Australian Government

Australian Centre for International Agricultural Research

SMALLHOLDER COFFEE PRODUCTION IN PAPUA NEW GUINEA – FARMER TRAINING GUIDE

UNIT 2: MANAGING YOUR COFFEE GARDEN

MODULE 8:
INTERCROPPING IN YOUR COFFEE GARDEN

Curry G, Tilden G, and Aroga L (2025) *Smallholder coffee production in Papua New Guinea: A training package for extension officers and farmers*, ACIAR Monograph No. 220, Australian Centre for International Agricultural Research, Canberra.

ACIAR Monograph Series No. 220 (MN220)

Cover: Intercropping coffee with food crops

Cover photo credits: Pennuel Togonave (Asaro), Emma Kiup (Bena) and Emma Kiup (Asaro)

Australian Government
Australian Centre for
International Agricultural Research

SMALLHOLDER COFFEE PRODUCTION IN
PAPUA NEW GUINEA – FARMER TRAINING GUIDE

UNIT 2: MANAGING YOUR COFFEE GARDEN

MODULE 8:
INTERCROPPING IN YOUR COFFEE GARDEN

The Smallholder Coffee Production in Papua New Guinea Training Program

The training program contains modules prepared in partnership with the Australian Centre for International Agricultural Research (ACIAR) and by CARE-International. The structures of the Extension Officer Training Program and the Farmer Training Program are shown in the table below. Some modules also contain references to additional training that learners are encouraged to complete as part of their training.

Extension Officer Training Program

Title	Module reference
Introduction to smallholder coffee production in Papua New Guinea	ACIAR smallholder coffee production in Papua New Guinea Training Package
Extension Principles	
Introduction to the Coffee Extension Officer and Farmer Training Guides	ACIAR Extension Officer Guide Unit 1 Module 1
The extension officer - roles and effectiveness	ACIAR Extension Officer Guide Unit 1 Module 2
Knowing Your Farmers	
Getting to know our coffee smallholders	ACIAR Extension Officer Guide Unit 2 Module 1
What factors affect smallholder coffee production?	ACIAR Extension Officer Guide Unit 2 Module 2
Strongim grup: course facilitator guide	CARE Organisational Strengthening Training

ACIAR Resource

Monograph MN220 Smallholder Coffee Production in Papua New Guinea: a training package for extension officers and farmers. This package contains the modules for both the extension officer training guide and the farmer training guide.

The ACIAR monograph is available online from **www.aciar.gov.au/publication/MN220-PNG-coffee-manual-1**

Hard copies of the ACIAR training package may be available by contacting ACIAR or the Coffee Industry Corporation (CIC).

CARE Resources

Organisational Strengthening Training
CARE Family Money Management Training

The CARE modules are available online from **https://pngcdwstandard.com/resources-for-use-by-cdws-working-with-wards-communities-groups-and-smes**

Hard copies of the CARE modules may be available by contacting the CIC or CARE-International.

Farmer Training Program

Title	Module reference
Becoming a Coffee Farmer	
Knowing your coffee tree	ACIAR Farmer Training Guide Unit 1 Module 1
Coffee nursery development	ACIAR Farmer Training Guide Unit 1 Module 2
Establishing a new coffee garden	ACIAR Farmer Training Guide Unit 1 Module 3
Managing Your Coffee Garden	
Weed Control	ACIAR Farmer Training Guide Unit 2 Module 1
Maintenance pruning and rehabilitation	ACIAR Farmer Training Guide Unit 2 Module 2
Shade management	ACIAR Farmer Training Guide Unit 2 Module 3
Drainage	ACIAR Farmer Training Guide Unit 2 Module 4
Pest and disease management	ACIAR Farmer Training Guide Unit 2 Module 5
Coffee berry borer management	ACIAR Farmer Training Guide Unit 2 Module 6
Soil fertility and nutrient maintenance	ACIAR Farmer Training Guide Unit 2 Module 7
Intercropping in your coffee garden	ACIAR Farmer Training Guide Unit 2 Module 8
Harvesting and Processing Coffee	
Coffee harvesting and processing	ACIAR Farmer Training Guide Unit 3 Module 1
Coffee grading systems and pricing	ACIAR Farmer Training Guide Unit 3 Module 2
Establishing a mini wet factory	ACIAR Farmer Training Guide Unit 3 Module 3
Coffee Marketing	
Understanding the domestic coffee market	ACIAR Farmer Training Guide Unit 4 Module 1
Kamapim ol praioriti	CARE Organisational Strengthening Training
Kamapim ol eksen plen	CARE Organisational Strengthening Training
Setim gutpela kastom bilong ronim grup	CARE Organisational Strengthening Training
Wok bilong meneja na memba na lida	CARE Organisational Strengthening Training
Coffee certification	ACIAR Farmer Training Guide Unit 4 Module 2
Fair trade certification	ACIAR Farmer Training Guide Unit 4 Module 3
Family money management	CARE Family Money Management Training

CONTENTS

MODULE TOPICS

CONTRIBUTING AUTHORS

Mark Thomas, Emma Kiup, Geraldine Tilden, Johannes Pakatul, Bartholomew Apis, Pennuel Togonave and George Curry

ACKNOWLEDGEMENTS

This module is part of a series of modules developed specifically as a resource for extension officers for training smallholder farmer groups and the training of cadet extension officers. Most of the information provided in this module is from the findings of ACIAR project ASEM-2008-036 and *The Papua New Guinea Coffee Handbook* (2nd edition), Coffee Industry Corporation Ltd.

The knowledge of the following contributors has been invaluable in the development and writing of this module:

Coffee Industry Corporation
Rauke Buimeng, Linda Bina, Samson Jack and Matilda Hamago

Australian Centre for International Agricultural Research
The development of this module was supported by the following ACIAR-funded projects:

- Improving livelihoods of smallholder families through increased productivity of coffee-based farming systems in the highlands of Papua New Guinea (ASEM/2008/036)
- Improving livelihoods of smallholder coffee communities in Papua New Guinea (ASEM/2016/100)

INTRODUCTION

Aim of Module:

This module aims to provide coffee farmers with information on suitable situations for intercropping, advice about the appropriate crops to grow and a general outline of production practices.

Intercropping is becoming a common practice in coffee gardens, particularly in areas where there is pressure on the land because of rising population density.

Growing short-term crops (intercrops) with coffee allows farmers to make greater use of a limited area of land, diversify their incomes, and grow fresh food for their household. Intercropping can improve returns to labour and strengthen food and income security, especially for women. Intercropping also has benefits for coffee production.

Growing short-term intercrops is an activity mostly undertaken by women, and while they are tending to the intercrops, they are likely to become more engaged in coffee production. Growing fertilised vegetables is an effective way of delivering nutrients to coffee trees.

