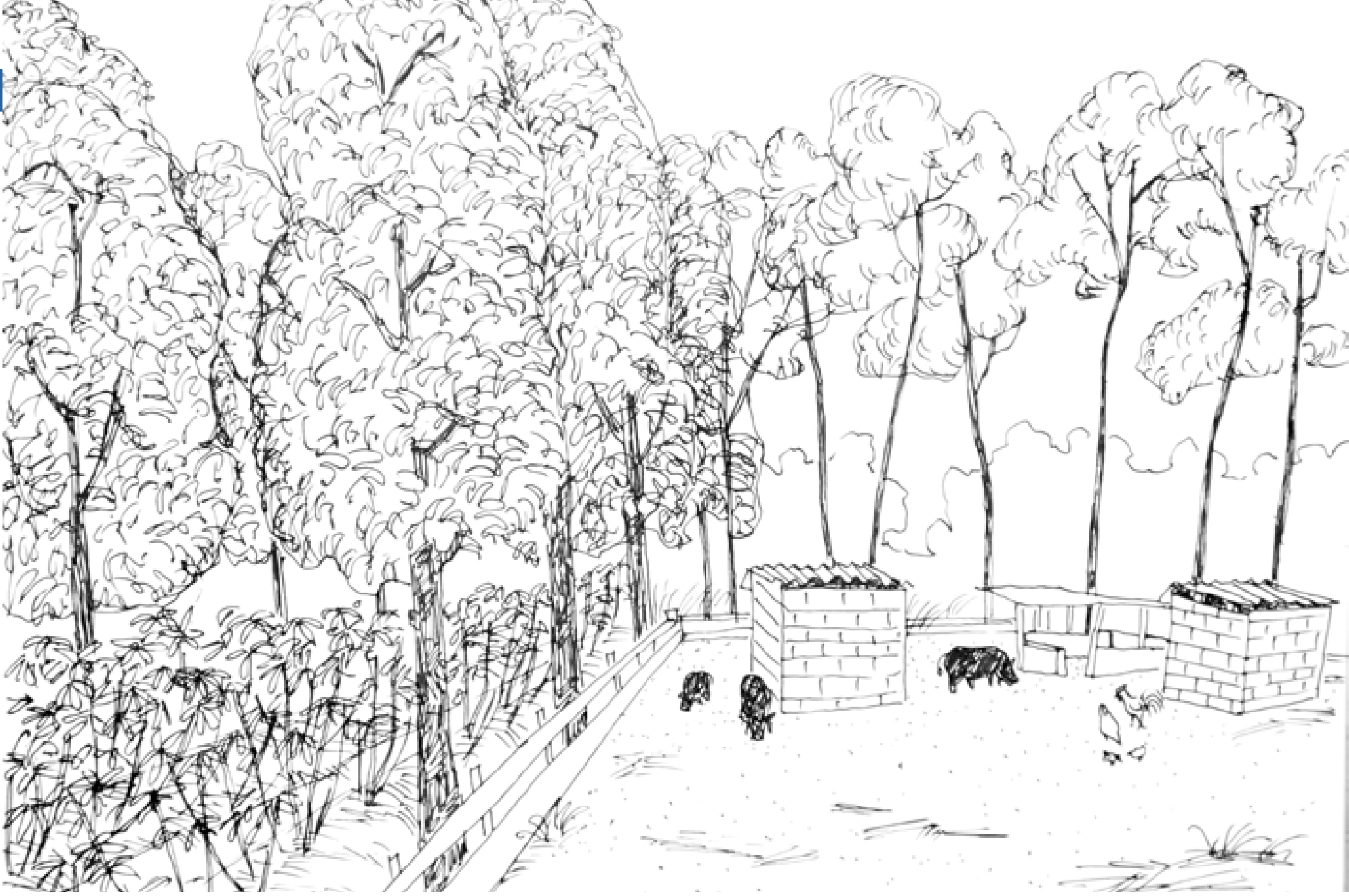
Case studies: document the sequence of events over time related to adoption and implementation of agroforestry practices of a household or person or location and facilitate in-depth understanding of the processes and outcomes of agroforestry practices with regard to climate resilience and other objectives as well as the factors behind the observed changes.

5.4 WHO SHOULD BE CONSULTED TO UNDERSTAND AGROFORESTRY RESPONSES TO CLIMATE CHANGE?

Ideally, the process of monitoring and evaluation of agroforestry practices should involve not only farmers but also extension workers, research agencies and the private sector.

Farmers as agroforestry practitioners are expected to conduct regular monitoring and evaluation of their practices. The results of monitoring and evaluation can be shared with a number of groups.

