HANDBOOK FOR SUSTAINABLE COFFEE PRODUCTION IN MALAWI

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Photographs were kindly provided by Karen Smith, John Thompson, Robin Saunders, and Iain Gatward; or from online sources in accordance with reuse policies.

1. INTRODUCTION

1.1. OVERVIEW OF THE INDUSTRY

Arabica coffee is one of a number of high value crops which historically has been grown in Malawi. It thrives in certain agro-ecological areas, has been supplemented by irrigation in other areas and is seen as providing sustainable income for growers in Malawi from smallholder to estate level.[1] Input costs (chemicals, fertilizer and irrigation) and management requirements tend to be significant; however coffee has allowed farmers to diversify their income and has proved highly compatible with other important agricultural crops in Malawi.

Coffee produced in Malawi is mainly sold as green beans to the international market, predominately to the United States and Europe. Only a small volume of Malawian coffee is branded locally and processed for the domestic market. Therefore it is an important crop in terms of assuring foreign exchange income for the country through export earnings and national strategies hope to increase this contribution further.[2] As there are a wide range of competitors internationally and target markets are generally outside of Africa, with transport costs working against landlocked Malawi, branding and quality are essential for exporters.

The industry comprises over 3,200 smallholders mostly located in Northern Malawi and the estate sector which is mainly in the Southern region[3]. Smallholders tend to average smaller yields than the estate sector, which is more intensive, but both are producing very high quality coffee for international markets.

1.2. FUNCTION OF THE HANDBOOK

This handbook has been produced through the Scottish Government-funded 'Trading with Climate Smart Supply (TraCSS)' project and is intended to facilitate the continued growth and development of the coffee industry in Malawi by meeting the needs of the estates and smallholder growers alike. It builds on existing materials and was developed in close cooperation with Malawian coffee growers with the aim of improving the productivity, quality and marketability of Malawian coffee by increasing the potential for all coffee producers to improve their growing practices and hence obtain increased economic gains throughout the sector. Annex 6: Good Coffee Management was produced to assist farmers in East Africa in the management of their coffee crops and uses illustrations and simple text to provide guidance for smallholder farmers and extension officers. It has been included here as it is highly applicable to Malawian farmers and is a useful training tool.

The TraCSS project, managed by Imani Development, was designed to stimulate sustainable economic growth in Malawi by encouraging the development of agricultural value chains. The project was developed in close cooperation with the coffee sector in order to improve the competitiveness of the coffee value chain in an inclusive, climate smart and pro-poor manner and to deliver improved smallholder incomes and reduce natural resource degradation.

This handbook should act as a guide to coffee growers in Malawi, however users should be aware that the information is intended for particular situations and modifications may be required for specific constraints or local conditions. For specific needs and questions, CAMAL should be contacted directly to provide advice and assistance as required.

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[1] World Bank, (2010). *Malawi Country Economic Memorandum.* World Bank: Washington.

[2] e.g. Ministry of Agriculture and Food Security, (2011). *Malawi Agricultural Sector Wide Approach (ASWAp).* Government of Malawi: Lilongwe.

[3] Chirwa, E., Dorward, A., and Kydd, J., (2008), "Smallholder Coffee Commercialisation in Malawi", Policy Brief 021. Brighton: Future Agricultures.

2. ENVIRONMENTAL AND CLIMATIC PREREQUISITES FOR OPTIMAL COFFEE GROWING

Each farmer must decide to what extent they can meet the basic requirements for economic coffee growing to be possible however this chapter should give an indication of the limitations of what is and is not feasible.

2.1. TEMPERATURE

The optimal temperature range should be between 20°C - 26°C as shown in the diagram[4]. Some variation in temperature is necessary for processes such as for stimulating flowering. However, prolonged variation outside of this range will prohibit good vegetative growth. Warmer temperatures lead to accelerated ripening and reduced beverage quality. Upper limit refers to daytime.