LEARNING OUTCOMES

By the end of this module you will:

- Understand why farmers may want to intercrop their coffee gardens
- Understand the advantages and disadvantages of intercropping
- Understand suitability guidelines for coffee gardens to use intercropping
- Understand which crops are suitable to intercrop with coffee
- Understand how to choose an intercrop and how to grow them

LESSON PLAN

Relevant Farmer Training Guide modules

- **Unit 2, Module 1** Weed control
- **Unit 2, Module 3** Shade management
- **Unit 2, Module 7** Soil fertility and nutrient maintenance

This module has three parts:

Sections 8.1 and 8.2	Purpose, advantages and disadvantages of intercropping
Section 8.3	Identifying if a coffee garden is suitable for intercropping and what to consider before starting
Sections 8.4 to 8.6	Suitable crops for intercropping, how to choose a crop and how to grow them

TIME REQUIRED TO COMPLETE THIS MODULE: 2 DAYS

LIST OF SYMBOLS:

Information relating to CBB

Farmer notes, brochures & factsheets

Information for farmers that must be taken very seriously

For the Extension Officer

TEACHING AIDS

- Farmer notes (one copy for each farmer plus spare copies)
- The coffee calendar and stickers
- A selection of crops that are suitable to intercrop and some that are not
- Photos of successful intercropping

PRE-TRAINING ACTIVITIES

- Confirm number of training participants
- Print sufficient copies of farmer notes
- Research appropriate planting density of intercropped cabbage, and the current cost of cabbage seed, N:P:K (12:12:17) fertiliser supply, and transport from the training place to the nearest market
- Source produce
- Arrange access to a coffee garden with potential to intercrop
- Arrange access to a coffee garden that is currently intercropped

PRELIMINARY ACTIVITIES

The farmers will complete two exercises prior to undertaking the module topics. These include the coffee calendar and the quiz. The purpose of these exercises is for the extension officer to assess the level of knowledge of farmers in the group prior to completing the module.

The coffee calendar

The coffee calendar lists the main events and activities occurring during an annual cycle of coffee production. The first item on the calendar is coffee berry development. All other activities are linked to the stage of development of coffee berries from flowering through to overripe cherry.

Annual coffee production events and activities (stickers)

1. Flowering and berry development
2. Harvesting coffee
3. Pulping and drying coffee
4. Maintenance – weeding, pruning, mulching, shade management, digging and maintaining drains, and maintaining fencing
5. CBB control measures

Using the stickers for each of the annual coffee activities listed above, work with the farmer group to attach them to the appropriate rows of the coffee calendar.

- Begin by attaching the progressive stages of coffee berry development from flowering through to bright red cherry ready for harvest, and to overripe cherry
- Complete the remaining sections linking each activity with the different stages of berry development
- For this module, integrate the activities relating to intercropping listed below

Intercropping activities

In a new or mature coffee garden

- Sow intercrop seed if propagating on a raised bed (preferably lightly shaded or in a shadehouse) close to the house
- Cultivate the soil where the intercrop seedlings are to be planted (the timing of this may differ depending on whether it is a new or mature coffee garden)
- Transplant seedlings or other planting material, such as cuttings
- Maintain the intercrop
- Harvest the intercrop
- Transport and market, or consume the intercrop

Quiz

- Before beginning the module topics, ask the farmers to complete the quiz at the end of this module
- Repeat the quiz on completion of the module topics

8.1 INTERCROPPING COFFEE GARDENS

Intercropping in a coffee garden is the practice of growing another crop, or crops, between the rows of coffee trees. There are many reasons why farmers might do this.

Population pressure and land shortages

- In many regions of PNG, farmers are experiencing land shortages due to rising population pressure
- Intercropping allows farmers to make use of the space between the coffee trees and potentially increase income per unit area of land
- By intercropping temporary food crops, farmers can increase/supplement their income or grow more food for their families

The space between the rows of coffee trees can be used to grow short-term crops. (*Source: Mike Webb*)

Agroforestry systems

Coffee agroforestry can provide many benefits to the coffee production system, but this production system is more complex and is not discussed in this module

Income diversification

- Intercropping enables farmers to diversify their income, thereby decreasing risk and increasing livelihood resilience
- Intercrops insure against crop failure and market fluctuations. In circumstances where there is a pest or disease outbreak in coffee or coffee prices are low, farmers have an alternative source of income
- If conditions allow, some farmers choose to intercrop multiple crops that have differing production cycles to each other and to coffee. This enables them to use labour more efficiently and earn income throughout the year
- A selection of perennial trees may be grown to provide permanent shade for the coffee trees, as well as to generate income from fruit, timber, firewood or other by-products

More secure income for women

- Men tend to have more control over coffee and the income it generates, while women have more control over the income from food gardening
- Intercropping gives women additional access to land for production of short-term crops to feed their family or earn money – this is particularly important in areas where there are land shortages
- Income from coffee is only seasonal, so growing short-term crops at different times of the year provides women with a more regular income, making it easier to care for their families

New and mature coffee gardens

New coffee gardens

- Interplanting young, non-bearing coffee trees with annual food and cash crops partly compensates for the high investment cost of establishing a new coffee garden
- Intercrops such as bananas provide temporary shade and mulch for new coffee trees while slower-growing permanent shade trees are becoming established

Young coffee tree surrounded by intercrops (*Source: Emma Kiup*)

Mature coffee gardens

- If there is sufficient light, short-term crops may be grown during the coffee off-season to earn additional income
- When there is a change in the coffee production cycle (e.g. when major pruning is undertaken to rejuvenate the coffee trees or as a control measure for coffee berry borer (CBB)), farmers can be without a coffee crop and therefore an income from coffee for up to two years. Marketable intercrops can be grown during the coffee regrowth period to replace some of the lost income

Current intercropping practices

Informal intercropping

Intercropping is practised in some coffee gardens, but usually in an ad hoc way. It is often done to fill gaps in the canopy where coffee or shade trees have died or been removed, or to take advantage of additional light near roads and pathways through coffee gardens.

Informal intercropping (*Source: Mike Webb*)

Formal intercropping

Some farmers use a more structured approach when intercropping, growing high-value, short-term crops in the inter-rows during periods of the coffee production cycle when enough light can get through.

This module focuses on the formal approach to intercropping. It provides farmers with information on the most appropriate methods to use to achieve the best outcomes from a limited area of land, while also having minimal impact on their coffee production.

Formal intercropping in a coffee garden in low shade conditions (*Source: Mike Webb*)

Activity 1: Potential income

Calculate the potential income from growing intercrops (e.g. cabbages)

Area of land to be intercropped	
Planting density	
Number of plants	
Quantity of seed	
Cost of seed	
Quantity of fertiliser	
Cost of fertiliser	
Cost of transport	
Market price	
Gross income	
Net income (profit)	

8.2 ADVANTAGES AND DISADVANTAGES

What are the advantages of intercropping coffee?

