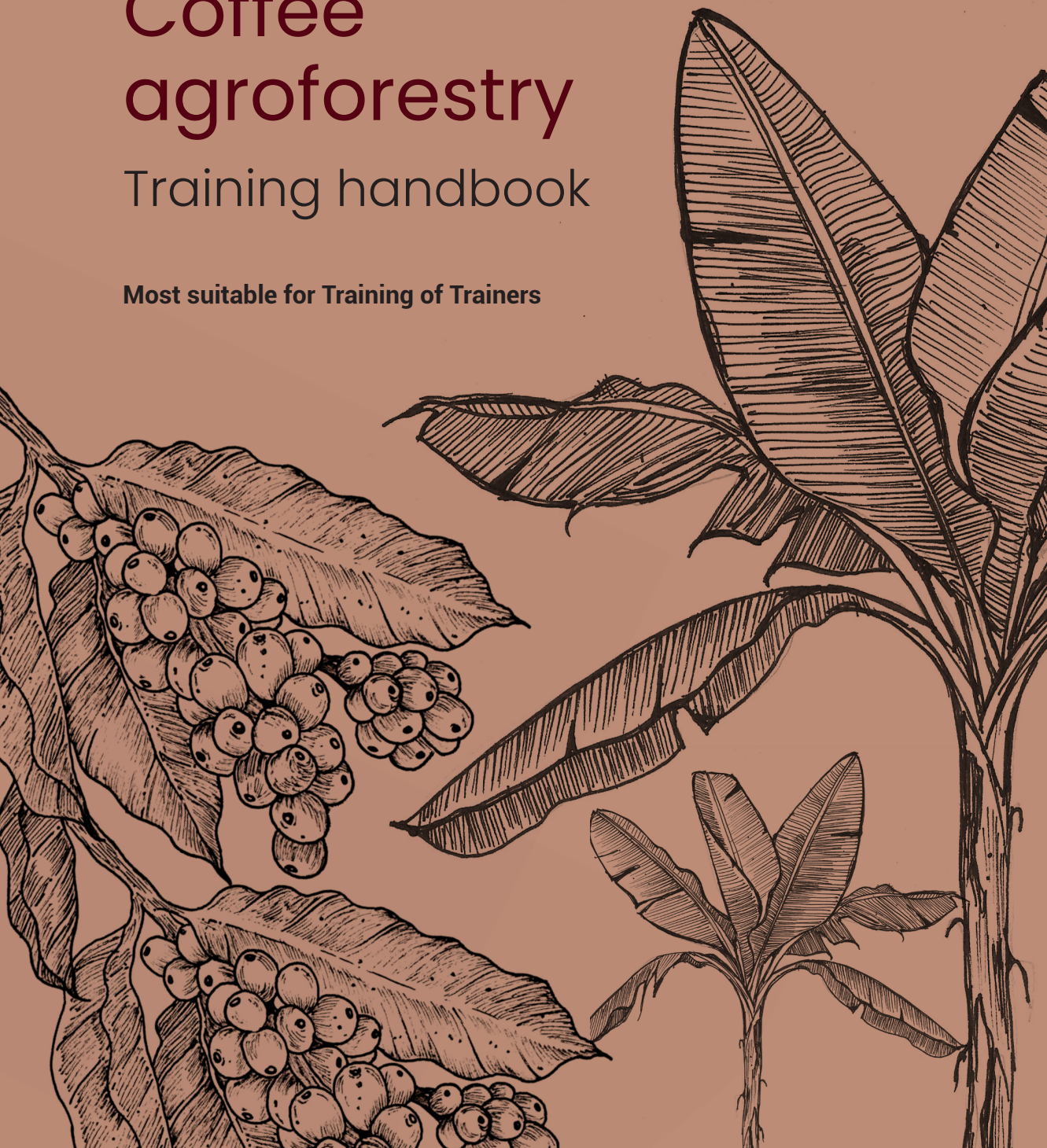
Coffee agroforestry

Training handbook

Most suitable for Training of Trainers



Coffee agroforestry

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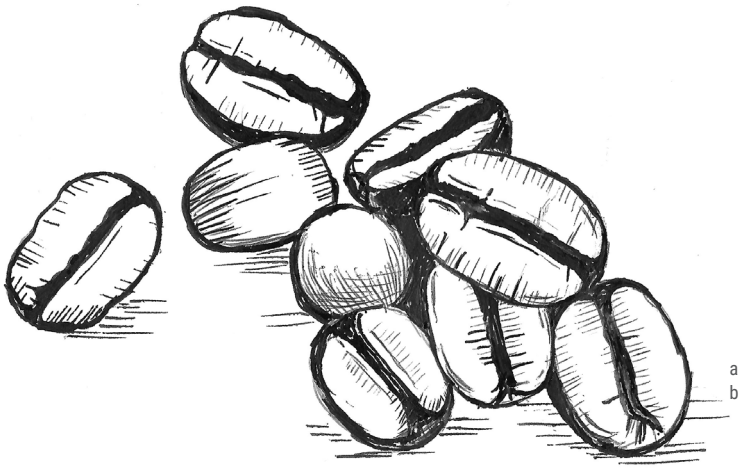
Most suitable for Training of Trainers

Prepared by
Joel Buyinza[a], Gerald Ongodia[a], Scovia Mudondo[a], Bernard Fungo[a] and Godfrey Natwaluma[b]



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Coffee agroforestry: Training handbook

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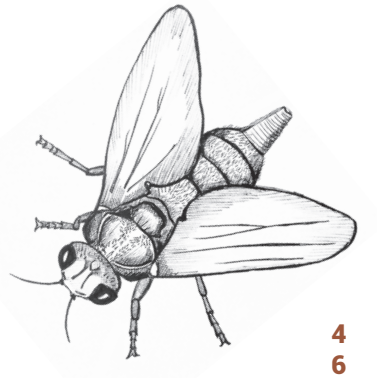

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Photo by Axel Fassio/CIFOR-ICRAF

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Introduction

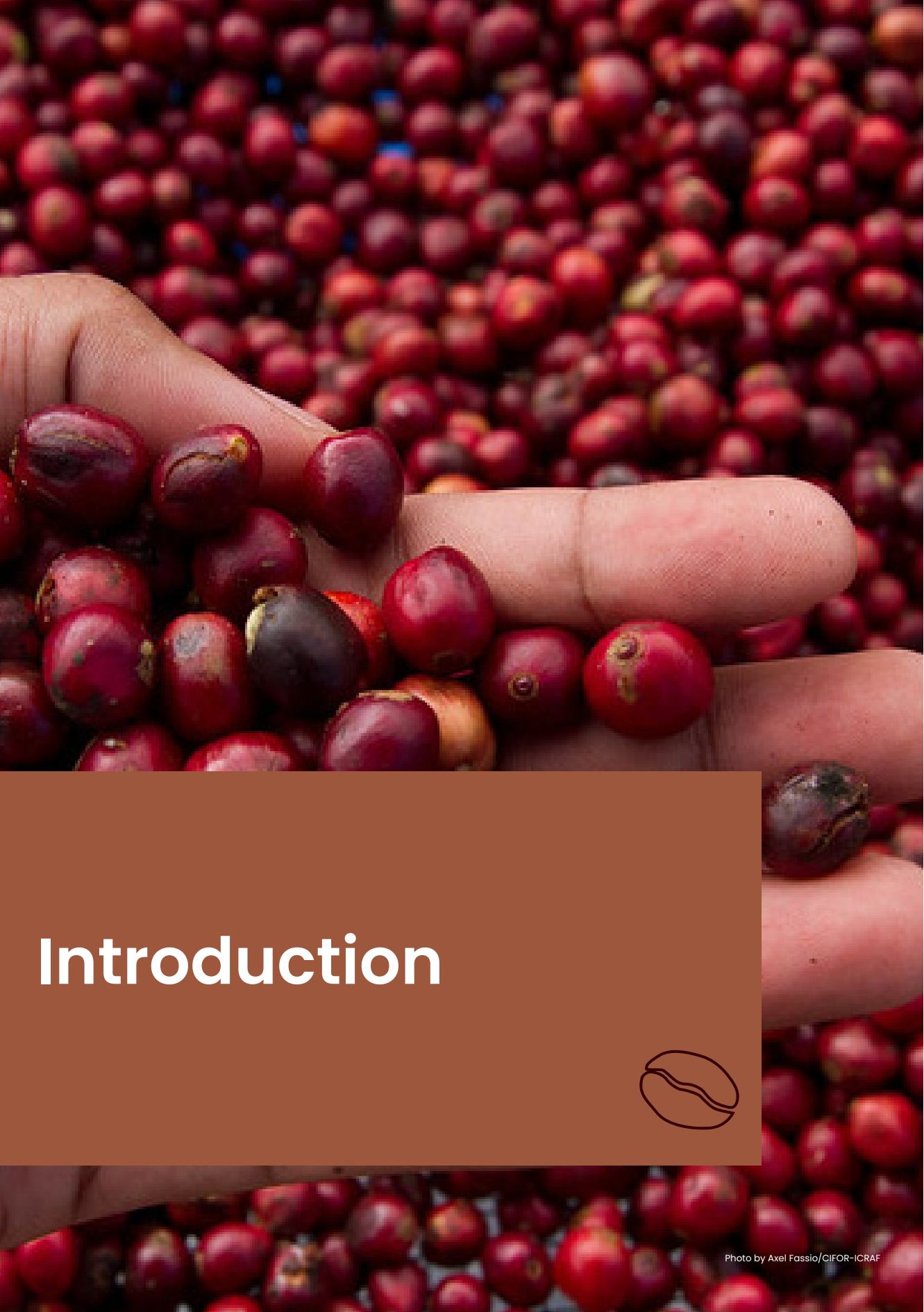


Photo by Axel Fassio/CIFOR-ICRAF

Introduction

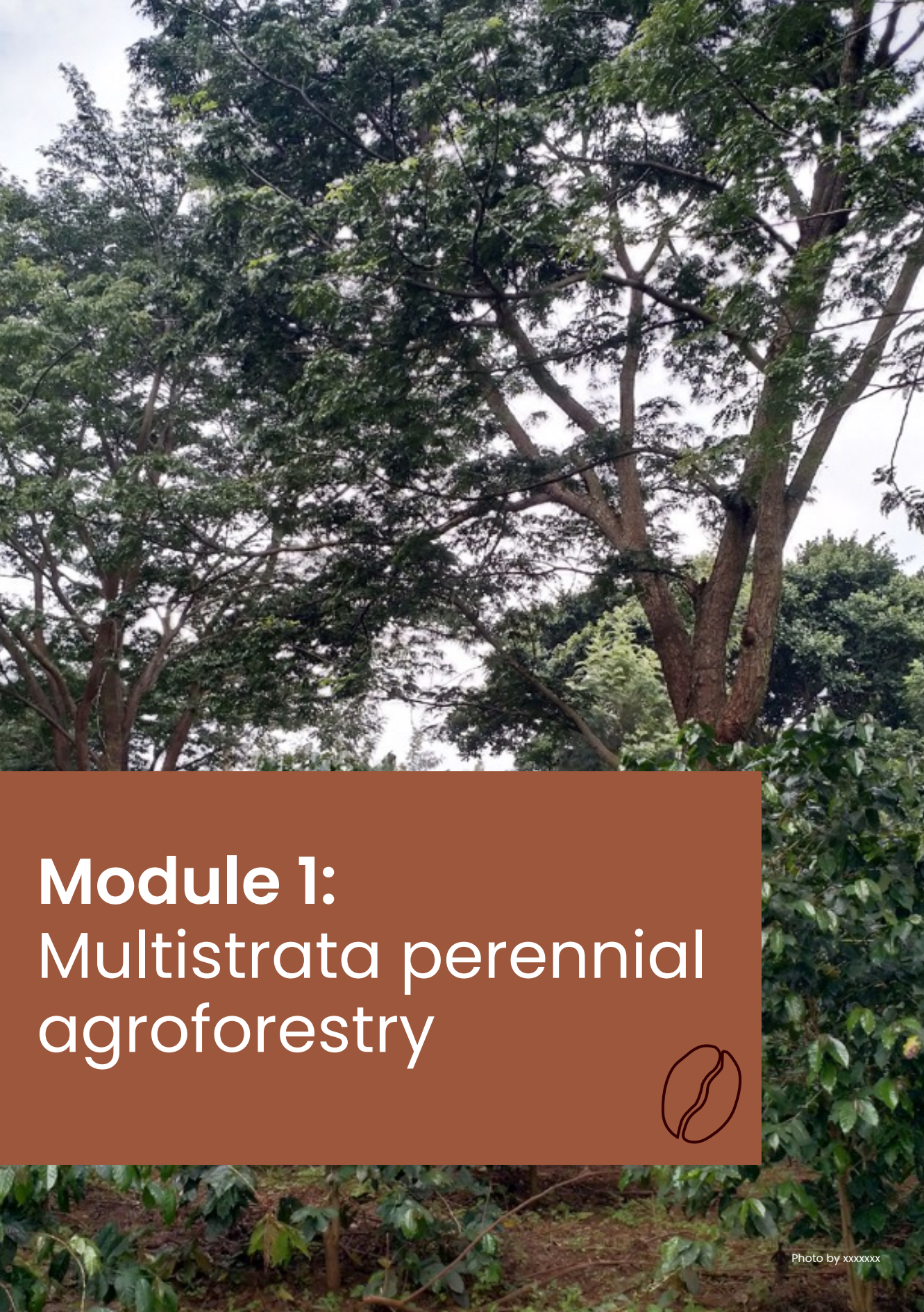
This training handbook supports extensionists, advisors and practitioners working on coffee agroforestry in Uganda.