- Extension workers, for technical issues related to agroforestry practices
- Research agencies (in agriculture, forestry, land-use), for technical issues beyond the capacity of local extension workers
- Private sector, in terms of post-harvest handling to maintain quality of agroforestry products



CHAPTER 6

PROMOTING AGROFORESTRY ADOPTION

Working collaboratively with farmers' groups, practitioners and extension workers to promote agroforestry is crucially important in achieving landscape resilience. Achieving resilience at landscape level requires collective action, including support from local governments. Information, education and capacity-building activities should be designed and supported, and various types of incentives may have to be in place, to stimulate agroforestry adoption.

The triadic approach enhances participation

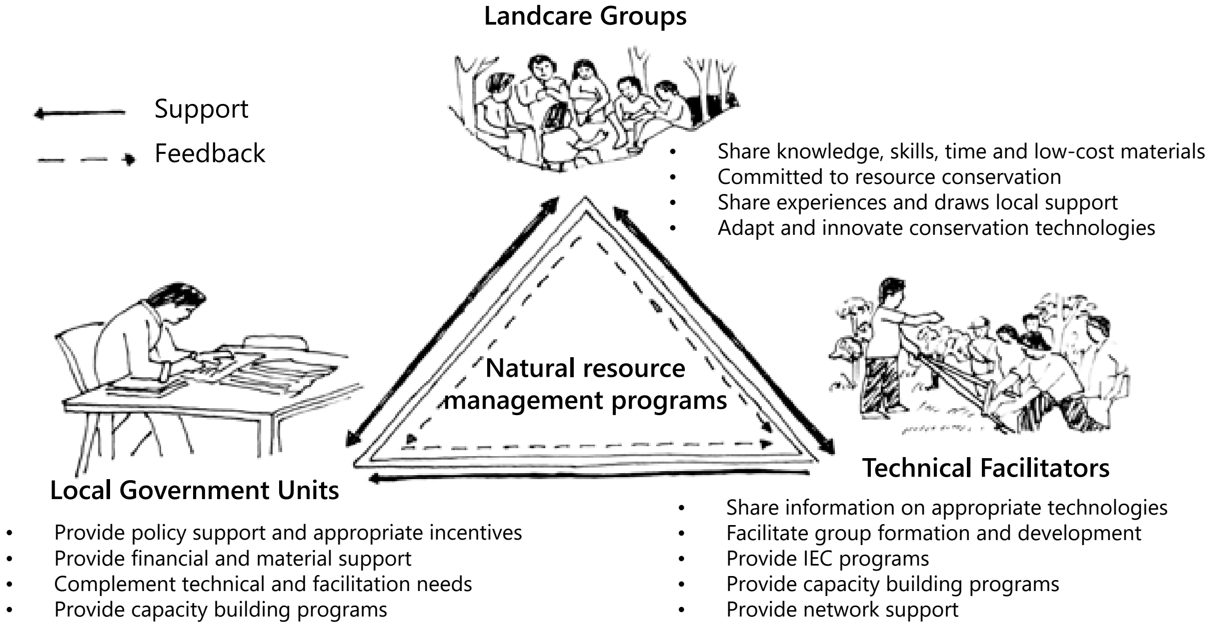


Figure 6.1 The triadic approach to participatory development of agroforestry.

Note: This approach was promoted under the Landcare Programme in the Philippines. The approach enabled rapid dissemination and adoption of agroforestry amongst farmers, facilitated by technical experts, and supported by local government officials. Source: Mercado et al (2005)

Farmers' groups can share experience through meetings, visiting exemplary farms, and field days. Material such as posters, photos and games along with field demonstrations can be produced by farmers' groups and extension workers to share important information. Farmers and extension workers can organize 'farmers' summits' to share designs, approaches, results, benefits and issues related to establishing agroforestry.

Figure 6.2 Sharing the knowledge

Farmers' groups can work with neighbours, extension workers and agroforestry specialists to continue the process of participatory agroforestry development. This includes expanding the scale of good agroforestry practices, bringing in new knowledge and planting material, testing new methods and designs of systems and experimenting with new practices, evaluating new species of crops and trees, employing new management approaches to trees, crops and soils, and organizing farmer-to-farmer exchanges and farmers' field schools.

Figure 6.3 Supporting collective action

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Annex 1: INCENTIVES FOR ADOPTION OF AGROFORESTRY PRACTICES

In many circumstances, farmers do not have enough capital to undertake agroforestry practices. They encounter common issues, such as lack of knowledge and skills; shortage of available land; low soil fertility; poor quality seeds and seedlings; restricted access to markets; limited or no access to credit and capital for short- and long-term investments; and weak networking or connectedness.