Improved coffee garden maintenance

- As they mature, intercrops can smother weed growth
- Any weeding of food crops will also benefit coffee
- Coffee and shade trees are more likely to be pruned regularly to allow more light to reach the food crops
- Fertiliser applied to food crops will also benefit the coffee trees
- Because time is spent tending to intercrops in the coffee garden, coffee trees will be harvested more regularly during the coffee season and out-of-season flowers will be more likely to be removed during the off-season (this is particularly important for CBB control)
- Women will become more involved in coffee garden maintenance through their work on food crops
- Farmers will tend to the coffee trees more regularly rather than having a 'seasonal' approach where they visit only during the coffee season but neglect the coffee garden for the rest of the year
- More regular visits to the coffee garden to tend food crops will alert the family to coffee tree maintenance problems, such as pest and disease outbreaks or drainage problems

Note: Refer to Farmer Training Guide Unit 2, Module 7 'Soil fertility and nutrient maintenance' for further information

Enhanced environmental benefits

Ecosystem services are benefits that we obtain from the environment, including food, water and energy. These are important for the soil and crops and benefit the farm and wider community. Intercrops can enhance these benefits by:

- Reducing soil temperature, which decreases evaporation, resulting in more available water for the plants and the environment
- Increasing biodiversity, as a greater diversity of organisms will be attracted to the wetter and cooler soils and the presence of a greater variety of plant species. This is important for crop pollination and pest and disease control. Diversity strengthens soil and plant health, making them more resilient
- Increasing soil biological activity, which improves the availability of nutrients and soil water storage
- Adding to soil organic matter and improving soil fertility through residues from food crops after harvest
- Reducing soil erosion when intercrops cover the soil surface
- Adding nitrogen to the soil and increasing soil fertility if food crops are legumes

Complementary resource use

- Different types of plants differ in the way they use soil resources such as water and nutrients. A range of plants in a garden will make more balanced use of soil resources compared with plants of the same type
- Coffee and food crops may also provide benefits for each other, such as attracting microorganisms that improve the soil (e.g. nitrogen fixers with legumes) or creating beneficial shade (e.g. coffee shade for establishing intercrops)

Labour and other social returns

- Growing intercrops can increase labour efficiency, as often both the coffee and intercrops are tended during the same visit to the garden
- Intercropping will integrate the activities of men and women
- There is evidence that women are moving away from investing labour in coffee production to pursue alternative and more secure income streams in food production. Intercropping strengthens this opportunity for women to the benefit of families
- Intercropping can increase food production (and thus income) without requiring additional land. This is particularly important in areas where land pressures are rising
- Intercrops may be used for customary obligations and strengthening community relationships

What are the disadvantages of intercropping?

Competition for space

- Intercrops may overcrowd the coffee garden
- Inappropriate crops may climb up the coffee trees

Competition for soil nutrients

- Some crops may use soil nutrients required by coffee
- The use of nutrients by intercrops may reduce soil fertility, especially if no supplementary nutrients are applied

Pests and diseases

- Some intercrops may harbour pests or diseases that affect coffee (e.g. kaukau hosts a weevil that eats the tips of the coffee, and it also attracts coffee ring borer)

Physical damage to the coffee trees

- The surface roots of coffee trees may be damaged when preparing the soil for planting or when harvesting intercrops

Advantages and disadvantages of intercropping in a coffee garden	
Advantages	**Disadvantages**
More efficient land use	Competition for space and too little air movement (unfavourable for pest and disease control)
Makes use of unused land	Competition for light (tall intercrops may over shade the coffee trees)
In a newly planted coffee garden, the coffee seedlings are maintained as the food crops are cared for (e.g. mulching, weeding, pruning, shade regulation and erosion control)	Competition for nutrients (additional soil nutrients may have to be applied)
In a mature coffee garden, intercropping encourages improved garden maintenance (e.g. weeding, pruning, shade regulation, harvesting)	More rapid decline in soil fertility if nutrients are not replaced
Improved access to land for women for food gardening	Coffee trees may be damaged during the cultivation or harvesting of intercrops.
More secure income stream for women	Intercrops may harbour pests or diseases that affect coffee
Women more involved in coffee production	
Environmental benefits (e.g. less evaporation; increased biodiversity, improved plant resilience, increased nutrient availability, less soil erosion)	
Improved soil nitrogen if growing legumes	
Complementary resource use by coffee trees and intercrops	
Increased labour efficiencies	

8.3 SUITABILITY OF COFFEE GARDEN

In what situations can intercropping be practised?

Before proceeding with intercropping, it is important to consider the following physical factors of the coffee garden.

- Shade
- Climate
- Soil type
- Slope

Shade level

- One of the most important requirements for most short-term vegetable crops is sufficient light
- Productivity of smallholder coffee is highest when shade levels are approximately 30%
- Most short-term vegetable crops require higher levels of light than coffee so the intercropping area should be open with little to no shade
- Many coffee gardens in areas where there are land shortages have an open spacing with low levels of shade, which is suitable for intercropping

Coffee garden with open spacing and little shade (*Source: Kingsten Okka*)

Climate

- Each intercrop has specific climatic requirements (e.g. temperature ranges and rainfall) to be productive

Soil

- Unless the farmer plans to spend time and money on soil improvements, the soil must be suitably fertile to provide sufficient nutrients to both the coffee trees and intercrops
- The application of fertilisers may prevent competition for nutrients. Fertilisers may be organic such as coffee pulp, animal manure or mulch, or purchased inorganic fertilisers
- Leguminous intercrops will supply the soil with nitrogen, but it is important to understand that these crops will take other nutrients and water from the soil

Coffee pulp spread around intercrops to improve soil fertility
(*Source: Emma Kiup*)

Slope

- Unless it is properly managed, intercropping should not be done in coffee gardens on steep slopes as soil erosion may occur when the soil is left bare after cultivation

Long-term intercropping of coffee with short-term crops

- It is possible for intercropping to be a permanent practice in the coffee garden as long as:
  - There is enough space between the coffee trees to minimise competition between the crops for water, nutrients, space and light, and to allow sufficient air movement, which is important for pest and disease control
  - Exported nutrients are replaced
- When establishing a new coffee garden, if intercropping is to become a permanent activity during the coffee off-season, it is recommended that a wider spacing be used when planting the new coffee seedlings
- Produce can be grown year-round for household consumption, or sold to gain a more regular form of income
- Permanent intercropping reduces income shortages caused by falls in coffee prices

Note: Suitable perennial or long-term plant species, such as bananas, fruit or nut trees, can be intercropped with coffee in an agroforestry production system.

8.4 SUITABLE CROPS

Crop characteristics

Although many crops can be intercropped with coffee, the following crop characteristics are important considerations.

Potential intercrops and their relevant characteristics	
Crop	**Characteristics**
Annual crops	Short-term crops
Legume crops	Fix nitrogen in the soil
Shallow-rooted vegetables	Less competition with coffee roots
Food crops that provide soil cover	Better protection of soil
Shade crops (e.g. banana)	Help to establish coffee seedlings

Mixed intercropping

Food crops

Not all food crops are suitable for intercropping with coffee. You should use only those that are recommended and avoid using those that are not.