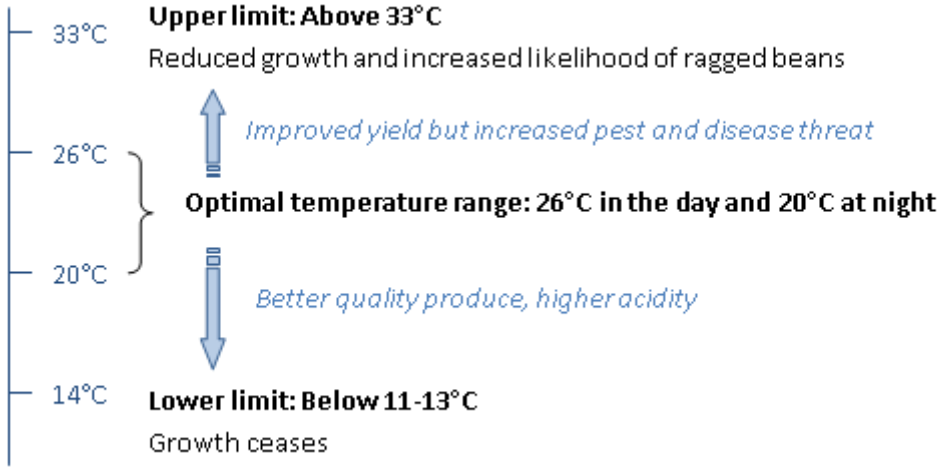


FIGURE 1. TEMPERATURE RANGE FOR COFFEE GROWING

2.2. WIND YIELD

High winds have an adverse effect on growth because they can cause excessive tree breakage and increase the demand for irrigation. Therefore in especially windy areas it may be desirable to include "windbreaks". See section 8.4 for more information on 'windbreaks'.

2.3. ALTITUDE

Altitude will generally affect the temperature and amount of rainfall in the area and should be between 900m and 2000m. Ideally, the land will lie between 900 m and 1,250 m. At high-lying land, and therefore colder temperatures, a warmer North/North-West aspect is often preferred whilst on low-lying, and hence drier land, a cooler East/South-East aspect is more desirable.

2.4. RAINFALL AND HUMIDITY

Rainfall should be between 1,100-2,000mm. Coffee prefers humid (above 50% at 1400hr) to dry conditions and therefore more than 1,100 mm of rainfall is required per annum. However, with more than 2,000 mm each year the plant may be too cold and wet for spraying or be attacked by different fungus.

[4] Allison A.G., et al. (1987), Coffee Handbook 1987 Harare: Coffee Growers Association.

Note:

- The water requirement and availability must be determined before there is a commitment to grow coffee
- The potential coffee land should be situated as close to a reliable water supply as possible in order to ensure the possibility of irrigation remains viable.
- Shade trees can also be used to improve humidity levels. See section 8.5 for more information.

2.5. SOIL AND LAND

Ideal conditions for soil and lands, in order to achieve optimal coffee growth, require:

- Free draining and free of any restrictions to root development down to a depth of 1m.
- Sandy loam/clay: Too sandy and it will require irrigation and additional nutrition. Too clay based and it will require drainage.
- Good aeration: A slope of less than 15% is ideal. Gradual slopes provide the best form of frost prevention and “barrier” trees to cold air can also help.
- Good soil fertility: The topsoil (30cm upper layer) should be rich in organic matter as it is this layer that the large majority of feeder roots are located.
- High moisture holding capacity: 10-14 mm water/10 cm soil depth.
- Slightly acidic soil with a pH between 4.5 and 5.5.
- Moderate temperature: This can be regulated using a mulching process as well as planting shade trees.

2.6. LAND MAPPING

Rainfall Map of Malawi

Data source: Malawi Department of Climate Change and Meteorological Services

= Rainfall between 1100mm and 2000mm per annum

The rainfall map of Malawi displays all areas that fall within the specified ideal annual rainfall limits.

It can be observed that there is adequate rainfall over much of Malawi. The Blantyre, Thyolo and Mulanje districts form one such area in the South East of the country. The Zomba and Mangochi districts are also highlighted as featuring appropriate rainfall conditions while further west there is adequate rainfall to be found from Mwanza district through Ntcheu and up to Dedza.

In the central and northern regions of Malawi there is a consistent area on the western shore of Lake Malawi from Nkhotakota up to Karonga and inland to include Rhumphi and Chitipa. There are also small areas in the Mchinji and Lilongwe districts that are highlighted as having appropriate rainfall conditions. Areas that get winter rain have higher potential.