To achieve maximum benefits from agroforestry, farmers need to understand its principles—and their application for coffee cultivation. The resource will help trainers and extension agents support farmers to design, establish and manage coffee agroforestry systems in a range of contexts.

The document has five modules:

- **Module 1** describes the general principles, design and management guidelines for multistrata perennial agroforestry systems, such as coffee agroforestry.
- **Module 2** presents coffee agroforestry in the Ugandan context, highlighting suitable tree species and their optimal spacing.
- **Module 3** demonstrates how to establish and manage nurseries to produce tree seedlings for integration into coffee farms.
- **Module 4** centres on establishing and managing tree seedlings in the field.
- **Module 5** focuses on managing mature trees in coffee agroforestry systems.

Each module has been designed around a specific learning objective, to keep trainees focused and provide easy assessment of progress.



Module 1: Multistrata perennial agroforestry

Photo by xxxxxxx

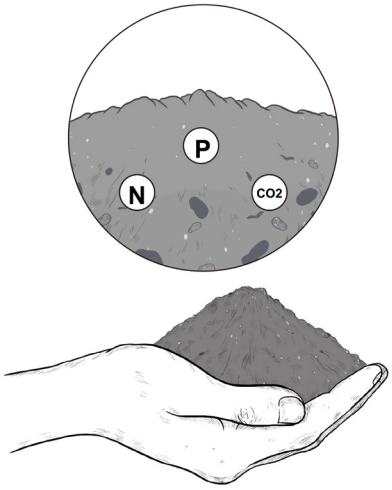
1.1 Description of the system

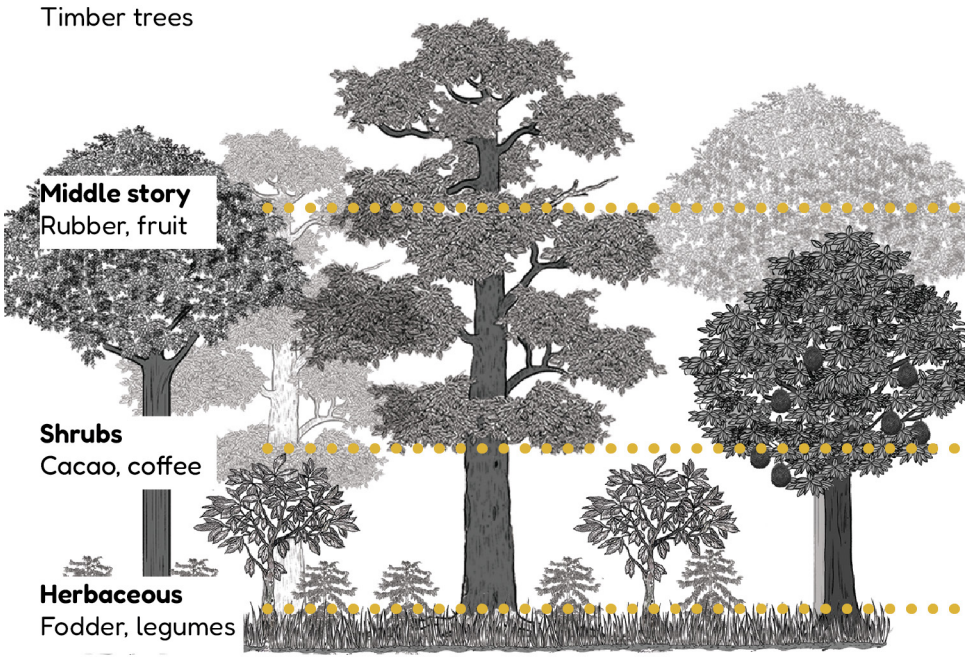
Multistrata perennial agroforestry systems—of which coffee agroforestry is one well-known kind—are the most complex of all agroforestry systems, and they can also be some of the most effective and efficient.

They are designed to make the most of the space available by arranging plants in space and time for maximum productivity of the flagship crop, and carefully managing the density of each layer. They include both 'simultaneous' and 'successional' systems, both of which take advantage of species' differing needs for water, light and nutrients.

In a simultaneous system, the same species and structure are maintained for the system's entire productive lifetime. Such systems deliberately combine species that reach different heights: plants and trees are selected so that each species or group of species occupies a specific layer based on its height and need for sunlight. As tree height changes over time, management is needed to maintain the different layers.

In a successional system, species composition and structure change over time, and the resource-sharing strategy is taken further by planting species with different life cycles. When these species are pruned or complete their life cycle, they leave a beneficial legacy of organic matter in the soil, and the results of their interactions with other plant, animal and microbial species, which improve soil structure, fertility and moisture content.





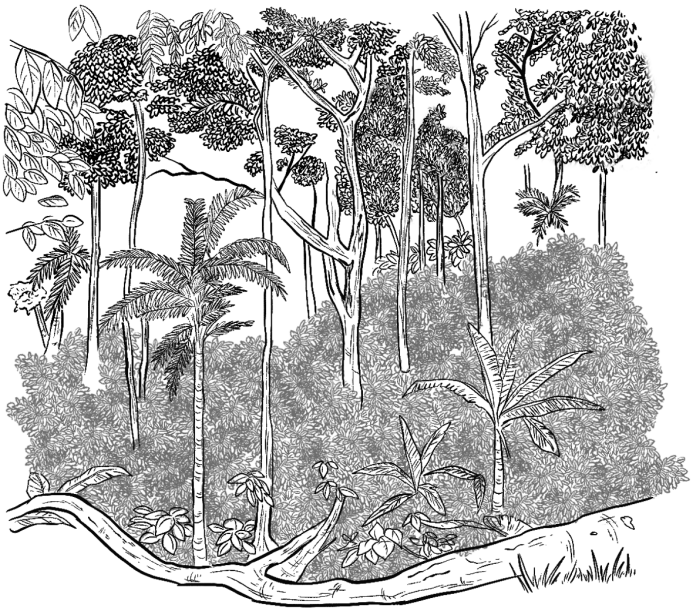
Multistrata systems vary greatly in their design and species composition depending on the region and farming community. They are usually designed around one 'flagship' crop that represents the main production objective—although such objectives can change over time as different products become available, components of the system mature, and market conditions and product values change. Because of the high investment these systems require in terms of labour and

planning, farming communities must be closely involved: only those that fully understand the time and commitment needed will reap their benefits.

Well-designed multistrata systems take advantage of existing seed stocks by supporting natural regeneration of native tree species whilst adding new components with livelihood potential, such as fruit trees and commodities like oil palm and rubber.

1.2 Design guidelines

Making the most of horizontal and vertical space requires a carefully designed canopy structure, based on the productive life cycles and heights of different species. In hilly terrain, trees should be planted following contour lines to minimise soil erosion.



The system should be designed to optimize productivity of the flagship species, with other species chosen to maximize synergies. This requires detailed knowledge of the flagship's physiological needs and productive stages.

Trees that produce a lot of foliage, and nitrogen-fixing species, enhance nutrient circulation and should be represented in each stage of the succession to reduce dependency on commercial fertilizers. The life cycles and productivity ranges of the different species should be mapped out to time the planting of successional stages to avoid productivity gaps and cash flow shortages.

Components must be managed continuously throughout the productive cycle of the system to regulate their population density, minimize competition and enhance complementarity. Farmers need to be aware that managing such a system is a demanding full-time job, and this must be compatible with their knowledge, experience, learning capacity, labour availability and aspirations.

Livestock can be included in the system, but plant species then need to be protected from damage and overgrazing. In uplands with steep slopes, zero-grazing strategies are more appropriate, as they prevent livestock damage to both the land and the system.

1.3 Management guidelines

The basic principle for managing multistrata systems is to manipulate species composition and spatial and temporal structure to provide the right amount of shade at the right time for the plants in the system. This requires detailed knowledge of the phenology of each species—that is, the timing of leaf loss, production of new leaves and shoots, flowering and fruiting.

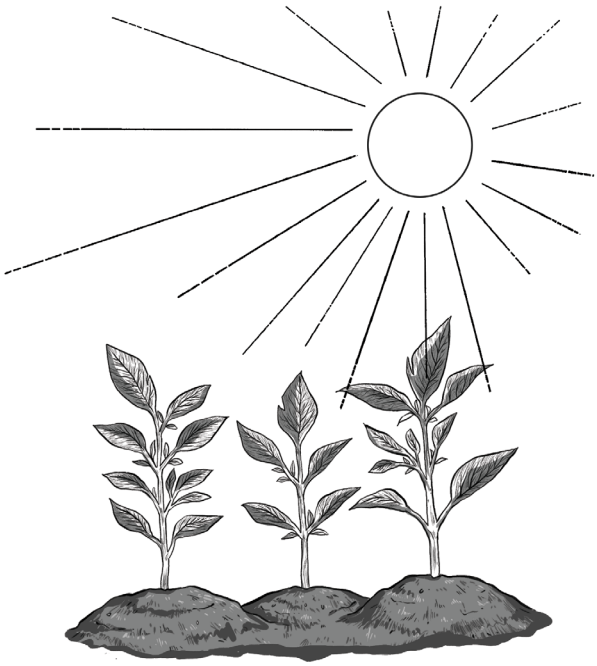
Light triggers plant growth and, therefore, extraction of nutrients from the soil. In low-fertility sites, and if fertilizer has not been added, excess light will stress the plant, leading to poor growth and low yield. Farmers can achieve maximum production for a given level of soil fertility by managing light penetration. To assess a system's shade structure, extension workers can follow this easy, three-step procedure:

1. Assess the exposure to sunlight of the system at different times of the day. Even on the same farm, different areas can receive very different amounts of sunlight, depending on their position in the landscape.

2. Walk through the system at different times of the day and observe the light penetration on the ground. This will tell you whether the system is too dense and if it requires thinning or pruning.

3. Discuss with the farmer the level of productivity that they can manage. How fertile is the soil? Can they afford to buy and apply additional fertilizer? Based on the available sunshine hours, decide on an optimal shade regime to achieve that level.