- The best choice of intercrops are often short-rotation, fertilised vegetables as the coffee trees will benefit from the added fertiliser, improving coffee productivity and quality. Short-rotation crops can also be grown outside the period of peak labour demand for coffee
- Legumes will provide the coffee trees with additional soil nitrogen
- Some intercrops harbour predators of coffee pests (e.g. pumpkin and cucumber attract ladybirds that control green scale)

- Short-term shallow-root vegetables can be cultivated during the early stages of coffee planting and after harvesting and pruning of mature coffee trees if there is sufficient light. They can also be planted during a change in production cycle (stumping), or to use marginal portions of the coffee garden
- Many fruit tree crops can be grown in coffee gardens at low planting densities so they do not compete with the coffee trees

Local beans and bananas planted in a smallholder coffee garden (*Source: Pennuel Togonave*)

Cabbages intercropped with established coffee trees (*Source: Emma Kiup*)

Unsuitable crops

- Tubers and other perennial crops that have cultivation requirements and growing systems that are not appropriate under coffee shade systems
- Crops that climb up the coffee trees and restrict their growth
- Crops that have naturally high demands for light, moisture or nutrients (e.g. Highlands pitpit, which extracts a lot of nutrients from the soil)
- Crops that harbour pests or diseases of coffee
- Perennial crops (e.g. banana) can be grown to shade young coffee trees but should be removed when permanent shade trees (e.g. yar) take over

Activity 2: Crops and produce

- Show a selection of produce from suitable crops
- Show photos of these growing as intercrops in a coffee garden
- Show a small selection of produce from unsuitable crops
- Discuss why they should not be used for intercropping

Suitability of food crops for intercropping with coffee

Type of food crop	Varieties	Suitability	Notes
Legumes	Soya bean, peanut, Pinto peanut, other non-climbing varieties	✓✓	• Suitable if sufficient light
	Asbin (winged bean)	✓	• Climbs up coffee trees • May be used if staked
Vegetables	Aibika, cabbage, pak choi, broccoli, kale, carrot, tomato, onion, zucchini, pumpkin, chilli, ginger, cucumber	✓✓	• Suitable if sufficient light
	Choko	✗	• Climbs up coffee trees
	Corn	✗	• Competes for light
Root crop	Potato	✓✓	• Suitable if sufficient light
	Kaukau, taro, tapiok, yam	✓	• May be used when the coffee garden is young or after coffee tree stumping, but not recommended in a mature coffee garden • Harvesting may damage coffee tree roots • Some varieties attract pests of coffee
Fruits and nuts	Pineapple	✓✓	• Suitable if sufficient light
	Banana	✓✓	• Provides shade for young coffee seedlings • Can be grown in mature coffee gardens if there are few permanent shade trees
	Kapiak (bread fruit), tamarillo (tree tomato), avocado, karuka (highland pandanus), marita (red pandanus)	✓	• May be used at low planting densities
	Muli (citrus)	✓	• May be used at low planting densities • Host coffee green scale, coffee leaf rust (CLR) and pink disease
	Guava	✓	• May be used at low planting densities • Hosts green scale
Grasses	Sugar cane	✗	• Competes for moisture and light
	Rice	✗	• Competes for moisture

✗ Unsuitable
✓ Can be grown, but not suitable in all circumstances
✓✓ Can be grown in new and mature coffee gardens

8.5 CHOOSING THE RIGHT CROP

Considerations

Suitable crops for intercropping vary depending on location. It is better for farmers to choose suitable crops based on established guidelines rather than by trial and error. Early success increases the chance of the farmer choosing to continue with intercropping.

Natural conditions and qualities of the coffee garden

- Consideration has to be given to the natural conditions and qualities of the coffee garden when selecting a crop to grow as growth requirements for individual crops differ
- Important qualities include availability of water, light, nutrients and space to grow
- There should be minimal competition between coffee and the intercrop for growing needs
- Things to consider include:
  - Age, size and spacing of coffee trees
  - Age, size and spacing of shade trees
  - Amount of shade
  - Soil fertility
  - Time of year when establishing the intercrop
  - Growth habit of the intercrop

Labour requirements

- Planting the right intercrop at the right time of the year means the labour demands of the coffee and the intercrop will not compete

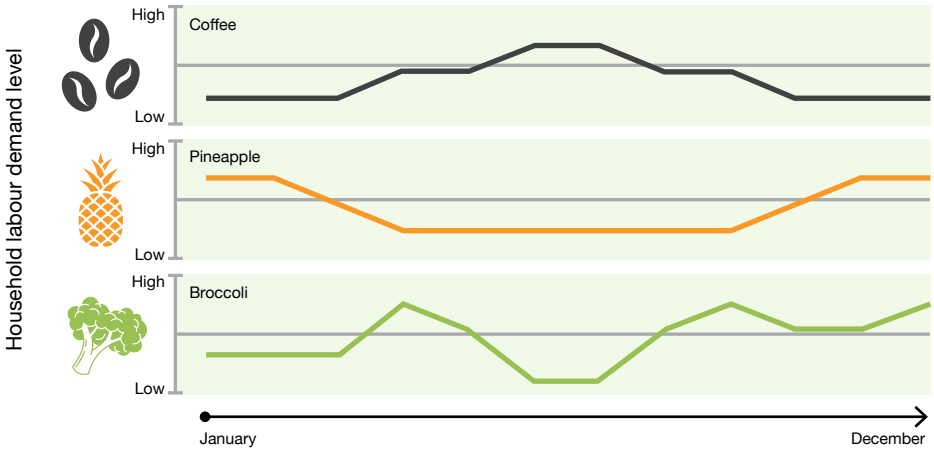
Maturity of the coffee garden

- Many crops can be grown in a new coffee garden as there is ample space, light and moisture, and less competition for nutrients
- Short-lived intercrops (e.g. bananas) that provide shade are ideal to intercrop during the initial establishment of the coffee garden because they protect the young coffee trees. Banana enhances soil moisture and improves soil structure and the passage of coffee roots
- In a mature coffee garden, there is often not enough available light for most intercrops due to the shade created by both coffee trees and shade trees (if present)
- In a mature coffee garden, there is more competition for nutrients due to the combined root systems of the coffee and shade trees
- In areas of high population density, many mature coffee gardens have wider spacing of coffee trees and lower levels of shade (firewood and timber shortages in these areas can lead to shade trees being felled to meet these needs). Crops requiring high levels of light can be intercropped in these coffee gardens

Young coffee trees intercropped with cabbages (*Source: Mike Webb*)

Stage of the coffee production cycle

- After the coffee flush period when mature coffee trees have been pruned, farmers can make use of the temporary increase in light, space and available labour to grow short-term intercrops
- To avoid competition for labour:
  - Do not grow intercrops that have high labour requirements during the peak of the coffee season
  - Time the planting of intercrops so that their peak labour demand periods (e.g. harvesting) do not coincide with the coffee harvesting period
- If growing more than one intercrop, select crops that have different production cycles both to each other and to coffee, so that labour can be used efficiently



Labour demand levels for production of coffee, pineapple and broccoli (*Adapted from Inu 2015: 143*)

Labour and intercropping

Do not grow intercrops that have high labour requirements during the peak of the coffee season, when labour is needed for coffee harvesting and processing.