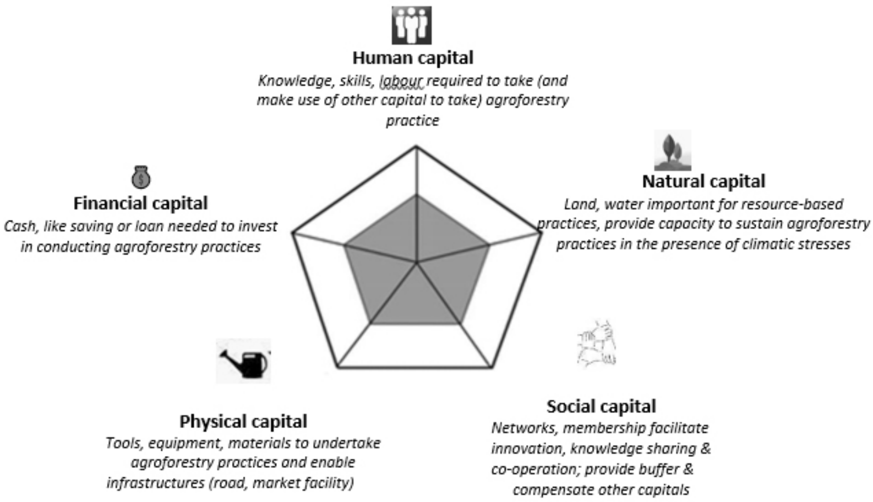

Figure A1.1 Types of capital. Source: FAO (2003)

There are various types of incentives that can be employed in supporting farmers to undertake agroforestry practices. Extension workers or agroforestry practitioners could potentially help farmers to access the different types of incentives listed below.

Table A1.1 Types of incentives

Type	Description
Direct incentives	Subsidies: paying for tree planting and environmental services; providing seedlings; guaranteeing prices of products; reducing taxes
	Rewards: premium prices for agroforestry products; technical assistance or guidance with inputs (e.g. seedlings, fertilizer)
Indirect incentives	Training to enhance knowledge and skills relevant to agroforestry
	Technical information, extension/advisory services
	Community campaigning and advocacy (using various means of communication, e.g. radio, public loudspeakers, meetings)
	Access to land and use rights
	Access to credit, preferential loans
	Establishment of community organizations, farmers' groups
	Adaption of government rules to local conditions
	Provision of market information (on products, price, location, buyers)

Annex 2: ECONOMIC ANALYSIS OF AGROFORESTRY PRACTICES

A. BUDGETING TECHNIQUES

Analysing the economics of agroforestry practices provides a basis for estimating financial needs and feasibility and highlights trade-offs between multiple benefits. Budgeting is a common technique suggested to be used in the analysis. For agroforestry practices, it poses unique budgeting concerns.

- **Long planning horizon**: A 'planning horizon' is a time period in which all costs and revenues for a given practice are realized. For agroforestry, it is longer than one season because of the tree component.
- **Irregular cost and revenue occurrences:** Many of the revenues and costs do not occur at regular or predictable intervals throughout the entire planning horizon but are irregular in occurrence.
- **Fixed tree component with variable crop or livestock component:** Agroforestry practices incorporate a fixed tree component with a crop or livestock component; the crop or livestock component may change over time.

B. PROCESS OF AGROFORESTRY BUDGETING

Developing enterprise budgets

An enterprise budget is a complete, detailed listing of all costs and revenues expected for each single enterprise, like specific crop products, livestock, fruit and timber trees. Development of an enterprise budget consists of the following steps.

Table A2.1 Development of an enterprise budget. Source: adapted from Gold et al (2015)

Step 1	*Define enterprise/component* What type of agroforestry practice (alley cropping, silvopasture, forest farming etc)? What species (common or scientific name)?
Step 2	*Estimate revenues* List all possible sources of revenue for an enterprise or component What are the possible sources of revenue (incentives, nuts, fruit, medicines, wood, fuelwood)? When are these revenues earned (years 1–10, after 10 etc)?
Step 3	*Estimate variable costs/operating costs* List, in detail, all possible sources of variable costs. What are the costs to establish (e.g. site preparation, planting)? To maintain the practice (e.g. chemicals, thinning)? To harvest (e.g. nuts, timber)? To market the products (e.g. advertising, transportation)?
Step 4	*Estimate fixed costs (ownership costs)* List all fixed costs which are contributing to resource ownership regardless of any productive activity being attempted. What are the costs of property/land (or land use) taxes, insurance, interest on (machinery, building) debt etc? When and how often will these costs occur?