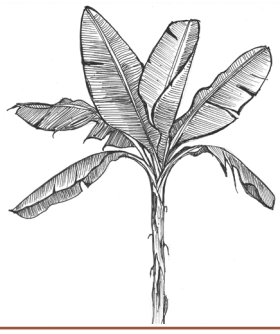
Using the assessments made in the above three steps, extensionists can work with farmers to develop an optimal monthly routine for managing the canopy and stock density.



Module 2: Coffee agroforestry

Photo by Axel Fassio/CIFOR-ICRAF

Learning objective



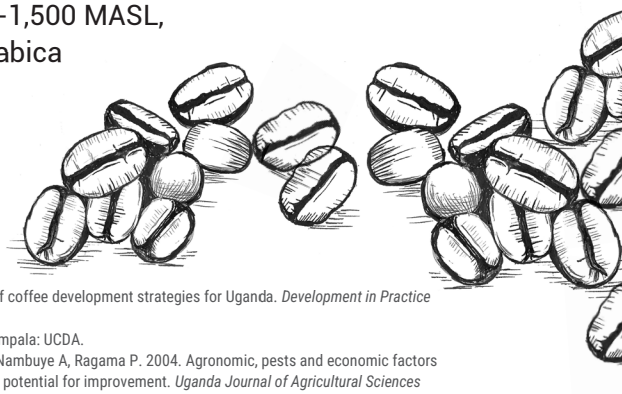
At the end of this module, trainees should understand why coffee agroforestry matters for Uganda. They should know about the various coffee agroforestry systems and which trees and shrubs might fit their context, including management for optimal results.

2.1 Coffee agroforestry in Uganda

Coffee agroforestry—also known as shade-grown coffee—is practiced by growing coffee together with other trees and shrubs for environmental, economic and social benefits.

Coffee is Uganda's most important cash crop and has sustained livelihoods for generations across a range of farming systems.[1] It makes up over 3% of GDP, contributes 20-30% of foreign exchange earnings, supports about 1.3 million smallholder households, and employs over 5 million Ugandans through coffee-related activities along the value chain.[2]

Ugandan coffee is mostly grown in mixed stands intercropped with food crops and shade trees, resulting in relatively sustainable production. Smallholder farmers cultivate most of the country's coffee—usually on farms of 0.5-2.5 hectares.[3] *Arabica* coffee is grown at 1,300-2,300 metres above sea level (MASL)—chiefly around Mt. Elgon, Zombo, Mt. Rwenzori and the Muhavura mountains. *Robusta* is mostly grown around the Lake Victoria Basin at 900-1,500 MASL, and lower altitudes adjacent to the Arabica growing areas.



1 Bolwig S and You L. 2007. Quality or volume? An economic evaluation of coffee development strategies for Uganda. *Development in Practice* 17(3): 433–38. doi:10.1080/09614520701337285.

2 UCDA (Uganda Coffee Development Authority). 2000. *Annual Report*. Kampala: UCDA.

3 Okecho SHO, Gold CS, Abele S, Nankinga CM, Wetala PM, Van Asten P, Nambuye A, Ragama P. 2004. Agronomic, pests and economic factors influencing sustainability of banana-coffee systems of western Uganda and potential for improvement. *Uganda Journal of Agricultural Sciences* 9: 415-427.

Yet the coffee sector—both in Uganda and internationally—is under the threat from climate change. The global area suitable for coffee production in unshaded plantations could decline by 60% under projected climate change by 2050[4] —but the effective use of agroforestry systems can mitigate these impacts and keep 75% of the current area in play for coffee production.[5] Boosting the uptake of coffee agroforestry is critical for climate resilience.

2.2 Common coffee agroforestry systems in Uganda

2.2.1 Tree-coffee agroforestry system

Shade trees (see Figure 1):

- protect sensitive coffee bushes from harsh winds and excessive light
- protect the soil against erosion
- regulate temperature and humidity
- may also provide timber, fruit, fuel wood, and medicines.
- can positively affects coffee quality[6] and resilience to climate change[7]
- improve nutrient cycling by taking in nutrients from deeper soil through their roots and dropping leaf litter on the surface.

Figure 1. A typical tree-coffee agroforestry system in Luwero. Photo by Joel Buyinza.

4 'What climate change means for the future of coffee, cashews, and avocados' (nationalgeographic.com)

5 Gomes LC, Bianchi FJJA, Cardoso IM, Fernandes RBA, Fernandes Filho EI, Schulte RPO. 2020. Agroforestry systems can mitigate the impacts of climate change on coffee production: a spatially explicit assessment in Brazil. *Agriculture, Ecosystems & Environment*, 294, 106858 https://doi.org/10.1016/j.agee.2020.106858

6 Gwali S and Kiyingi I. 2012. Productivity and profitability of robusta coffee agroforestry systems in central Uganda. *Uganda Journal of Agricultural Sciences* 13(1):85-93

7 Tschora H and Cherubini F. 2020. Co-benefits and trade-offs of agroforestry for climate change mitigation and other sustainability goals in West Africa. *Global Ecology and Conservation* 22. https://doi.org/10.1016/j.gecco.2020.e00919

Table 1 provides a summary of key agroforestry trees and shrubs recommended for integration into Ugandan coffee farming systems.

Table 1. Selected multipurpose agroforestry tree and shrub species, associated benefits and management

Agroforestry tree and shrub species	Description	Benefits and management in coffee farming systems
Recommended coffee agroforestry tree species		
Cordia Africana, commonly called: • Large-leaved Cordia • Mukebu in Luganda & Lusoga • Chichikiri in Lugishu & Lumasaba • Muzugangoma in Runyankore	• Deciduous tree • Boraginaceae family[8] • 550–2,600 MASL growth altitude range • Likes warm and moist areas • Often grows along riverbanks	• Mature fruit have sweet edible pulp • Timber: furniture, beehives, boxes, mortars • Medicine: bark, roots • Fodder (leaves in dry season) & bee forage • Shade and mulch for coffee plants • Soil conservation, boundary marker • Increased spacing (>12m) increases branch and crown diameter, making it a good agroforestry tree species • 40% pruning regime recommended at 6-month intervals • High coppicing ability:[9] multiple sprouts around cut branches should be frequently removed after pruning to regulate shading
Albizia coriaria, commonly called: • Mugavu in Luganda • Kumoluko in Lugisu • Musita in Lusoga -Muyenzayenze in Rukiga • Musisa/Murongo in Runyankore	• Deciduous tree • Fabaceae family • Pioneer species • Height up to 36m • High light requirements	• Initially slow growing • Nitrogen-fixer • Provides fodder, bee forage, medicine from bark and roots,[10] shade (flat, spreading crown) • 12x12m spacing recommended • 30% annual canopy pruning regime recommended for mature trees (with sound safety measures for pruners and coffee plants below: use ropes to direct-cut branches in spaces without coffee)
Ficus natalensis, commonly called: • Bark-cloth fig • Mutuba in Luganda • Mutooma/Ekittoma in Runyankore • Mugaire in Lusoga	• Evergreen tree • 12-30m in height • Upright branches • Dense, drooping crown • Aerial roots may hang down from branches • Base of trunk is often a mass of interwoven roots	• Fast growing • Used for making bark cloth • Living fence around homes • Attracts birds and insects which can be potential pollinators, while providing ecological benefits • At wide spacing, useful for shade in coffee, cocoa and banana plantations • Commonly propagated through stem cuttings with varying spacing • Spacing of 12x12m • 50% pruning regime recommended[11]

continued to next page

8 Katende AB, Birnie A, Tengna SB. 1995. *Useful Trees and Shrubs for Uganda: Identification, Propagation and Management for Agricultural and Pastoral Communities*. Technical Handbook No. 10. Regional Soil Conservation Unit, Nairobi, Kenya.

9 Buyinza J, Muthuri CW, Denton MD, Nuberg KI. 2023. Impact of tree pruning on water use in tree-coffee systems on smallholder farms in Eastern Uganda. *Agroforestry Systems* 97, 953–964. https://doi.org/10.1007/s10457-023-00842-2

10 Namukobe J, Kasenene JM, Kiremire BT, Byamukama R, Kamatenesi-Mugisha M, Krief S, Dumontet V, Kabasa JD. 2011. Traditional plants used for medicinal purposes by local communities around the Northern sector of Kibale National Park, Uganda. *Journal of Ethnopharmacology*. 136(1):236-245.

11 Ssebulime G. 2018. Canopy management, leaf fall and litter quality of dominant tree species in the banana agroforestry system in Uganda: Rural Outreach Programme (ROP). *African Journal of Food, Agriculture, Nutrition and Development* 18(1) : 13154-13170

Table 1. Continued

Agroforestry tree and shrub species	Description	Benefits and management in coffee farming systems
Recommended coffee agroforestry tree species		
Ficus mucuso, commonly called: • Mukunyu, Kabalira in Luganda • Kiloko in Kwamba	• Evergreen shrub or tree • Usually around 12m high, but can grow up to 30m • Straight trunk • Large spreading branches • Open crown	• Fast growing • Easily coppices • Good nurse tree for banana and coffee[12] • Plant at wide spacing (>12m) for shade in homesteads • Intercrop with coffee or banana
Ficus ovata, commonly called: • Eboliboli in Ateso • Kookowe, Mukookowe in Luganda • Mukokokwoyo in Lugwere	• Grows in deciduous woodland, wooded grassland, riverine and lakeside areas • Height 12-15m	• Plant cuttings or seedlings widely spaced (>12m) as mature tree has a spreading crown • improves soil fertility when interplanted with crops
Multipurpose agroforestry shrubs		
Calliandra calothyrsus, commonly called: • Calliandra • Kawoomera-mbuzi in Luganda	• Nitrogen fixer • Large • Multi-stemmed • Spreading branches: 4-6m	• Fast growing on good sites • Easily coppices when cut back • Vigour of stand declines with age (lasts 7-12 years): good to integrate into system early • Enhances soil fertility through nitrogen fixation • Bee forage to attract pollinators • Soil erosion control • Fodder for livestock • Spacing of 1x1m with cutting-back/pruning frequency of 9 weeks optimal for forage and soil organic carbon[13] • Can be integrated into a coffee system as hedgerows/strips • Use as a fast-growing firewood source reduces pressure on other agroforestry tree species in coffee farming systems, thus enhancing their integration and retention to provide shade

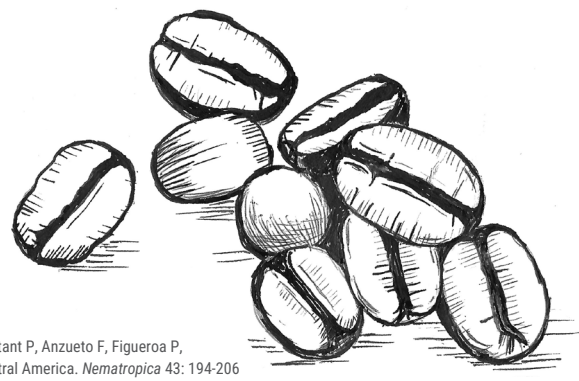
continued to next page

12 Katende AB, Birnie A, Tengna SB. 1995. *Useful Trees and Shrubs for Uganda: Identification, Propagation and Management for Agricultural and Pastoral Communities*. Technical Handbook No. 10. Regional Soil Conservation Unit, Nairobi, Kenya.