Altitude Map of Malawi

Data Source: Harvest Choice interactive data query (USAID)

= Altitude between 900m and 2000m above sea Level

The altitude map of Malawi displays all areas in the country that fall within the ideal altitude band for growing coffee.

It can be seen that a large proportion of the northern and central regions of the country fall within the ideal growing zone in terms of altitude. The exceptions being the low altitudes around the lake and the high altitudes on the Nyika Plateau.

The southern region features less suitable areas in this regard. Appropriate regions can be identified in a large area from Thyolo to Zomba, a belt from Mwanza to Dedza districts and the Mangochi Highlands. The highlighted area around Mt. Mulanje is deceptive in that it mostly features the lower slopes of the mountain itself (which is a forestry reserve).

Temperature Map of Malawi

Data source: Malawi Department of Climate Change and Meteorological Services

= Max 32°C & Min 13°C

The temperature map of Malawi displays all areas that fall between the upper and lower temperature limits for coffee growing.

It can be observed that most of the country falls within the limits specified for coffee growing. The only region that features temperatures that are too high is the lower shire valley and a narrow band around the shores of Lake Malawi. The remaining regions that have not been highlighted have recorded temperatures below the minimum threshold in winter.

Soil Map of Malawi

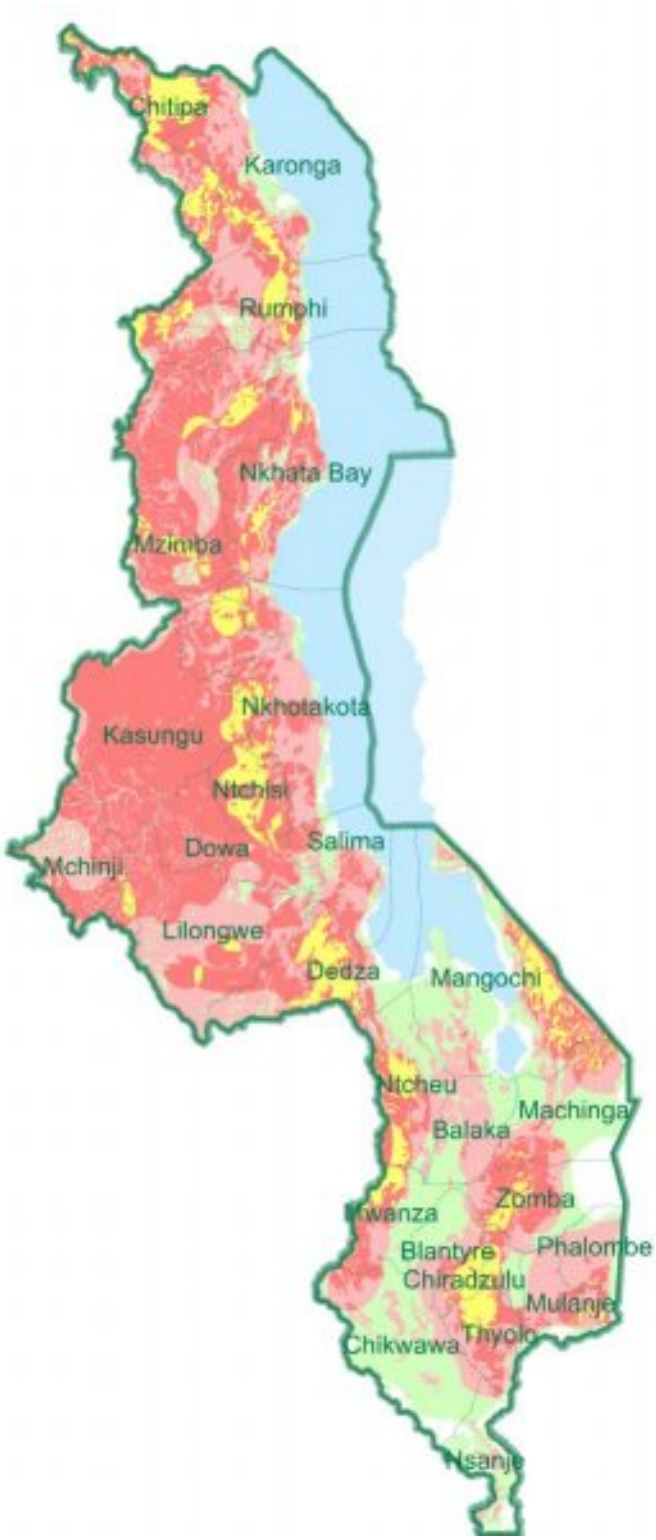
Source: Food & Agriculture Organisation (FAO) Soil Database

= 4.5<PH<5.5, over 1m deep, well drained

The soil map of Malawi highlights all areas that feature soils of appropriate depth, PH and drainage for coffee growing.