Marketing

- If an intercrop is to be grown for marketing, it is important to consider if there will be demand for the crop
- If many farmers are already supplying markets with a particular crop, the price may decline and returns on labour may not be adequate
- If the market is not within a reasonable distance, transport costs will be higher and time to market will be longer, both of which can reduce profit (spoilage and damage rates can increase with road distance to market)
- A method of transport must be available to transport the crop
- Forming a new farmer group or cooperative, or joining an existing group, may increase opportunities for market access and enable members to share transport costs. It may also enable better access to seeds, fertilisers and other farm inputs

Objective:

To assess a coffee garden to see if it is suitable for intercropping

You will need:

Access to a coffee garden with areas of:
- **Shade**
- **Open spacing or little shade**

EXERCISE 1

Assessing the suitability of a coffee garden

Discussion

1. Compare the two areas and assess:
   - Space
   - Level of light or shade level
   - Soil type
   - Slope
2. Decide if the low-shaded area is suitable for intercropping. Explain why or why not.

Objective:

To determine suitable intercrops for the coffee garden

You will need:

Access to the open-spacing low-shade areas in the coffee garden used in Exercise 1

EXERCISE 2

Choosing a suitable intercrop

Discussion

Discuss the types of intercrops that would be suitable for this coffee garden. Consider each of the themes discussed in this module:

1. Match the intercrop to climate
2. Maintenance requirements of the coffee garden prior to planting intercrops
   - Shade levels from coffee and shade trees (e.g. is pruning necessary?)
   - Drainage (e.g. is maintenance required?)
   - Weed levels
   - Condition of fences (e.g. are they pig and goat proof?)
3. Labour requirements
4. Maturity of the coffee garden
5. Stage of the coffee production cycle
6. Growth needs of the intercrop
7. Market access

8.6 GROWING INTERCROPS

Periods of high intercropping labour demand occur during intercrop establishment and harvest. Some labour is also required for maintenance, such as weeding and fertilising during the growth phase.

Sourcing seed

To produce a healthy and uniform intercrop, it is best to source good quality seed.

Raising seedlings

- Seedlings of most short-term vegetable crops should be ready for transplanting 4–6 weeks after sowing
- In a new coffee garden, seedlings can be transplanted at any time
- In a mature coffee garden, it is preferable for seedlings of short-term intercrops to be transplanted into the inter-rows just after the coffee flush season
- Seeds for the intercrop should be sown to allow sufficient time for the seedlings to establish and be strong and healthy and ready for transplanting at this time
- For best results it is preferable to grow the seedlings in a raised bed (preferably lightly shaded, or in a shadehouse) close to the house so that they can be tended to regularly
- Using healthy soil, sow the seeds at high density and thin out the seedlings once germination occurs, to allow air movement and space for growth

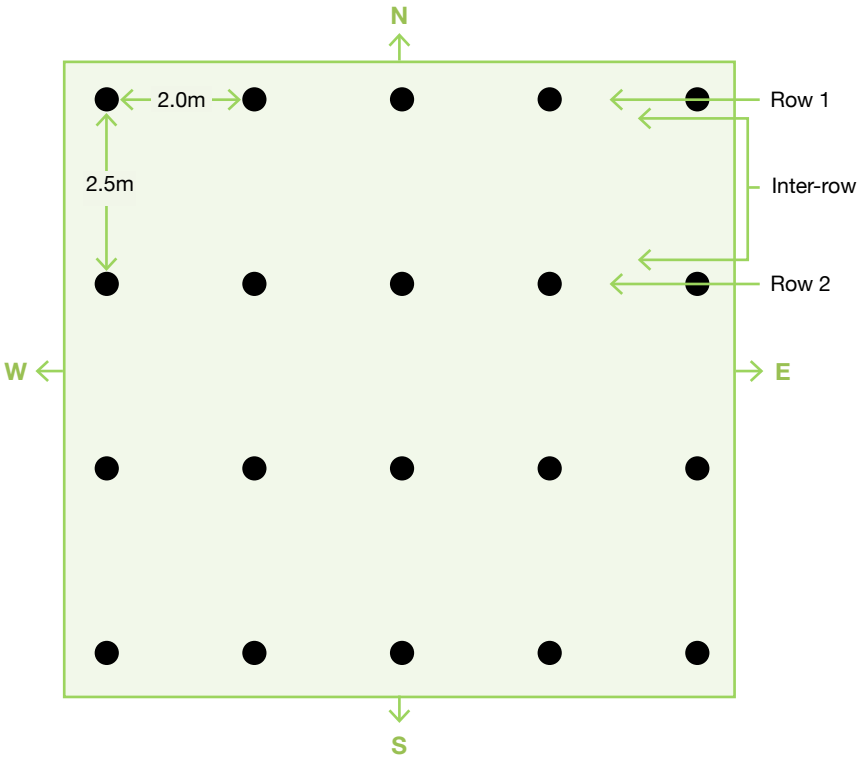
Left: Cabbage seedlings thinned out to reduce density; Right: Cabbage seedlings ready to be transplanted into the coffee garden (*Source: Emma Kiup*)

Land preparation and planting intercrop seedlings

New coffee garden

- Planting of intercrops can be done while a new coffee garden is being established
- The recommended coffee tree spacing of 2.5 m x 1.5 m used when growing tall coffee varieties will allow sufficient space for intercropping
- Keep a distance of at least 30 cm between the newly planted coffee trees and the intercrop to avoid competition for nutrients and water
- Intercropping 30 cm or more from young coffee trees can be done for two to three years or until the coffee trees produce too much shade, limiting light access for intercrops
- Intercropping with temporary shade trees (e.g. banana) will provide shade for the young coffee trees while the permanent shade trees are establishing
- If the coffee garden is to be **permanently intercropped** with short-term crops, the coffee trees should be planted at the recommended spacing for long-term intercropping (2.5 m x 2.0 m)

Note: Refer to Farmer Training Guide, Unit 1, Module 3 'Establishing a new coffee garden' for further information



Low-density spacing of coffee trees for long-term intercropping (2.5 m x 2.0 m)