13 Fungo B, Buyinza J, Sekatuba J et al. 2020. Forage biomass and soil aggregate carbon under fodder banks with contrasting management regimes. *Agroforestry Systems* 94: 1023–1035 https://doi.org/10.1007/s10457-019-00473-6

Table 1. Continued

Agroforestry tree and shrub species	Description	Benefits and management in coffee farming systems
Multipurpose agroforestry shrubs		
Sesbania sesban, commonly called: • Sesbania • Muzimbandegeya in Luganda Omunyeganyegye in Rukiga	• Deciduous • Nitrogen fixer • Short-lived • Grows up to 8m • Prolific seeder: approx. 110,00 seeds/kg • High germination rate	• Firewood • Poles • Fodder (leaves) • Mulch • Soil conservation and improvement • Nitrogen fixation • Shade (especially for young coffee) • Fibres (young stems) • Soap (from leaves) • Fast growing, short rotation period • Easily coppices when young, requires regular pruning • Can harbour root-knot nematodes, which have been found to attack coffee in Central America:[14] may not be suitable where these are common
Gliricidia sepium, commonly known as: • Gliricidia • Quick stick	• Fast growing • Leafy • Leguminous • *Fabaceae* family	• Fast-growing • Firewood • Charcoal • Fodder (from leaves, shoots, pods) • Bee forage • Mulch (conserves soil moisture, reduces runoff) • Shade • Nitrogen fixation • Soil conservation and improvement • Living fence • Living stakes • Intercropping with coffee provides green manure, soil stabilization



14 Villain L, Sarah JL, Hernandez A, Bertrand B, Anthony F, Lashermes P, Charmetant P, Anzueto F, Figueroa P, Carneiro RMDG. 2013. Diversity of root-knot nematodes parasitizing coffee in Central America. *Nematropica* 43: 194-206

Figure 2 below shows the Uganda Coffee Development Authority's recommended shade trees by region.[15] Yet its list of species is not exhaustive: we advise trainers and extension agents to work with farmers to identify other locally adopted species for coffee agroforestry. Many farmers are willing to share observations about how their coffee performs when integrated with certain tree species.

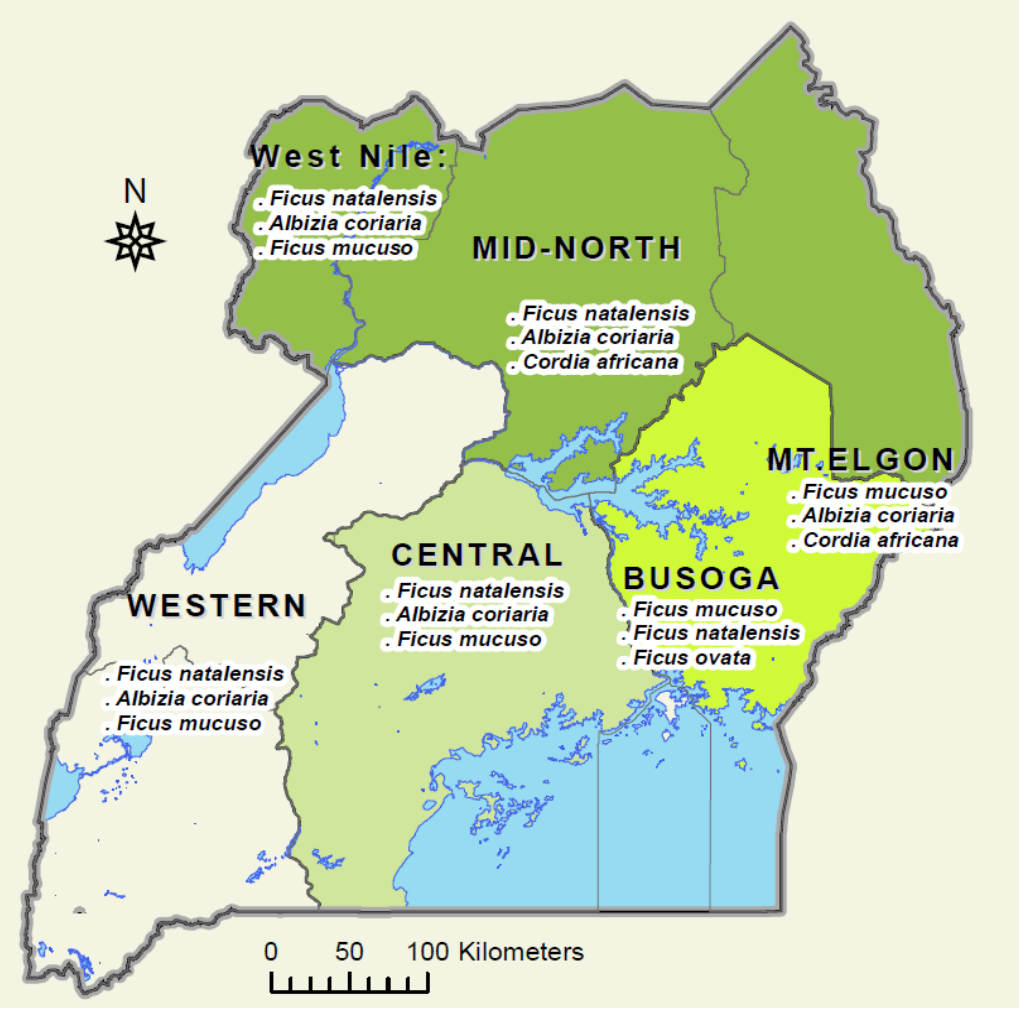


Figure 2. Map of Uganda showing recommended shade trees by region.[16]

15 UCDA (Uganda Coffee Development Authority). 2019. *Robusta Coffee Handbook*. Kampala, Uganda. 148. https://ugandacoffee.go.ug/sites/default/files/2022-03/Robusta%20Coffee%20Handbook.pdf

16 UCDA (Uganda Coffee Development Authority). 2019. *Robusta Coffee Handbook*. Kampala, Uganda. 148. https://ugandacoffee.go.ug/sites/default/files/2022-03/Robusta%20Coffee%20Handbook.pdf

2.2.2 Coffee-banana agroforestry system

In this system, farmers integrate banana plants into coffee farms (Figure 3). The climate-smart agricultural practice—which is common in Uganda's highlands—increases farmer incomes, improves resilience to climate impacts, and sequesters more carbon than monocropping systems.

Figure 3. A typical coffee–banana system in Sheema. Photo by Joel Buyinza.

2.2.3 Other coffee agroforestry systems

These may include a combination of trees, banana and coffee (Figure 4), or a combination of trees, coffee and an understory shade-tolerant annual crop such as beans, supplemented by small-scale animal husbandry for household food security.[17,18]

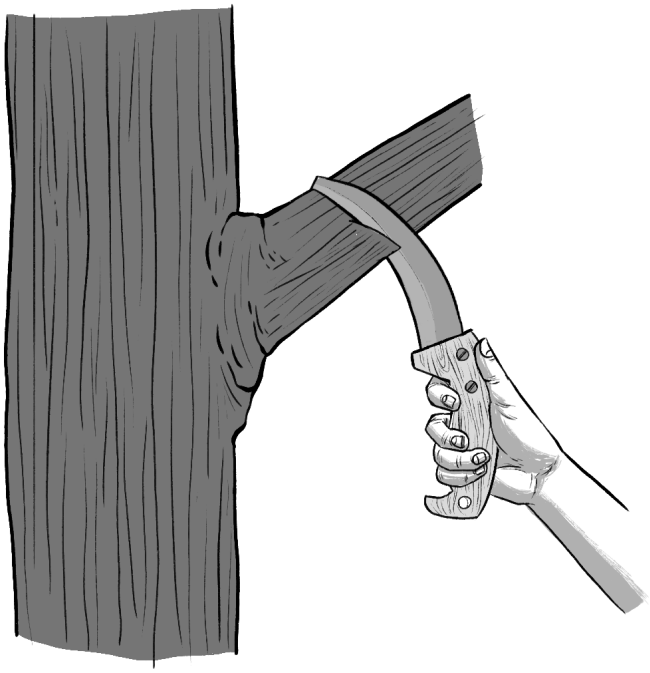
Figure 4. A more complex coffee agroforestry system with trees and banana.

17 Gwali S and Kiyingi I. 2012. Productivity and profitability of robusta coffee agroforestry systems in central Uganda. *Uganda Journal of Agricultural Sciences* 13 (1): 85-93

18 http://www.ugandacoffee.org/index.php?Itemid=49&id=36&option=com_content&task=view

2.3 Management issues in coffee agroforestry

Uganda's coffee sector faces challenges including growing land shortages, pests and diseases, aging coffee trees and a lack of quality planting materials, among others. These hamper productivity and force farmers to pursue intensification strategies that integrate coffee with multi-purpose trees and other agricultural crops.[19] Although farmers increasingly use trees on coffee farms, their management is still largely uninformed by modern agroforestry knowledge.[20] As such, in module 5, this manual provides an appropriate procedure for pruning existing trees in coffee farms.



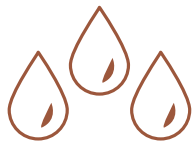
19 Arnold M and Dewees P. 1998. *Rethinking approaches to tree management by farmers*. Overseas Development Institute: London

20 Buyinza J, Nuberg IK, Muthuri CW, Denton MD. 2021. Farmers' Knowledge and Perceptions of Management and the Impact of Trees on-Farm in the Mt. Elgon Region of Uganda. *Small-scale Forestry*. https://doi.org/10.1007/s11842-021-09488-3

2.4 How coffee agroforestry builds resilience to climate change and price volatility

Coffee farmers are vulnerable to external factors such as price volatility and weather changes. Introducing trees or other woody perennials into monocultural coffee farms provides benefits for plantations and farmers:

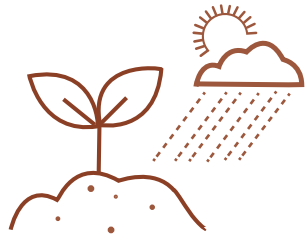
Boosts biodiversity



Increases water availability

Restores soil health and productivity: trees' deep root networks can retrieve nutrients from deeper levels of soil, and they can also fix nitrogen into soil ecosystems

Recreates the canopy-like environment in which coffee naturally thrives



Protects soil from erosion and overexposure to changing weather conditions

Lowers soil and air temperatures[21]

By increasing ground cover and soil nutrient availability, reduces water runoff and soil evaporation, making more water available

Acts as a windbreak

Diversifies income streams of coffee-producing communities, meaning they can harvest other crops and products for year-round income opportunities.

21 Gomes LC, Bianchi FJJA, Cardoso IM, Fernandes RBA, Fernandes Filho EI, Schulte RPO. 2020. Agroforestry systems can mitigate the impacts of climate change on coffee production: a spatially explicit assessment in Brazil. *Agriculture, Ecosystems & Environment* 294, 106858.

Module 3:
Tree nursery establishment

Photo by Axel Fassio/CIFOR-ICRAF

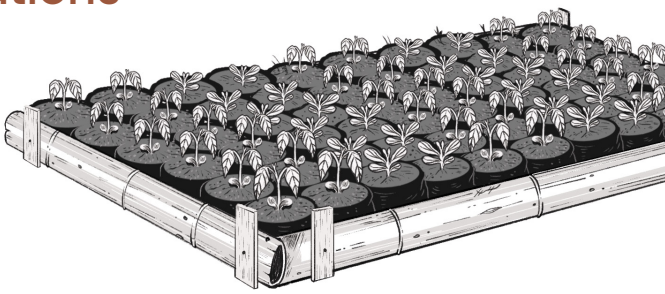
Learning objective

At the end of this module, trainees should be able to set up an individual or community tree nursery, mix soils, and undertake potting, seedling management and pest and disease control.

3.1 What is a tree nursery?

This is a place where young trees (seedlings) are given special care. It can be temporary/ 'flying' (used for a short period such as a season or year) or permanent (used ongoingly). Seedlings can be raised from seed, stem or root cuttings, and wildings.

3.2 Basic considerations for a nursery site



- Location
- Availability of water
- Skilled labour force
- Market for the seedlings.

The ideal nursery site should have at least ¾ of the following requirements:

- Easily accessible
- Good permanent water supply: e.g., spring, river, well, piped water
- Gently sloping, well-drained site
- Good supply of suitable soil materials

Avoid sites with heavy clay soils, swampy valley bottoms and exposed hilltops.