It is apparent that much of the southern region of malawi is unsuitable in this regard save for a relatively narrow region stretching from Thyolo through to Zomba. The highlands of the Mangochi district feature another area which is highlighted as having appropriate soils. Adequate soil conditions can also be found in the south west from Mwanza through to Ncheu.

The central and northern regions feature a greater area of appropriate soil coinditions with the exception being the regions around the lake and certain river systems on the western side of the country.



Map of Optimal Growing Areas in Malawi

= Ideal Rainfall, Altitude, Temperature & Soil

= 3/4 Conditions met

= 2/4 Conditions met

= 1/4 Conditions met

Combining the four parameters reveals the ideal growing areas for coffee in Malawi.

The Blantyre, Thyolo, Zomba and Mangochi and districts are currently coffee producing areas in the south. The area to the west from Mwanza to Dedza and Salima is also highlighted as an ideal area.

The central region features a large region around Ntchisi and Nkhotakota which is suitable. As well as a small band in the Mchinji district.

All of the northern districts indicate areas which are ideal for growing coffee with a particularly significant section identified in Chitipa. Coffee is currently being grown over many of these areas.

Many of the ideal (gold highlighted) areas are currently coffee producing regions. Farmers looking for new areas with potential should also consider the places that satisfy three of four parameters, particularly those that are adjacent to the ideal areas.

2.7. ADDITIONAL CLIMATE PARAMETERS

Table 1 displays additional Malawi meteorological data from stations are closely situated to key coffee growing areas. Coffee producers are encouraged to take note of important variables such as average number of rainy days, and the average onset and cessation of the rainy season.

Please note that this data represents historical trends and it is possible that future conditions will differ.

TABLE 1. ADDITIONAL CLIMATE INFORMATION AROUND KEY GROWING AREAS

	CHITIPA	MZUZU	NKHOTAKOTA	NTAJA	MAKOKA	THYOLO
Mean Annual Total Rainfall (mm) 1997 - 2011	801 - 1000	1001 - 1200	1201 - 1400	801 - 1000	1001 - 1200	1201 - 1400
Annual Mean Rain Day Freq (No of days >10mm) 1997 - 2011	31 -33	34 - 40	34 - 40	28 - 30	31 - 33	34 - 40
Mean Annual Rain Season Onset (period start date) 1997 - 2011	17-Nov	12-Nov	27-Nov	22-Nov	12-Nov	12-Nov
Mean Annual Cessation (period start date) 1997 - 2011	06-Apr	26 Apr or Later	21-Apr	27-Mar	06-Apr	16-Apr
Annual Mean Daily Max Temp (°C) 1990 - 2005	28 - 29	24 - 25	28 - 29	28 - 29	26 - 27	26 - 27
Annual Mean Daily Min Temp (°C) 1990 - 2005	19	13 - 14	20 - 21	19	17	18

Source: Climate Systems Analysis Group for USAID Vulnerability Assessment (2013)

2.8. CLIMATE CHANGE

Climate Change is one of the major challenges affecting the agricultural sector in the next 50 years. The International Panel on Climate Change (IPCC) estimates that it is 'extremely likely' that greenhouse gas emissions are changing the world's climate. The term 'global warming' is often used to describe this effect but the implications for local climates can be variable. The impact of continuously increasing concentrations of greenhouse gasses in the atmosphere is likely to be significant in Malawi.

2.8.1. CLIMATE CHANGE & CLIMATE MODELS

Scientists have attempted to predict the impacts using Global Climate Models (GCMs). Using these models the future climate conditions are estimated and projected based on different emissions scenarios. These models are relatively skilful at producing large scale global weather patterns but become more uncertain when applied to a local scale. It is important to understand that there is a degree of uncertainty in these projections at a local scale. However, this does not mean that science is uncertain about the fundamental physics behind greenhouse gasses and climate change at a global scale.