Established coffee garden

- Open spacing with low levels of shade is required for intercropping in an established coffee garden
- In addition to rejuvenating the coffee trees, pruning of coffee trees after the coffee flush season will open up the canopy and allow some light for intercropping
- Land preparation for intercrops between the coffee rows should be done after the coffee flush season
- It is better to grow intercrops after the coffee flush season because:
  - There is less competition for family labour
  - Vegetable intercrops are more likely to be ready for harvesting during December–January, when demand for them is high
- Avoid damaging the coffee tree roots during intercrop cultivation
- At the end of the coffee flush season there is an abundance of coffee pulp remaining from processing which is often left at the pulping station. The pulp is rich in nutrients, particularly potassium, which is required in large quantities by vegetable and other food crops (and coffee). The pulp should be applied promptly to the prepared land to improve soil fertility and avoid nutrient leaching
- Some intercrops may require an application of additional nutrients in the form of inorganic fertiliser (e.g. N:P:K). Fertiliser should be applied at planting, during growth and again when the crop is maturing
- When preparing for intercrops, ensure there is sufficient space between the coffee trees and intercrops to manage competition. Keep a distance of at least 60 cm between the coffee and the intercrop to avoid competition for nutrients and water

Note: Refer to Farmer Training Guide Unit 2, Module 7 'Soil fertility and nutrient maintenance' for further information

Coffee pulp is rich in nutrients and is a valuable form of organic fertiliser for use on both coffee trees and intercrops. (*Source: Pennuel Togonave*)

Cabbages intercropped in a mature coffee garden (*Source: Emma Kiup*)

An intercropping scheme for cabbage (planting location and density) when growing tall coffee varieties

Planting intercrop seedlings in an established coffee garden
(*Source: Emma Kiup*)

Fertiliser application rates for cabbages

Growth phase	Quantity of fertiliser per plant
Transplanting	10 g (1 level tablespoon)
Mid-growth – side dressing	20 g (2 level tablespoons)
Final growth phase/ maturing	20 g (2 level tablespoons)

Based on fertiliser with an NPK ratio of 12:12:17

Maintenance of the intercrop

Manage soil nutrients

- Many vegetable crops have high nutrient demands. Apply inorganic fertiliser or organic matter such as coffee pulp, kitchen waste, crop residues and animal manures to intercrops to improve crop health. The coffee trees are also likely to benefit from the fertiliser
- When applying coffee pulp and any other fresh organic material, do not use too much and apply it away from the stem of the intercrop to avoid 'burning' the plant
- Monitor for nutrient deficiencies

Nutrient	Symptoms of deficiency
Nitrogen (N)	The oldest leaves appear pale and lack the lustre of healthy ones. Yellowing appears at leaf tips and will affect all the leaves.
Phosphorus (P)	Older leaves turn a darker green followed by a purplish tint starting from the leaf margins. Leaf tips dry off.
Potassium (K)	Yellowing bands along the leaf margins of older leaves with brown spots developing along the margins as symptoms advance. Younger leaves are usually unaffected.
Boron (B)	Stunting and distortion of the growing tip that can lead to tip death, brittle foliage, and yellowing of lower leaf tips. Flowering and fruiting are reduced and developing fruit is often distorted.
Zinc (Zn)	Yellowing between the leaf veins, rolling of the margins and smaller leaves than normal.

Boron deficiency

- Boron deficiency is common in soils in the highlands
- Boron deficiency affects fruit production (including coffee cherry production) and can cause deformities in roots, shoots and leaves
- Boron deficiency is simple to solve

Note: Refer to Farmer Training Guide Unit 2, Module 7 'Soil fertility and nutrient maintenance' for further information

Suspected boron deficiency in cabbage (left) and banana (right)
(*Source: Mike Webb*)

Club root in broccoli. Brassicas (e.g., broccoli, cabbage, cauliflower and kale) are more susceptible to club root if the soil is deficient in boron
(*Source: Mike Webb*)

Manage weeds

- Remove weeds from around the intercrop to avoid competition for nutrients and moisture
- Weed debris may contain weed seeds, so it is better to remove weeds prior to them flowering and producing seed
- Nutrients taken up by weeds can be recycled by using the weed debris as mulch around the intercrop or coffee trees. As the mulch decomposes, the nutrients within it are made available to the intercrops or coffee trees

Monitor for pests and diseases

- Regularly monitor for pests and diseases
- If infestations of pests or disease infections are low, they may not cause a significant problem and can be ignored
- In some instances, pests may be removed by hand and diseases remedied by removing the part of the plant affected
- For significant impacts of pests or diseases, seek advice for management

Harvesting intercrops

- Ensure the coffee tree roots or branches are not damaged while harvesting intercrops
- Unless they are diseased, leave the roots and stems of the intercrop in the ground where they will add to soil structure and return nutrients

Post-harvest

- If tidying up harvested intercrops for marketing to improve presentation, remove residues (e.g. excess leaves) **before** the produce is removed from the coffee garden
- Leaving the leaves or other residues in the coffee garden will help minimise nutrient loss

Transporting and marketing the intercrop

- Carefully time harvesting just prior to transporting to market to preserve market freshness and quality
- Allow sufficient time for transporting the produce to market or organise others to transport the produce
- The farmer may wish to sell to a reseller or market the produce themselves

Objective:

To assess and evaluate an intercropped coffee garden

You will need:

Access to an intercropped coffee garden

EXERCISE 3

Assessing an intercropped coffee garden

Discussion and practical activity

Working with the group, assess, measure, record and discuss:

1. The general condition of the coffee trees and the intercrops
2. Maintenance of the coffee garden
   - What is the status of weeds and pruning?
   - Are cherries present on the coffee trees?
3. Planting arrangement
   - Is there enough space for both the coffee trees and the intercrop?
4. Presence of pests and diseases
   - Could the coffee trees have been negatively affected by the presence of the intercrop?
5. Nutritional status of the coffee trees and intercrops
   - Are there any obvious nutrient deficiencies (see table on page 26)?
   - Are there any visual clues of competition for nutrients?
   - Has fertiliser been applied?
6. Demand for labour
   - How much labour would be required for the intercrop?
   - Would the periods of high labour demand for the intercrop be outside the periods of high labour demand for coffee?
7. Market access
   - What would market access be like for the intercrop?

8.7 KEY MESSAGES

- Farmers may choose to intercrop their coffee for several reasons:
  - Because they face land shortages and wish to increase their income or household food supply
  - To diversify and secure their income, including women's income
  - To make use of land in a new coffee garden
  - To make use of land during the off-season in a mature coffee garden
  - To make use of land during a change in the coffee production cycle (e.g. stumping old coffee trees)
- Intercropping benefits coffee gardens by increasing coffee tree maintenance, enhancing the quality of the garden environment, and offering better labour and social returns
- Possible negative impacts of intercropping on coffee trees include new pests or diseases, or new competition for the coffee trees for light, soil moisture and nutrients
- If planning to intercrop, farmers must first assess the shade level, climate, soil fertility and slope of the coffee garden
- The most suitable crops to intercrop with coffee are short-rotation, fertilised vegetables, as the coffee trees will benefit from the added fertiliser, improving coffee productivity and quality
- When deciding which crop to intercrop, farmers must consider:
  - The conditions in the coffee garden
  - Labour requirements
  - Maturity of the coffee trees
  - Stage of the coffee production cycle
  - Growing needs of the intercrop
  - Market access

8.8 QUIZ

Place a '✓' in the correct box.