3.3 Materials needed for nursery establishment

- Spades
- Hoes
- Wheelbarrow
- Grafting knife
- Plastic ribbon
- Trowel
- Sharpening stone.

Minimise establishment costs by using locally available materials where feasible—e.g., jerry cans, potting bags, hoes, basins, winnowers, pangas, tins, banana fibre, poles, timber, grass, mats and nails.

To prepare a new nursery site:

- Cut down trees and shrubs
- Destroy termite mounds
- Dig the area thoroughly
- Allow grass to grow and stabilize
- Protect from animals and thieves.

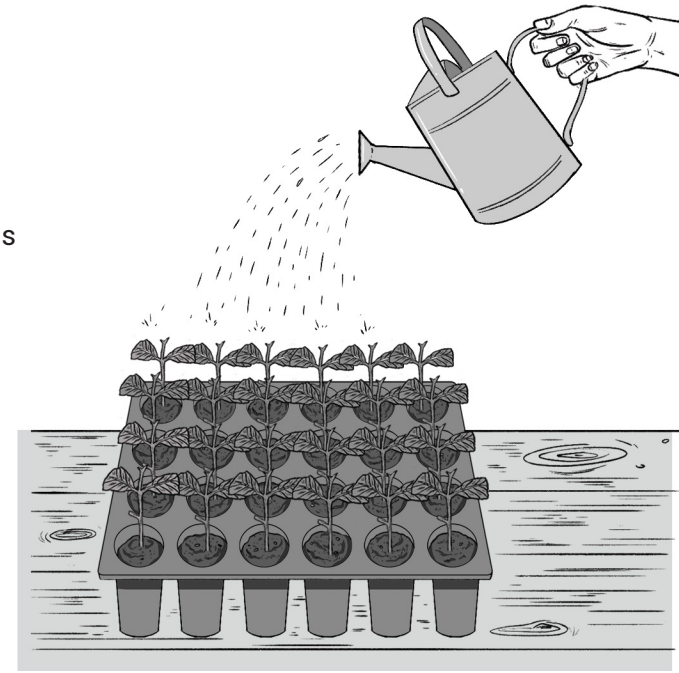
3.4 Nursery establishment procedure

1. Level site for beds, firm soil
2. Mark out beds
3. Erect beds using durable poles
4. Create shade with locally available material
5. Erect rivets (sawn timber or poles) around beds

There are two main methods of propagating seedlings:

- Direct sowing into pots/planting trays
- Broadcast sowing into a seedbed, then pricking out seedlings into pots/planting trays

Note: While seed type may dictate which method to use, the direct sowing approach is usually best because it produces a natural root system that provides good anchorage and efficient uptake of water and nutrients from the soil. If not done carefully, the pricking out method can cause problems like constricted or curled roots, resulting in 'J-rooting', which leaves seedlings prone to instability and stress-induced uneven growth during transplanting.



3.5 Common soil mixtures for nursery seed beds and transplant beds

i. Standard seedbed soil mixture (SSM)

SSM is usually made from 50% sieved black forest top soil and 50% sieved sand—a 1:1 ratio—but this can be varied depending on the clay-to-sand ratio of the available soil..

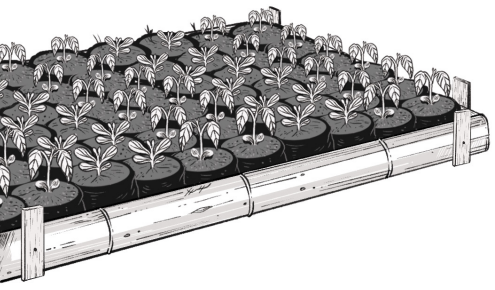
Use of components:

• **Forest soil:** Holds moisture to promote good germination
• **Sand:** Produces porous, textured soil that allows for good root penetration and facilitates pricking out.

ii. Standard transplant bed mixture (STM)

STM can be used in transplant beds or polythene tubes/pots. It contains:

- 60% unsieved forest soil
- 10% sand
- 10% small stones (1cm diameter)
- 10% clay
- 10% composite manure.



STM can be used in transplant beds or polythene tubes/pots. It contains:

- 60% unsieved forest soil
- 10% sand
- 10% small stones (1cm diameter)
- 10% clay
- 10% composite manure.

Use of components:

- **Sand and small stones:** Good root penetration and drainage
- **Clay and top forest soil:** Helps bind near the roots to improve moisture intake and nutrient retention
- **Composite manure:** supplies organic matter and nutrients to soil.

These mixtures can be left to settle for 2-4 weeks before use and kept moist to allow weed growth.[22]

Note: In Uganda, general practice is to use 4-5 basins/wheelbarrows of composite to 1-2 basins/wheelbarrows of soil for transplant beds/pots. For seed beds, we usually use 50% sieved forest topsoil and 50% coarse sand.

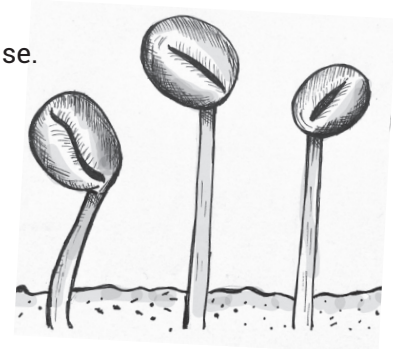
3.6 Methods of sowing seed

i. **Broadcasting:** Spreading seed on top of SSM, by hand or using a mechanical broadcast—usually best for small-sized seeds.
ii. **Drill-sowing:** Making ruts or drills in SSM, then dropping in seeds in a line and covering lightly.
iii. **Direct sowing:** Planting large-sized seeds directly in containers/pots or the field.

When to use seedbeds

- To test viability when seed is old or germination is low/unknown (before filling many containers and potentially wasting resources)
- If seed does not store well
- If containers are unavailable, or not filled in time to use.

Depending on the conditions—including seed size, number of plants wanted and labour availability—a combination of direct sowing and seedbeds may be best. Most nurseries use seedbeds to germinate seeds.



22 Allowing weed growth at this stage minimizes the later emergence of weeds during germination and growth of the target tree seedling.

Direct sowing into containers/polyethene pots

This saves time, labour and money, because the extra step of preparing a seedbed and transplanting is eliminated. Although it takes a little longer to plant small seeds directly into the containers, it is easier and cheaper than pricking out. Direct sowing lets seedlings grow undisturbed, reducing stress.

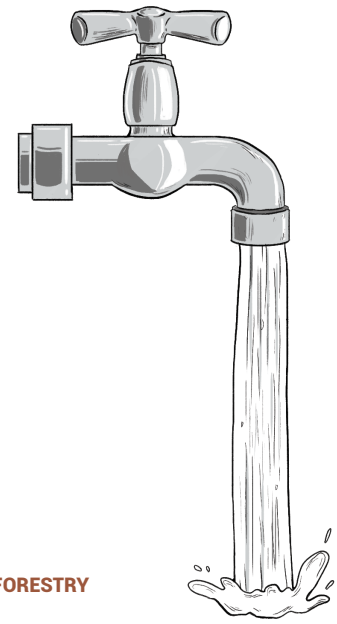
Direct sowing into the field

Some trees/shrubs can be established by sowing seeds directly into an area where they can grow until harvest time. Known as direct sowing, this suits areas with reliable rainfall, and species and technologies that require many trees/shrubs, e.g., live fences, dense woodlots and improved fallows.

3.7 Tree nursery management

i. Watering

A regular clean water supply is essential for plant growth. Plants are made from over 90% water and when grown in containers can't 'search' for water below the soil surface.



The amount of water seedlings require depends upon:

- Age
- Amount of sunlight
- Soil type
- Turbulence (presence of wind).

Avoid dirty water (as it can contain diseases) and saltwater.

Good nursery watering practices:

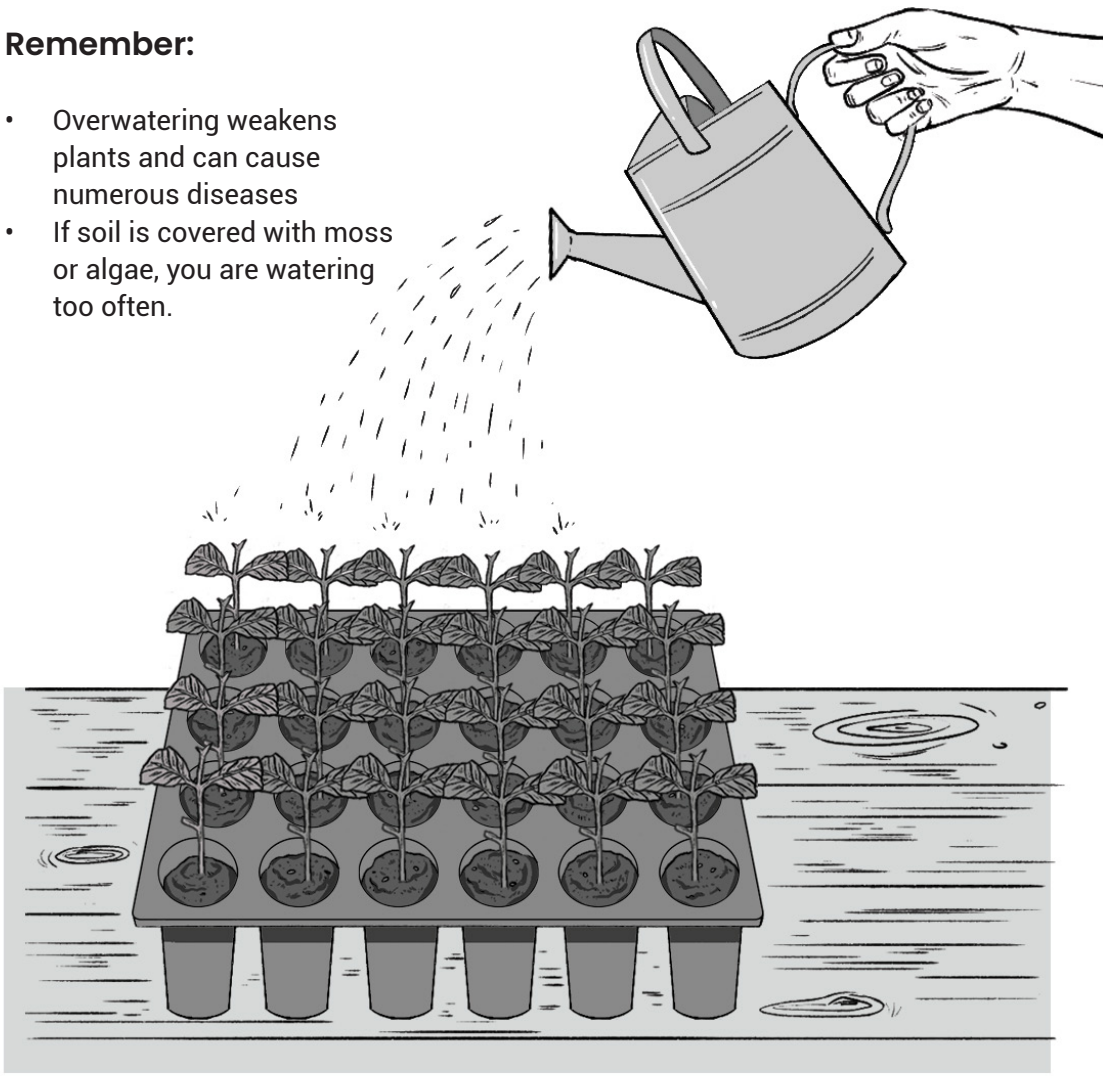
- ✔ Regularly checking water status of leaves to determine when to water
- ✔ Watering in early morning and/or late evening.

Poor nursery watering practices:

- ✕ Watering on a fixed schedule
- ✕ Directing water to leaves, not soil
- ✕ Watering at midday
- ✕ Watering quickly and only wetting the soil surface.