C. DEVELOPING AN AGROFORESTRY CASH-FLOW PLAN

A cash-flow plan combines the details from different enterprise budgets in an agroforestry practice and adds a time dimension, providing information necessary to assess and forecast the economic feasibility of the agroforestry practice over time.

Table A2.2 Six key steps to develop an agroforestry cash-flow plan. Source: adapted from Gold et al (2015)

Step 1	*Define the practice* What type of agroforestry practice is it? (alley cropping, silvopasture, forest farming etc) What are the enterprises (tree, crop, livestock species) that make up the practice?
Step 2	*Calculate annual revenues* What are the total revenues each year from tree, crop and/or livestock enterprises?
Step 3	*Calculate variable costs* What are the total variable costs each year from tree, crop and/or livestock enterprises?
Step 4	*Calculate fixed costs* What are the total fixed costs each year for tree, crop and/or livestock enterprises?
Step 5	*Calculate net income for each year* Net income = Total revenues – Total variable costs – Total fixed costs
Step 6	*Analyse the results* Net present value (NPV) of the calculated annual net income $NPV = \sum\left(\frac{B_t - C_t}{(1+r)^t}\right)$ Bt: the benefit at time t Ct: is the cost at time t r: is the selected discount rate and t: is time. * *The net present value of the agroforestry practice can be compared to the net present value of other alternatives, e.g. crop (soybean/maize/coffee) monoculture, to see which practice is the most economically profitable.*

D. EXAMPLES OF USEFUL FORMS

AGROFORESTRY ENTERPRISE BUDGET

Agroforestry practice: *Alley cropping*..........Area... ha

Species: *Black Walnut*..Spacing: ....

No.	**Item**	**Amount ($)**	**Time interval**
1	Revenues (from products & others)		
	Nuts/fruit	255.00	Years 11–40
	Timber (thinning)	600.00	Year 10
	Timber (Sawlogs, veneer etc)	2,000.00	Year 40
2	Variable/operational costs		
	2.1 Establishment		
	Site preparation	50.00	Year 1
	Seedling and fertilizer	100.00	Year 1
	Planting	120.00	Year 1
	2.2 Maintenance		
	Fertilization	45.00	Year 4-6
	Pruning	100.00	Year 12
	Thinning	100.00	Year 10
3	Fixed costs		
	Land-use fee	5.00	Year 1-50
	....		

AGROFORESTRY CASHFLOW PLAN

Agroforestry practice: *Alley cropping*.........Area   ha

Tree species: *Black Walnut*..............................Spacing: ....

Crop/livestock species: *Hay*................................. Spacing: ....Unit: $

	Year 1	**Year 2**	**Year 3**	**........**	**Year (n)**
Revenues (R)					
Tree					
Crop/livestock					
Total revenue					
Variable/operational costs (V)					
Tree					
Crop/livestock					
Total variable costs					
Fixed costs (F)					
Tree					
Crop/livestock					
Total fixed cost					
Net Income/loss = R – V- F					

E. EXAMPLE OF CALCULATING NPV

Net Present Value or NPV of an investment in agroforestry refers to the difference between the present value of cash inflows (total revenues) and the present value of cash outflows (total costs) over a period of time. A positive NPV means the investment can yield profit (revenues exceeding costs) over time whereas a negative NPV implies that the costs of investment still exceed the revenues over the specified period of time. Based on the costs and revenues provided in the agroforestry cash-flow plan and assuming the discount rate (R) is 7%, the NPV of the investment in agroforestry can be calculated as follows.

Year (t)	Variable cost	Fixed cost	Total cost (C)	Revenue/ benefit (B)	Net benefit (B-C)	(1+R)^t	(B-C)/ (1+R)^t
1	2,400	350	2,750	1,650	-1,100	1.07	(1,028.04)
2	1,100	350	1,450	1,850	400	1.14	349.38
3	1,120	350	1,470	2,175	705	1.23	575.49
4	950	350	1,300	2,075	775	1.31	591.24
5	1,115	350	1,465	2,325	860	1.40	613.17
6	1,025	350	1,375	2,300	925	1.50	616.37
7	1,050	350	1,400	2,600	1,200	1.61	747.30
8	1,050	350	1,400	2,700	1,300	1.72	756.61
9	1,050	350	1,400	7,800	6,400	1.84	3,481.18
NPV = ∑(Bt-Ct)/(1+R)^t =							**6,702.69**

The NPV of the investment in agroforestry as illustrated in the example above is USD 6702.69. This means that over the period of nine years, the investment in agroforestry can yield a positive cash flow (profit) of USD 6702.69.