1. Which of these is **not** a reason to intercrop coffee?

- A Land shortage
- B Maximise income from coffee
- C Diversify income
- D Provide secure income for women household members

2. Which aspect of coffee production will **not** be improved by intercropping?

- A Labour supply
- B Coffee garden maintenance
- C Labour efficiency
- D Biodiversity

3. Which of these is **not** likely to result from intercropping short-term vegetable crops?

- A Competition for moisture and nutrients
- B Greater threat from CBB
- C Competition for space
- D Root damage

4. Which characteristic of a coffee garden is the most important when deciding whether or not to start intercropping?

- A Shade level and availability of light
- B Soil type and climate
- C Climate and coffee tree spacing
- D Slope and drainage

5. Which of these potential impacts of intercropping would have the most **negative** effect on coffee production?

- A The coffee trees will be neglected
- B The intercrop will climb or interfere with the growth of the coffee trees
- C The peak labour demands for the intercrop will clash with the peak labour demands for coffee
- D The crop will not cover the ground and prevent weed growth

6. What are the best crops to intercrop with mature coffee trees?

- A Short-term vegetables and legumes
- B Deep rooted vegetables and perennials
- C Temporary shade crops like banana
- D Short-term vegetables and root crops

7. Which crops should **not** be intercropped with mature coffee trees?

- A Pumpkin and cucumber
- B Soya bean and peanut
- C Cabbage and kale
- D Kaukau and choko

8. When is the best time to grow intercrops in a coffee garden?

- A After the coffee trees have flowered but before harvesting begins
- B Before the coffee trees are pruned
- C After the coffee flush season
- D During the coffee flush season, when there is labour present in the coffee garden

9. When should coffee pulp be applied to intercrops?

- A After the pulp has decomposed so it does not 'burn' the intercrops
- B Just before the intercrops are harvested
- C As soon as possible after coffee processing to avoid leaching of nutrients
- D During coffee flowering, when labour is available

10. Where is the best place to remove residues (e.g. leaves) from intercrops?

- A At the coffee pulping station
- B Next to the house so they can be composted easily
- C At the market just before the produce is sold
- D In the coffee garden after the intercrops have been harvested

11. Which of these is the most important task to carry out when growing intercrops in a coffee garden?

- A Apply inorganic chemicals (e.g. glyphosate) to remove weeds
- B Replace nutrients exported from the coffee garden
- C Grow the intercrops close to the coffee trees to prevent weed growth
- D Plant shade trees to protect the intercrops

12. What types of fertiliser can be applied to intercrops to promote growth?

A Inorganic fertilisers
B Crop residues and kitchen waste
C Coffee pulp and animal manures
D All the above

13. How might growing intercrops benefit women?

A Allows them to take more control of coffee production
B Allows them to be more involved in coffee garden maintenance as they tend to intercrops
C Provides them with a more secure income
D B and C

14. Which of these is a critical requirement for intercropping to become a permanent practice in a coffee garden?

A Optimum shade for the coffee trees
B Ongoing maintenance of the coffee garden
C Easily accessible market
D Sufficient space and light, and replacement of exported nutrients

True or false

Place a '✓' in the correct box.

	True	False
a. Growing intercrops contributes to household resilience by diversifying income and providing a more secure income for women.	☐	☐
b. Some intercrops can harbour pests or diseases of coffee.	☐	☐
c. Increased biodiversity resulting from growing intercrops will decrease nutrient availability.	☐	☐
d. Growing coffee and intercrops that have peak labour demands at different times of the year puts too much pressure on household labour.	☐	☐
e. Market access is not important when deciding which intercrop to grow.	☐	☐
f. Unless properly managed, coffee gardens on steep slopes or with poor soil fertility should not be intercropped.	☐	☐

Answers to quiz questions

Multiple choice

1. Which of these is **not** a reason to intercrop coffee?

   Answer = B. Maximise income from coffee

   Section 8.1. Intercropping is becoming a common practice in coffee gardens, particularly in areas where there is pressure on the land because of rising population density. Growing short-term crops (intercrops) alongside coffee trees allows farmers to make greater use of a limited area of land, diversify their incomes and grow fresh food for the household. Intercropping can improve returns on labour and strengthen food and income security, especially for women.

2. Which aspect of coffee production will **not** be improved by intercropping?

   Answer = A. Labour supply

   Section 8.2. The availability of household labour, or the labour supply, is fixed. Intercropping has the potential to increase labour efficiency and improve returns on labour.

3. Which of these is **not** likely to result from intercropping short-term vegetable crops?

   Answer = B. Greater threat from CBB

   Section 8.2. In fact, it is likely that the threat from CBB will be reduced. Because time is spent tending to intercrops in the coffee garden, the coffee trees will be harvested more regularly during the coffee season and out-of-season flowers will be more likely to be removed during the off-season, which is particularly important for CBB control.

4. Which characteristic of a coffee garden is the most important when deciding whether or not to start intercropping?

   Answer = A. Shade level and availability of light

   Section 8.3. While it is important to have suitable soil fertility and climate, the most important requirement for many short-term vegetable crops is sufficient light. The intercropping area should be open with little to no shade.

5. Which of these potential impacts of intercropping would have the most **negative** effect on coffee production?

   Answer = C. The peak labour demands for the intercrop will clash with the peak labour demands for coffee

   Section 8.5. One of the most important considerations in establishing intercropping is labour requirements. Labour demands for coffee and the intercrop should never compete. Do not grow intercrops that have high labour requirements during the peak of the coffee season, as labour is required for coffee harvesting and processing during this period.

6. What are the best crops to intercrop with mature coffee trees?

   Answer = A. Short-term vegetables and legumes

   Section 8.4. Annual short-rooted crops that grow in the coffee off-season, and legumes, which add nitrogen to the soil, are the best crops to intercrop with mature coffee trees.

7. Which crops should **not** be intercropped with mature coffee trees?

   Answer = D. Kaukau and choko

   Section 8.4. Some root crops should not be intercropped with mature coffee trees because their cultivation practices and growing systems are not appropriate. The coffee tree roots may be damaged during harvesting of the intercrop. Kaukau is particularly inappropriate as it hosts a weevil that attacks coffee and it also attracts coffee ring borer. Choko climbs up coffee trees restricting their growth.

8. When is the best time to grow intercrops in a coffee garden?

   Answer = C. After the coffee flush season

   Section 8.5. After the coffee flush period when mature coffee trees have been pruned there is a window of opportunity for growing short-term intercrops. Labour is also available for intercropping after the flush season.