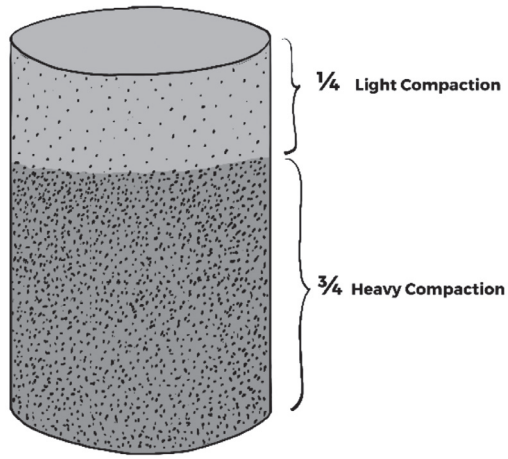
Remember:

- Overwatering weakens plants and can cause numerous diseases
- If soil is covered with moss or algae, you are watering too often.



ii. Pot filling and nursery layout

- Fill polythene tubes/ pots with soil under shade beside soil heap at transplant bed site
- Soil should be moist enough to run freely into the tube, and easily firmed to form the bottom of the tube
- First ¾ of soil should be heavily compacted for a firm base, followed by light compaction for the remaining ¼ (see figure below): a good worker can fill 100 pots/polythene tubes/hour



- Shade protects new seedlings from direct rain and sun: it should be dense at early stages and graduallly reduced until it is completely removed during the hardening-off period
- To avoid direct sunlight reaching the seedlings, orient beds east to west, except on slopes where they run along the contour.

Figure 5. Potting compaction (top) and nursery seedbeds (above).

iii. Pricking out

This is the act of lifting seedlings from seedbeds into transplant beds or pots. Poor pricking out practices include:

- Waiting until plants are large and have long roots
- Pricking out plants into dry soil and then watering them
- Constructing shade after pricking out is done
- Carrying seedlings in your hand or on a plate without water
- Preparing the holes with a finger—the hole might be too small or big depending on the size of the finger used.

iv. Shade and watering after pricking out

After pricking out, transplants need full shade for the first 2–3 weeks, then ½ shade for 1 week, after which no shade should be necessary. As shade is decreased, watering intensity must be increased.

v. Weeding

This entails removing weeds to reduce competition for water and nutrients.

vi. Root pruning

Seedlings' root growth must be checked regularly: root pruning—cutting back the actively growing roots of the transplants—may be necessary if planting is delayed. It serves to:

- stop the roots of seedlings intertwining
- help transplants develop good root systems for easy establishment in the field
- prevent transplants from penetrating into the soil and getting established within the nursery site.

Note: Wait at least 2-3 days after root pruning to plant seedlings, as they will be stressed and need time to recover.

vi. Hardening off

Creating 'harder' conditions for the seedlings—such as by reducing watering—as the planting season approaches produces tougher seedlings that can better withstand the stress of being planted out.

Note: Never carry seedlings over from one season to the next: the roots become 'pot-bound' and cannot respond quickly when planted out.

viii. Nursery hygiene

Good hygiene in the nursery site helps to grow healthy, quality seedlings.

ix. Nursery records

Effective nursery management requires up-to-date records, including:

- all seed purchases
- sowing dates
- germination dates
- germination percentage
- seedling sales/distribution records
- nursery equipment.

Each bed should be clearly labelled, with a separate record of the labels kept in the nursery office in case those in the beds are destroyed or misplaced.

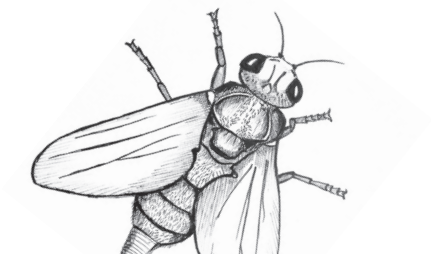
3.8 Common pests and diseases in tree nurseries

a. Pests

Gall flies are occasionally found in nurseries; their impact on seedlings is higher under water stress.

b. Diseases

'Damping off' is a condition in which young seedlings rot at the root collar, die and fall over. It is a sign they are getting too much water, and it can be controlled by reducing or stopping watering until the situation improves.



3.9 Common tree nursery problems and solutions

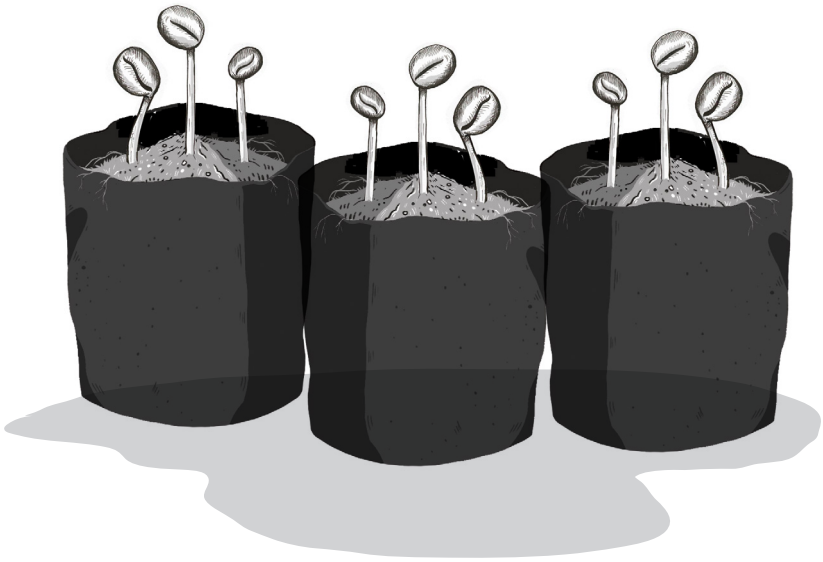
Table 2. Common tree nursery problems and solutions

Problem	Solution
Variable tree seedling quality and growth rates	• Only buy recommended, good-quality seed • Cull (sort) seedlings better • Discard rejects and late germinants
Seedling numbers lower than expected	• Sowing seed too deep • Poor seed storage • Follow any pre-germination treatment recommendations • Double sow % to allow for low germination
Seedlings are too large or small when rains arrive	• Plan better • Sow at correct time • Stagger sowing • Communicate better with field/customers
High seedling deaths (stems rot when very young)	• Routinely drench with fungicide at sowing • Keep systemic fungicide(s) in reserve
Compacted soil in pots	• Mix sand with soil to improve drainage • Check for over-watering
Poor root development	• Reduce pricking out (or supervise better) • Use fertilizers • Routinely check root development (see photo above)
Root coiling in pots	• Plant out or sell • Root prune older seedlings frequently
Chlorosis (yellowing) of foliage	• Apply fertilizers (only after trials to determine dose) • Check watering

continued to next page

Table 2. Continued

Problem	Solution
Weak-looking seedlings	• Reduce shade • Fertilize seedlings
No space to expand nursery	• Select site carefully
Shortage of water at critical times	• Before starting the nursery, ensure water supply is adequate (approx. 10 litres of water/m2 nursery bed/day) • Have an emergency water supply
Customers or beneficiaries do not pick seedlings	• Communicate regularly with customers/ beneficiaries • If seedlings are for sale, insist on advance payment • Field staff should monitor and remind farmers to prepare land early enough • Set up seedling distribution centres in communities



Module 4:
Tree seedling establishment and management

Photo by Axel Fassio/CIFOR-ICRAF

Learning objective

At the end of this module, trainees should understand key considerations for planting a seedling in the field, the practice of pitting, and general tree planting rules.

4.1 Key consideration before planting a seedling in the field

Before planting seedlings in the field or an orchard, you must gradually accustom them to growing in natural conditions. In the last few weeks before planting, watering should be reduced and sun exposure increased. Seedlings must be watered very well in the last few days before planting.

Farmers must consider the varying spacing requirements of different species, which are determined by tree crown diameter and root structure. Silvicultural studies have shown that increased spacing (>12 m) increases the branch and crown diameter of some species, such as *Cordia africana*.[23]

4.2 Tree planting rules

- Plant trees 2.5 cm deeper than they grew in the nursery
- Make sure the hole is big enough for the tree—preferably at least 30x30 cm
- Avoid planting seedlings with J-roots—better to do root pruning before planting out
- Plant seedlings straight into the soil
- Keep roots cool and moist until they are in the ground
- Firm soil around the root system, taking care not to disintegrate it
- Plant when soil conditions are right.

23 Katende AB, Birnie A, Tengna SB. 1995. *Useful Trees and Shrubs for Uganda: Identification, Propagation and Management for Agricultural and Pastoral Communities*. Technical Handbook No. 10. Regional Soil Conservation Unit, Nairobi, Kenya

4.3 Factors that determine success or failure of seedlings in the field

- **Site selection:** Within each site, factors such as soil type, topography, climate, and pest and disease pressure affect survival.
- **Species selection:** A species' heat tolerance and ability to withstand common pests and diseases are key to survival in the field.
- **Post-transplant care:** After planting out, the seedling requires adequate water, balanced nutrition, minimum mechanical damage, and pest and disease control.

4.4 Planting a tree seedling in the field: Key steps

Step 1: Planning

Poor pre-planting organization, and poor supervision during planting, can result in considerable loss of seedlings (poor survival).

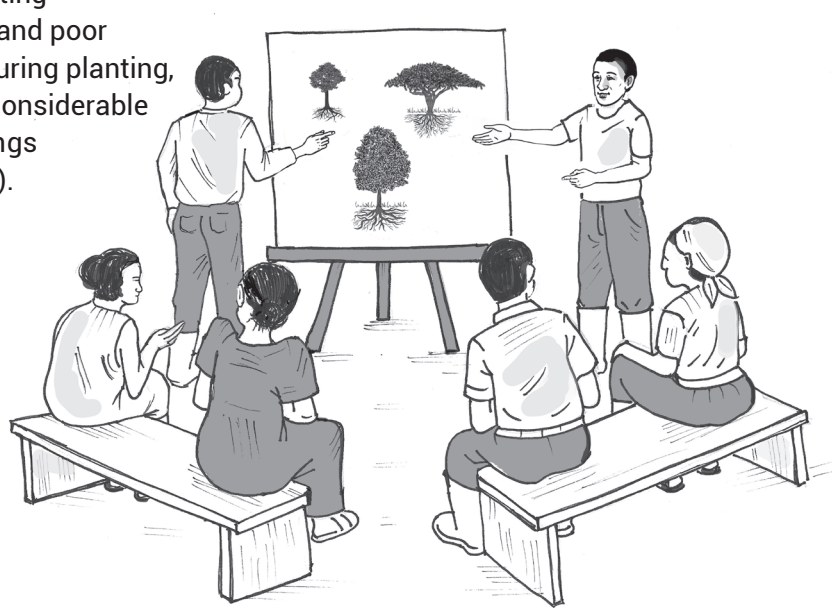


Figure 6. A well-designed coffee agroforestry system (Source: 43 Factory Coffee).[24]

The following elements must be considered:

- **Tree species selection:** Choose species that fit the site and purpose.
- **Time of planning:** Time planting with the right rainy season. Use a rain gauge to calculate rainfall buildup, or wait for 2-3 days of heavy rains within a week, then dig test pits to 30cm to make sure soil is moist to this level.
- **Plant distribution:** Transportation of seedlings from nursery bed to planting site is best done the evening before planting starts. Onsite, water seedlings again if transportation lasted more than an hour. Store them under shade.
- **Onsite organization:** Carriers with baskets can distribute seedlings ahead of planters, who then move across the area in a horizontal line. The supervisor comes behind, making sure that people are planting effectively, and no spots are missed.

Note: It is common practice in Uganda for farmers to randomly scatter shade trees in their coffee plantations. We however recommend that they begin establishing well-designed agroforestry systems (see figure above) to ease management and allow mechanization in future.