2.8.2. CLIMATE CHANGE PROJECTIONS

The Malawi climate projections for the 2020-2040 period (using a high emissions scenario - RCP 8.5) are largely uniform across the country:

- Later start to the rainy season
- Higher rainfall during mid-season
- Earlier cessation of rainy season
- Increases in mean and extreme temperatures in October and November

Climate projections for the 2040-2060 period (using the same emissions scenario) are more variable and conditions for stations near key coffee growing areas can be observed in Table 2. The general trends for this period can be summarised as follows:

- Decrease in monthly rainfall in the early parts of the rainy season (including December)
- Increase in the length of the dry spell during the early parts of the rain season
- Increase in mid-season rainfall (Jan – March)
- General increase in temperature, particularly before rains and during early rainy season
- Most stations indicate a decrease in rainfall at the end of the rainy season
- Less heavy rain days (>20mm) during early season and more heavy rain days during late season

2.8.3. IMPLICATIONS

The implications of climate change for coffee growing are numerous. The erratic rainfall and projected shorter season increases the importance of irrigation and soil moisture conservation methods. Increasing temperatures will likely see a change in the ideal altitude band for growing coffee with higher altitudes being more favourable. The higher frequency of storm events would have implications for suitable planting areas, increasing the importance of wind breaks and field drainage and design. The risk of growing coffee in Malawi increases but steps can be put in place for mitigating the risk.

TABLE 2. PROJECTED CLIMATE CHANGE FOR THE SUMMER RAIN SEASON PERIOD: 2040-2060. (RCP 8.5)

STATION	CHANGE IN TOTAL MONTHLY RAINFALL			CHANGE IN HEAVY RAIN DAYS (>20MM)		CHARGE IN EARLY SEASON DRY SPELL DURATION	CHANGE IN HEAT SPELL	CHANGE IN MAX TEMP	CHANGE IN MIN TEMP
	EARLY SEASON (NOV,DEC)	MID SEASON (JAN, FEB)	LATE SEASON (MAY, APR)	EARLY SEASON	LATE SEASON				
CHITIPA	----------	↑	----------	----------	↑	↑	↑	↑	↑
MZUZU	↓	↑	↑	↓	↑	↑	↑	↑	↑
NKHOTAKOTA	↓	↑	↓	↓	↑	↑	↑	↑	↑
NTAJA	↓	↑	↓	↓	↑	↑	↑	↑	↑
MAKOKA	↓	↑	↓	----------	----------	↑	↑	↑	↑
THYOLO	↓	↑	↓	----------	----------	↑	↑	↑	↑
↑	Increase								
↓	Decrease								
----------	No Discernible Change								

Source: *Climate Systems Analysis Group for USAID Vulnerability Assessment (2013)*

3. PLANNING AND BUDGETING

Planning is important for ensuring that farmers are well prepared for the work ahead both in terms of the time that they need to have available and the resources that they require in the short and the long term. This forward thinking allows for all tasks to be completed efficiently and will maximise revenue for the farmer.

3.1. WHAT SHOULD BE INCLUDED IN THE PRELIMINARY PLANNING?

In order to start growing coffee there are 9 basic requirements which must be achieved:

- Have sufficient capital
- Have a long-term financial plan
- Have a suitable cycle taking into consideration local agro climatic conditions and model
- Have adequate water
- Mulch coffee where possible
- Have a plant population of 1600 to 2300 plants/ ha depending on variety.
- Have the right variety for your area which must preferably be CBD and rust resistant and be capable of producing a marketable quality.
- Eradicate couch grass, star grass and sword grass in the coffee fields prior to planting out coffee seedlings.
- Use good certified seed

3.2. BUDGETING

Coffee is a perennial crop with a long gestation period between income and expenditure. Annual expenditure will exceed income for a minimum of three years from the start of a new coffee project. This implies that there is a considerable build-up of investment. A large part of the total expenditure will be of a capital nature or on indirect costs such as overheads or paying salaries. The key to success is good financial planning, keeping expenditures down and being committed to establishing the crop efficiently and building up a good income stream from high quality and high volume coffee. Example Budget templates are available in Annex 2.