9. When should coffee pulp be applied to intercrops?

   Answer = C. As soon as possible after coffee processing to avoid leaching of nutrients

   Section 8.6. The pulp should be applied promptly to the prepared land to improve soil fertility and avoid nutrient leaching.

10. Where is the best place to remove residues (e.g. leaves) from intercrops?

    Answer = D. In the coffee garden after the intercrops have been harvested

    Section 8.6. When harvesting intercrops or tidying up harvested intercrops for marketing to improve presentation, leave the residues in the coffee garden to help minimise nutrient loss.

11. Which of these is the most important task to carry out when growing intercrops in a coffee garden?

    Answer = B. Replace nutrients exported from the coffee garden

    Section 8.2. If the nutrients exported from an intercropped coffee garden are not replaced, the fertility of the soil will deplete rapidly.

12. What types of fertiliser can be applied to intercrops to promote growth?

    Answer = D. All the above (Inorganic fertilisers; Crop residues and kitchen waste; Coffee pulp and animal manures)

    Section 8.6. Many vegetable crops have high nutrient demands. Apply inorganic fertiliser or organic matter (e.g. coffee pulp, kitchen waste, crop residues and animal manures) to intercrops to improve crop health. The coffee trees are also likely to benefit from the fertiliser.

13. How might growing intercrops benefit women?

Answer = D. B and C (Allows them to be more involved in coffee garden maintenance as they tend to intercrops; Provides them with a more secure income)

Sections 8.1 and 8.2. Many women grow short-term vegetable crops for household consumption and for marketing, particularly in areas where there are land shortages. Intercropping enables them to use land which is already available. Coffee income is usually controlled by men and is only received annually. Growing short-term cash crops provides women with a regular and more secure income.

14. Which of these is a critical requirement for intercropping to become a permanent practice in a coffee garden?

Answer = D. Sufficient space and light, and replacement of exported nutrients

Section 8.3. It is possible for intercropping to be a permanent practice in the coffee garden if there is sufficient space between the coffee trees to minimise competition between the crops for water, nutrients, space and light. Exported nutrients must also be replaced.

True or false

a) Growing intercrops contributes to household resilience by diversifying income and providing a more secure income for women.

Answer = TRUE

Section 8.1. Intercropping allows farmers to make use of the space between the coffee trees and potentially increase their income per unit area of land, increase or supplement their income or grow more food for their families, diversify their income, ensure against crop failure and market fluctuations, and increase labour efficiency. It also provides women with access to land and a more regular income.

b) Some intercrops can harbour pests or diseases of coffee.

Answer = TRUE

Section 8.2. Some intercrops may harbour pests or diseases that affect coffee (e.g. kaukau hosts a weevil that eats the tips of the coffee, and also attracts coffee ring borer).

c) Increased biodiversity resulting from growing intercrops will decrease nutrient availability.

Answer = FALSE

Section 8.2. Increased biodiversity increases soil biological activity, which improves the availability of soil nutrients.

d) Growing coffee and intercrops that have peak labour demands at different times puts too much pressure on household labour.

Answer = FALSE

Section 8.5. Having peak demands at different times of the year means the labour demands of the coffee and intercrop will not compete.

e) Market access is not important when deciding which intercrop to grow.

Answer = FALSE

Section 8.5. If the market is not within a reasonable distance, transport costs will be higher and time to market will be longer, both of which can reduce profit. Access to inputs such as seeds, fertilisers and other farm inputs required for the intercrops will also be more difficult.

f) Unless properly managed, coffee gardens on steep slopes or with poor soil fertility should not be intercropped.

Answer = TRUE

Section 8.3. Unless the farmer plans to spend time and money on soil improvements, the soil must be suitably fertile to provide sufficient nutrients to both the coffee trees and intercrops. Also, intercropping should not be done in coffee gardens on steep slopes unless it is properly managed, as soil erosion may occur when the soil is left bare after cultivation.

8.9 SOURCES OF FURTHER INFORMATION

Coffee Industry Corporation (2016) *The Papua New Guinea Coffee Handbook* (second edition). Available at www.cic.org.pg/wp-content/uploads/2021/08/52029_CIC-Handbook.pdf

Curry GN, Webb M, Koczberski G, Pakatul J, Inu SM, Kiup E, Hamago MR, Aroga L, Kenny M, Kukhang T, Tilden G and Ryan S (2017) *Improving livelihoods of smallholder families through increased productivity of coffee-based farming systems in the highlands of PNG*, final report FR2017-08 for ACIAR project ASEM/2008/036. Available at espace.curtin.edu.au/handle/20.500.11937/54174 or www.aciar.gov.au/publication/asem-2008-036-final-report

Ghodake RD, Gaupu K, Guman K, Simin A and Kanua MB (1995) I*ntercropping of coffee in the highlands of Papua New Guinea* Technical Report 95/2, PNG Department of Agriculture and Livestock.

Inu SM (2015) *The influence of socio-economic factors in farm investment decisions and labour mobilisation in smallholder coffee production in Eastern Highlands Province, Papua New Guinea*, M. Phil thesis, Curtin University, Perth, Australia. Available at espace.curtin.edu.au/handle/20.500.11937/1938

Kiup E (2014) *Nutrients in coffee, food crops and soil within the coffee garden system in the Eastern Highlands of Papua New Guinea*, unpublished independent project and dissertation, James Cook University, Queensland, Australia.

Kiup E (2017) *Maximising nutrient utilisation and soil fertility in smallholder coffee and food garden systems in Papua New Guinea by managing nutrient stocks and movement.* Master of Philosophy thesis, James Cook University, Queensland, Australia. Available at DOI: 10.4225/28/5afb63161fb3c

Kufa T, Nestere A, Shimber T, Taye E and Yilma A (2008) 'Intercropping coffee with other crops', in Adugna G, Bellachew B, Shimber T, Taye E and Kufa T (eds.) *Coffee Diversity and Knowledge: Proceedings of a National Workshop. Four Decades of Coffee Research and Development in Ethiopia, 14–17 August 2007,* Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia.

Njoroge JM and Kimemia JK (1995) 'Effect on the yield and growth of a young compact Arabica coffee hybrid of intercropping with food crops in 3 agro-ecozones in Kenya', *Expl Agric* 31(1): 49–55. DOI: 10.1017/S001447970002500X

Pakatul J, Curry G, Apis B, Togonave P and Webb MJ (2020) *Potential for vegetable intercropping with coffee in the PNG Highlands,* International Agriculture Extension Conference, University of Goroka, 10–14 September 2017.

Winston E, Op de Laak J, Marsh A, Lempke H and Chapman K (2005) *Arabica coffee manual for Lao-PDR,* FAO, Bangkok. Available at www.fao.org/3/ae939e/ae939e00

Wintgens JN (ed.) (2009) *Coffee: Growing, Processing, Sustainable Production: A Guidebook for Growers, Processors, Traders, and Researchers* (second edition), Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim.

Australian Centre
for International
Agricultural Research

Australian
Aid