24 https://43factory.coffee/en/news/will-coffee-production-by-agroforestry-or-monoculture-destroy-the-environment/

Step 2

Conduct **lining out** to determine seedling planting spots, thus making weeding easier and distributing trees effectively in the system. Spacing depends on species growth rates, tree forms, water and nutrient availability, and future management.

Step 3

Undertake **pitting** by using a hoe to remove vegetation to a 60cm radius around planting spot; digging out topsoil and putting it aside; then digging up subsoil and placing on opposite site of pit. Dig pit to ≥30x30cm.

Step 4

Replace soil in pit—starting with topsoil.

Step 5

Remove polythene tube/ potting bag from seedling before planting it, either by cutting from the soil or sliding from seedling for reuse.

Step 6

Ensure the seedling is firmly planted in the soil by carefully pressing around it, while ensuring the surrounding soil around the seedling is not disintegrated—this can damage seedlings' roots and affect survival and growth.

Step 7

If the seedlings are to be watered, dig a dish around the planting to facilitate this.

4.5 Seedling protection in the field

The following measures can be taken to protect planted seedlings, depending on local survival risks:

- Put stakes around each seedling to protect from browsing animals.
- Clear the field of any existing termite mounds and apply rocket at each planting spot to minimize termite damage.
- Increase watering if heat stress is threatening seedling survival. Simple mechanisms like bottle irrigation can be used, especially for small-scale planting.

4.6 Weed control

Weeding eliminates or suppresses unwanted vegetation that impairs tree growth by competing for light, water and nutrients.

- Weeding intensity varies with vegetation, soil type and the species' ability to compete.
- Cultivating desirable plants yields better results than just getting rid of weeds; it also breaks the soil and promotes aggression and water penetration. It is best done when weeds are young.
- Possible weeding regime: 1st year—weed 3 times; 2nd year —weed twice; and 3rd year—weed once.

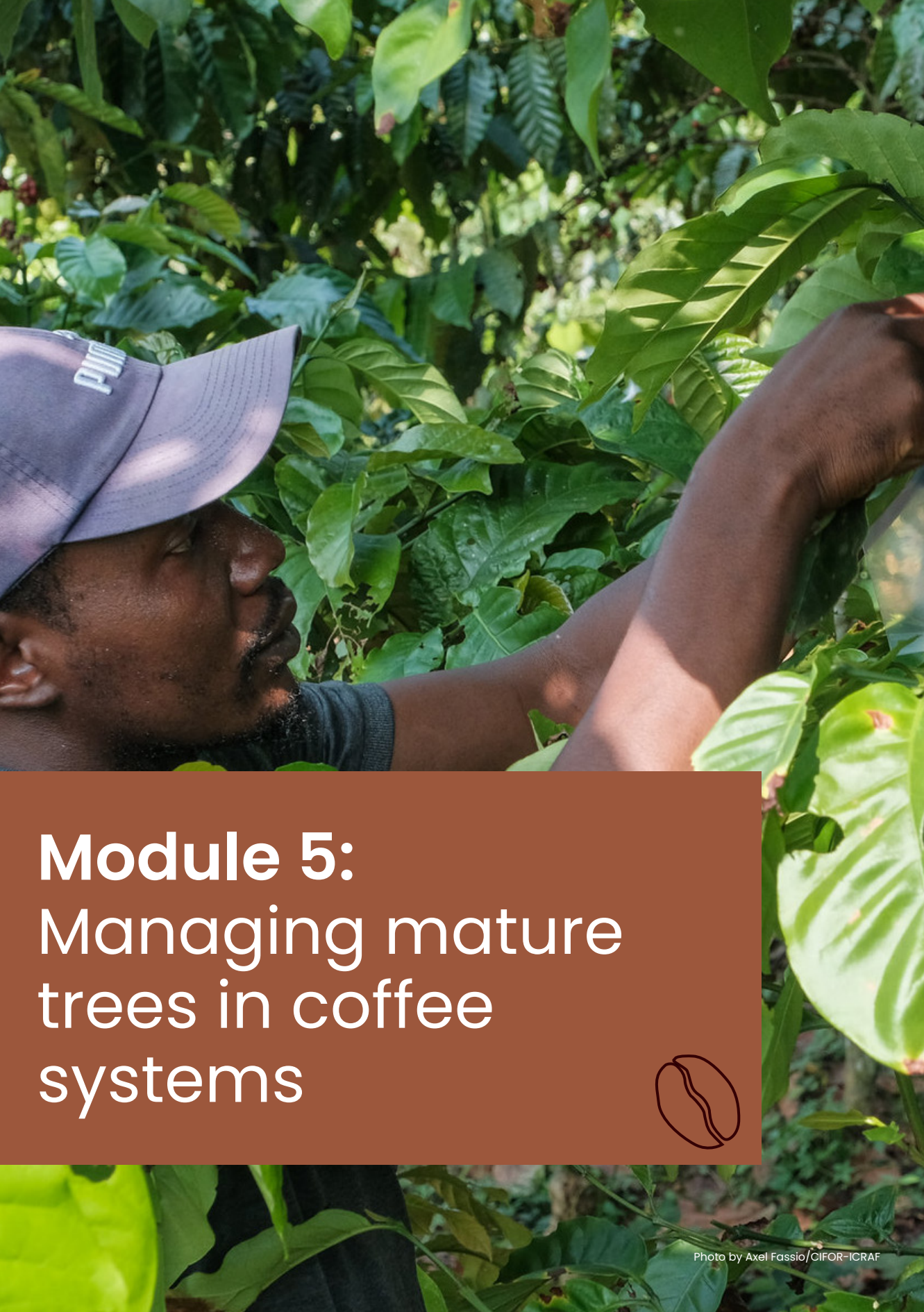
Methods of weed control include:

- **Clean weeding:** Turn over soil to expose weed roots for an effective kill; a second hoeing is helpful after 2-4 weeks, to arrest weeds while they are weak. This operation is costly and should be limited to small areas of sensitive trees.
- **Strip weeding:** Restrict the hoed area to a strip of 50-75cm on either side of the planting raw.
- **Spot weeding:** Confine hoeing to a radius of 30-60cm from each plant. In areas with tall grasses, this can be combined with the suppression method or slashing.
- **Chemical control:** Suppress or kill weeds using chemicals. Translocation chemicals (glyphosate) are commonly used, but such use should be limited due to environmental concerns.
- **Use of cover crops:** Plant agricultural crops to suppress weeds, especially between rows of trees—in such cases, avoid climbing or tall crops, don't plant crops within 30cm of a tree, and weed regularly.

4.7 Beating up/gap filling

This expression refers to replacing dead or struggling seedlings in a recently planted area, to avoid large gaps: if >25% of seedlings in the field are dead, replacement is required.

Fill gaps 2-4 weeks after planting to ensure uniformity, especially when establishing a woodlot or boundary planting. Doing so later on is a waste of time, as the new seedlings won't catch up and will end up being thinned out.

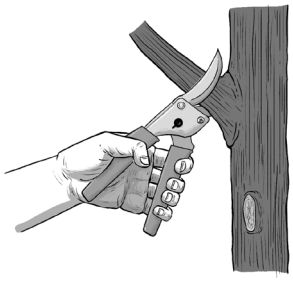


Module 5: Managing mature trees in coffee systems

Photo by Axel Fassio/CIFOR-ICRAF

Learning objective

At the end of this module, trainees should be able to safely undertake tree canopy pruning, thinning, lopping, pollarding and coppice management.



5.1 Tree canopy pruning

The purpose of pruning in commercial forestry is to produce trees with single straight stems and more valuable, knot-free trunks. In agroforestry systems, pruning is also done to minimize the negative effects of shade, including competition for light and below-ground water and nutrients.[25] It also prolongs the intercropping period where farmers can introduce understorey annual crops such as common beans.

Advantages of pruning agroforestry trees

- Significantly reduces competition for light and water
- Cut leaves and branches contribute to soil organic matter, act as mulch
- Can help control pests, fungus and disease, especially where dense canopies create a moist microenvironment
- Prolongs the period of intercropping, sustaining crop production below trees (see Figure 7).

Figure 7. A site in Butta (Manafwa district) where canopy pruning enables the farmer to grow beans below coffee for a prolonged period. Photo by Joel Buyinza.

25 Buyinza J, Muthuri CW, Denton MD, Nuberg KI. 2023. Impact of tree pruning on water use in tree-coffee systems on smallholder farms in Eastern Uganda. *Agroforestry Systems*. https://doi.org/10.1007/s10457-023-00842-2

5.2 Key considerations for pruning in coffee systems

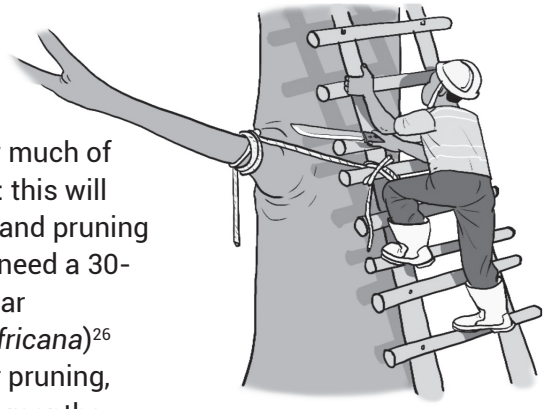
a. Ensure minimal crop damage

- Rope branches to be cut; make sure the rope doesn't interfere with freefall when making the second cut
- Carefully lower cut branches onto the ground and place between coffee rows
- Prune just after coffee harvest season, before flowering
- Prune when there is no other crop below the coffee to avoid trampling.

b. Lower risks for pruners

- Minimise risk by using experienced pruners with protective gear—including helmets
- Climber should secure tools when not in use
- Don't prune straight after heavy rain, as trunks will be slippery
- Remember some tree branches are weaker than others
- To climb, tie a ladder to the tree with a rope looped through a strong branch, as illustrated below.

c. Identify appropriate pruning regime



The farmer should decide how much of the canopy to remove for light: this will vary by tree species, age, size and pruning frequency. Most mature trees need a 30-40% pruning regime ≥ once/year
Where trees (such as *Cordia africana*)[26] produce multiple sprouts after pruning, remove re-growths ≥ every six months.

26 Buyinza J, Muthuri CW, Denton MD, Nuberg KI. 2023. Impact of tree pruning on water use in tree-coffee systems on smallholder farms in Eastern Uganda. *Agroforestry Systems*. https://doi.org/10.1007/s10457-023-00842-2

5.3 Three-cut procedure for tree canopy pruning

This procedure minimizes branch splitting and pruning damage.

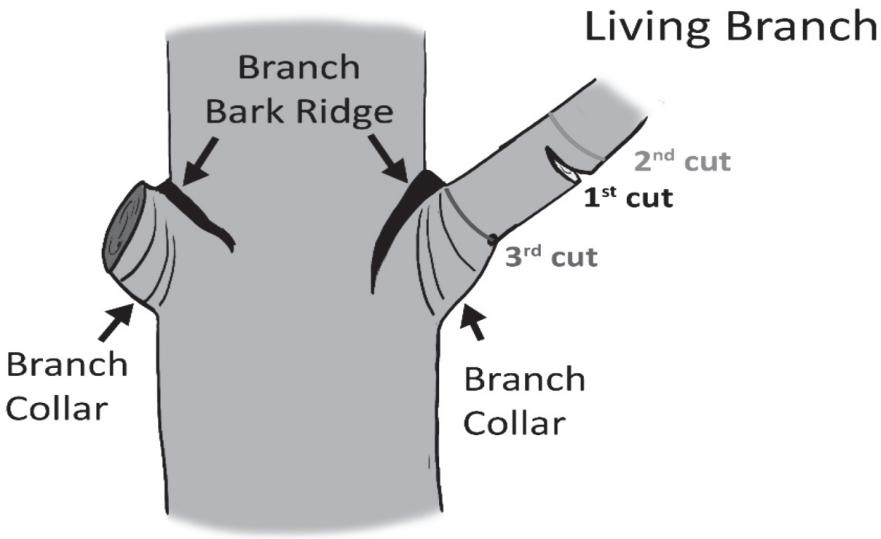


Figure 8. Three-cut procedure.