Annex 3: EXAMPLES OF CLIMATE-RESILIENT AGROFORESTRY PRACTICES

1. MANGROVES WITH SHRIMPS IN COASTAL MANGROVE AREA IN CA MAU, VIET NAM

Location: Mangrove area in Ngoc Hien District, Ca Mau Province, Southwest Viet Nam

Main source of income/livelihood: Shrimp and other aquatic products (e.g. fish, crabs)

Mangrove resource: Deforested and degraded owing to expansion of shrimp farming

Key problem: Shrimp disease and deaths owing to hot temperatures (in particular) and polluted water

Climate-change issue: Average temperature increased 1°C over last 35 years and 0.5°C in last 11 years and is expected to continue to increase in coming years

Year	2020	2030	2040	2050	2060	2070	2080	2090	2100
T °C	27.8	28.1	28.4	28.7	29.0	29.3	29.6	29.9	30.2

Source: Dang Huu Lac (2014)

Agroforestry practice: mangrove (60%) and shrimp raising (40%) at farm level.

Household plants and *Rhizophora apiculate* on 50–60% of households' farmland area (of 3–5 ha); using the remaining farmland area (50–40%) for shrimp aquaculture.

Figure A3.1 Mangroves with shrimp-raising

Results

- At household/farm level: obtained natural food for shrimps, reduced water pollution, lowered the heat of rising temperatures and created favourable environments for shrimp and other fisheries; increased shrimp production and household incomes 1.5–2 times.
- At landscape level: mangrove forest cover increased from 39 to 44%, helping increase resilience of the mangrove landscape and contributing to climate-change mitigation and adaptation.

2. FOREST TREES WITH CROPS AND LIVESTOCK IN A SANDY, DRY AREA IN THUA THIEN HUE, VIET NAM

Location: Nam Gian Village, Quang Thai Commune, Quang Dien District, Thu Thien Hue Province, North-central Coast Viet Nam

Main source of income/livelihood: Agricultural production and raising livestock

Key problem: Largely abandoned and unproductive land owing to poor, sandy soils and hot, dry temperatures (more than 40°C in summer)

Climate-change issue: Increasing temperatures, up by 0.5°C in 2020 compared to 1980–1999 (Duc Binh and Quoc Toan 2017)

Agroforestry practice

- *Acacia crassicarpa* plantation with trees planted in hedges on 3.3 ha of sandy soil; width of each hedge 15–21 m, consisting of 5–7 rows of trees; helping to lower high temperatures, reduce water evaporation and wind damage, and modify the microclimate
- Different crops like cassava, tobacco and onion planted in alleys between tree hedges
- A part of the land, around 500 m^2 in total, used for housing and raising chicken and pigs

Figure A3.2 Alley cropping by household

Figure A3.3 Pig-raising by household

Results

- At household/farm level: good and stable annual income of about VND 325,000,000 (USD 14,000) despite increasingly hot temperatures in the summers.
- At landscape level: more than 20 other households adopted and implemented similar agroforestry practices on their individual land; increased planted forest area in the village by more than 100 ha in total; modified the microclimate; and enhanced landscape resilience to increasing temperatures.

3. COFFEE AGROFORESTRY IN THE UPLANDS OF LAMPUNG PROVINCE, INDONESIA

Location: Sumberjaya, upper part of the Way Besai Watershed, Lampung Province, Indonesia.

Main source of income/livelihood: Robusta coffee production

Key problem: Decreased coffee production and quality. Desire to avoid coffee cultivation shifting to higher elevations, causing forest degradation and consequently sediment in water reservoir

Climate-change issue: Increasing temperatures (2–4°C predicted)

Agroforestry practice

Multi-strata coffee cropping system. Coffee is grown together with vegetables and medicinal plants under shade of *Erythrina lithosperma, Leucaena glauca, Paraserianthes falcata* and various species of fruit trees by farmers on their individual land.

Results

- At farm level: multiple benefits as trees provide shade and maintain suitable temperature and humidity for coffee; increase coffee yields and income for the farmer; reduce run-off, soil nutrient leaching and soil erosion; reduce total crop failure as more than one plant species cultivated.
- At landscape level: area of multi-strata coffee increased, leading to positive land-use change, bringing many environmental benefits, such as controlled erosion and decreased sediment, increased biodiversity, increased carbon stock, water regulation, and forest protection, helping to increase the resilience of the watershed landscape to predicted climatic issues, particularly increasing hot temperatures.

Figure A3.4 Multi-strata coffee agroforestry cultivated on farmer's land, Sumberjaya. Source: ICRAF/Prasetyo (2013)

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