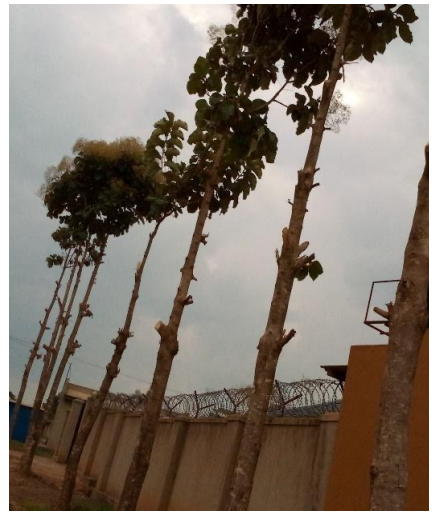
i. 30cm from trunk, cut halfway through branch from underside
ii. 3cm past the first cut, cut through branch from top side until branch falls away; it will break between the two cuts and hang on rope
iii. Cut back resulting stub to collar of branch
iv. Carefully lower hanging branch to the ground, guiding to fall between coffee rows; cut branch into small pieces (use large sections as firewood and leave the remainder on the ground as mulch.)

Note: It's best to prune in the dry season because scars dry out quickly, discouraging fungal growth. Some hardwoods—e.g., eucalyptus, *Maesopsis eminii* and *Terminalia*—are self-pruning when grown close together.

Figure 9. Examples of poor and good pruning

Poorly pruned trees: at left, the branches are cut too far from the branch collar; tree on the right is over-pruned (too many branches removed).

Poorly pruned pines: too much crown removed (only ¼ left).



Poorly pruned teak (too much crown removed, long nodes left).

Well-pruned teak: ¾ of the crown remains, and pruned branches are cut close to stem.

5.4 Thinning

- As trees mature, they can get crowded: competition causes declining growth rates and can increase shading on understorey crops
- Thinning is a selective process of removing/killing some trees so that those remaining grow steadily, minimising light and water competition
- It's also a chance to remove poorly formed trees and lower value species from the system
- It's most urgent in high density, high survival systems on good sites
- Where there's high variation in growth and survival, thinning is only needed where trees are dense.

5.5 Coppicing

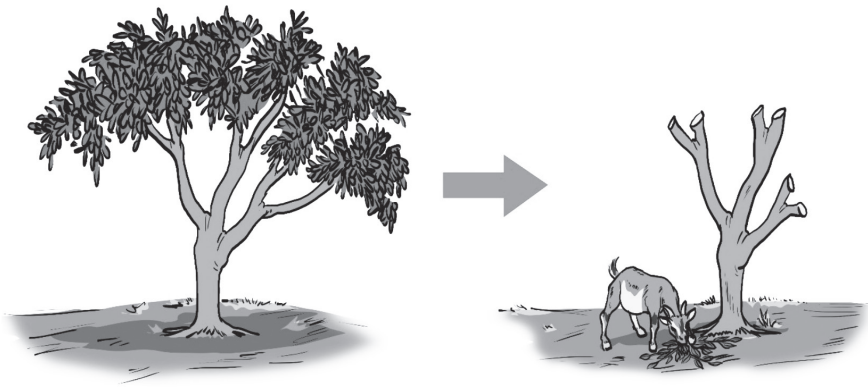
- This technique can be used to manage trees that produce multiple shoots on their stumps
- Trees are cut down to their stumps and allowed to re-sprout
- Readily coppicing trees don't need frequent replanting and are thus useful for fuelwood and poles.

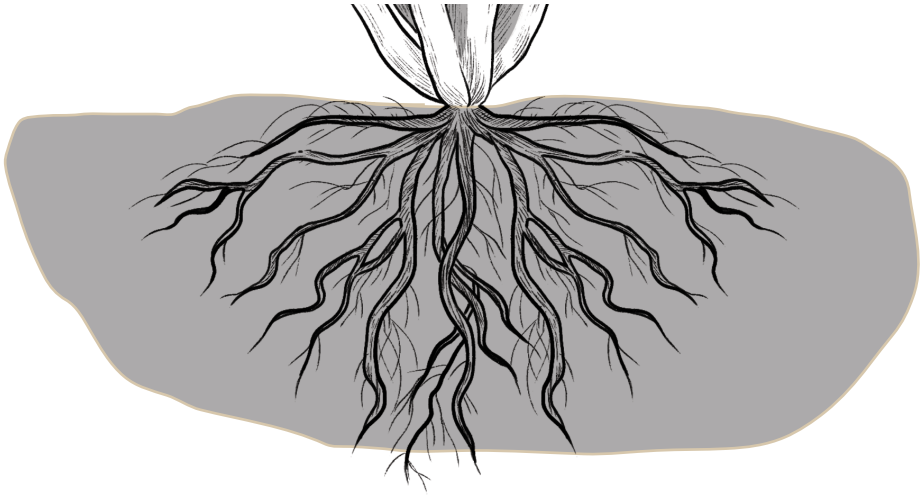
5.6 Lopping

- This is the cutting of branches from a standing tree, e.g., for fuel, fodder or medicine
- It is best to cut side branches, not the main stem.

5.7 Pollarding

- This involves cutting off the entire crown, so the tree sends out new branches from the top of the remaining trunk, at ≥2m height
- New shoots are high up and therefore more protected from animals
- Sprouting after pollarding is usually vigorous because the root system is well-established
- It is mainly done on fodder trees, boundary and scattered trees, and compound trees.





5.8 Root pruning

This is the cutting of live roots:

- to reduce competition with associated crops
- to avoid damage to buildings
- to harvest medicine.

It's best to do when the tree is ≥ 4 years old, but this period may be shorter for fast-growing species. Subsequent root pruning can be done during garden preparations before planting associated crops.

Steps in root pruning:

- Mark a distance of 30cm from the tree(s)
- Dig a 30x30cm trench to expose roots
- Cut exposed roots with a panga/axe
- Put back soil to cover the trench
- Repeat when required.

5.9 Pest and disease control in coffee agroforestry

5.9.1 Principles for controlling pests and diseases

- **Manage tree shade**: This is a critical on-farm practice for smallholders; poor shade management can increase pests/diseases.
- **Avoid sharing farm equipment:** It's common for farmers to share equipment like pangas and axes, but this should be avoided where possible as it can transfer pests/diseases.
- **Undertake coffee agronomic practices:** Managing coffee through weeding, pruning and rehabilitation minimises pest/disease risk.
- **Regularly sanitise farm equipment:** This is especially key when it is likely to be shared between farms.
- **Avoid integrating tree species that are alternative pest hosts** or unfriendly to coffee, e.g., *Albizia chinensis, Eucalyptus*, and *Measopsis eminii*.
- **Seek and implement extension advice:** Strictly follow guidelines on pest/disease control, and report outbreaks as early as possible.

5.9.2 Control measures for the coffee black twig borer

The Black Coffee Twig Borer (BCTB) is a tiny beetle that bores mainly into the primary branches and stems (usually on the underside) of a host coffee plant, where it lays its eggs. The larvae then create further tunnels through the plant tissues, causing significant damage to the stem. The beetle spends much of its life inside the coffee branch and is usually only seen when the branch is broken open. We provide remedies for prevention, monitoring and direct control of the BCTB in Table 3.

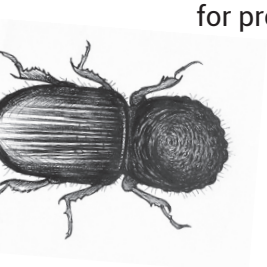


Table 3. Documented remedies for coffee black twig borer [27,28]

Prevention	Monitoring	Direct control
• Keep coffee field weed-free • Apply organic manure/ fertilizer for plant health and vigour • Promote good soil and water conservation practices • Regularly monitor for twig borer symptoms on alternative hosts, such as avocado and cocoa close to coffee fields • Avoid cultivating alternative hosts—e.g., *Albizia chinensis*, *Maesopsis eminii, Ficus natalensis* and avocado	• Use ethanol-baited traps (pour ethanol into empty water bottles, make two holes on each side) to monitor populations and outbreaks • Check daily for wilting, yellowing, dry/dead branches with small hole (bicycle spoke size) at entry point, especially during dry season • Split affected branches to check for white spongy (fungal) growth and small light brown to shiny black beetles • Look out for light green leaves of infested branches on coffee plants, and withered leaves	• Prune/cut and burn all infested branches/twigs • Provide additional water if available during dry periods • Encourage other farmers in the area to control the borer • Promote tree health and vigour for resistance to infestation and recovery from attacks • Use systemic chemicals on affected branches/twigs • Biological control may be possible through mass rearing of natural enemies—but requires further research

27 Lina W. 2016. *Infestation and management of the black coffee twig borer in Uganda—and the potential impact of the leguminous tree Albizia chinensis on robusta coffee*. Independent project/Degree project/SLU, Department of Ecology. https://stud.epsilon.slu.se/9644/1/wu_l_161010.pdf

28 ICRAF. 2017. Ecologically inhibiting the black coffee twig borer. World Agroforestry News, 6 December. https://worldagroforestry.org/news/ecologically-inhibiting-black-coffee-twig-borer

Principles of agroforestry design

Agroforestry design involves deciding what will be produced, selecting the components of the system, and determining how they will be arranged. These decisions also define how and when the components will be established, and how they will be managed. It also includes other considerations, such as how to support the enabling environment for agroforestry. Farmers have been designing agroforestry systems for millennia – sometimes consciously, sometimes instinctively. Professionals can support this process by applying the three principles of agroforestry, as defined below.[29]

The principle of farmer-centredness: In designing agroforestry projects and programmes, put the goals and aspirations of farming families first, before considering how you will meet other, wider goals.

The principle of aptness to place, people and purpose: In designing agroforestry projects and programmes, remember that 'one size fits all' does not apply: all agroforestry systems need to be customized to local conditions.

The principle of synergy: In designing agroforestry projects and programmes, harness the full potential of agroforestry by ensuring that trees, crops and livestock interact in mutually beneficial ways that sustain multiple ecosystem services.

29 Gassner A and Dobie P. eds. 2022. *Agroforestry: A primer. Design and management principles for people and the environment.* Bogor, Indonesia: Center for International Forestry Research (CIFOR) and Nairobi: World Agroforestry (ICRAF).

Coffee agroforestry

Training handbook

Coffee agroforestry in Uganda: Design & management principles for people & planet

Coffee is Uganda's most important cash crop and has sustained livelihoods for generations across a range of farming systems. Yet the coffee sector — both in Uganda and internationally — is under the threat from climate change. However, the effective use of agroforestry systems can mitigate these impacts and keep 75% of the current area in play for coffee production. Boosting the uptake of coffee agroforestry is critical for climate resilience.

Coffee agroforestry — also known as shade-grown coffee — is practiced by growing coffee together with other trees and shrubs for environmental, social and economic benefits. Agroforestry is not new: farmers have practised it for thousands of years, and scientists have recognized it since the 1970s as a productive and ecologically sustainable form of agriculture and land use. But agroforestry is now at centre stage: it is promoted as a land-use strategy to support climate change mitigation and adaptation, biodiversity conservation, sustainable agriculture and other goals.

This training handbook supports extensionists, advisors and practitioners working on coffee agroforestry in Uganda. To achieve maximum benefits from agroforestry, farmers need to understand its principles — and their application for coffee cultivation. The resource will help trainers and extension agents support farmers to design, establish and manage coffee agroforestry systems in a range of contexts.

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The Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) harnesses the power of trees, forests and agroforestry landscapes to address the most pressing global challenges of our time – biodiversity loss, climate change, food security, livelihoods and inequity. CIFOR and ICRAF are CGIAR Research Centers.

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