The various options for sources of finance (own capital, borrowing from financial institutions or using equity funds) will need to be considered in each individual case. Farmers should also look into the various insurance options available to them in order to mitigate some of the apparent risks in coffee growing.

4. TYPES AND VARIETIES

Choosing a variety that complements the local conditions will ensure that the farmer has the best chance of producing a high quality crop that will earn commercial success.

4.1. VARIETY SELECTION

It is imported that some general principles are considered when selecting a variety. The following considerations should be made:

- Thrives in local climatic conditions (e.g. withstand shocks such as droughts).
- Economic constraints.
- Specific management practices required.
- Intolerance to common diseases (for more information see Section 14.51).
- Harvest time and length of planting cycle.
- Desired coffee cup quality: This is heavily influenced by the time of year in which the bean develops and ripens e.g. varieties which tend to ripen in the cooler months before October or November should produce the best quality coffee.
- Potential yield: This is affected by coffee bean size and the size of the plant e.g. dwarf varieties, whilst being easier to harvest efficiently, need to be grown at higher plant populations to maximise fruit yields. It is also important, however, to consider that a higher plant population can lead to poorer bean size and bi-annual bearing.

4.2. VARIETY DISTRIBUTION

Ultimately the Department of Agricultural Research Services (DARS), in the Government of Malawi, has control over seed introduction and dissemination; this is usually done in conjunction with the Coffee Association of Malawi.

The Smallholder Coffee subsector has high number of coffee varieties. However this section focuses on varieties that are grown in higher proportion amongst the many. The other varieties grown by farmers but of not very significant volumes are SL28, SL34, Mundo Nouvo, and Kent.

4.2.1. GEISHA VARIETY

Geisha Variety is a single tree selection from Geisha 56. It is a land race that was selected for resistance to Fusarium Wilt, a serious disease that almost wiped out the coffee industry in Malawi. It is also tolerant to CBD but is highly susceptible to Coffee Leaf Rust. Geisha variety is a tall, medium yielding variety with excellent cup quality in the right conditions. It is widely grown by Smallholder farmers.

4.2.2. AGARO

Agaro is a single tree selection S Agaro 60. It is a land race that was selected for the same reason as Geisha – its tolerance to Fusarium Wilt. It is susceptible to Coffee berry Disease and leaf Rust. Agaro is a tall, medium yielding variety with good cup quality.

4.2.3. CATURRA

Caturra is a short with a thick core and has many secondary branches. It has large leaves with wavy borders similar to Coffee Bourbon and is a mutation of the Bourbon variety. It is susceptible to CBD, Fusarium Wilt and Leaf Rust. Caturra is high yielding variety production large berries of good cup quality.

4.2.4. CATIMOR

Catimor is a cross between Hybrid of Timor and Caturra. It was bred in Portugal to provide high yields and resistance to diseases. Catimor 129 is tolerant to both Coffee Berry Disease and Coffee Leaf with an average quality cup. However Catimor Pop 1-5 is only resistant to Coffee Leaf Rust and susceptible to CBD.

4.2.5. NYIKA

Nyika variety is a selection from Catimor 129. It is a dwarf variety with wonder internodes and broad leaves. It was selected for resistance to Coffee Leaf Rust and Coffee Berry Disease. It is a high yielding variety with average to good cup quality.

4.2.6. CATUAI

The plant is relatively short, and the lateral branches form close angles with the primary branches. The fruit does not fall off the branch easily, which is favourable with areas with strong winds or rain. This is a hybrid of Mondo Novo and Caturra. It is very susceptible to Coffee Berry Disease and Leaf Rust. Catuai is a high yielding variety and has good cup quality. It has either yellow or red cherries.

4.3. VARIETIES COMMONLY USED IN MALAWI

Under the TraCSS project, new varieties are being trialled to test their suitability for growing commercially in Malawi. The results of these tests will not be available until the trials are completed in 2015 and therefore the information presented here is soon to be updated by CAMAL. It is important to note that new varieties differ in ripeness and sugar content so evaluation of quality has to be scrutinised carefully, which is why trials are being undertaken and results will take time to analyse and include in this manual.

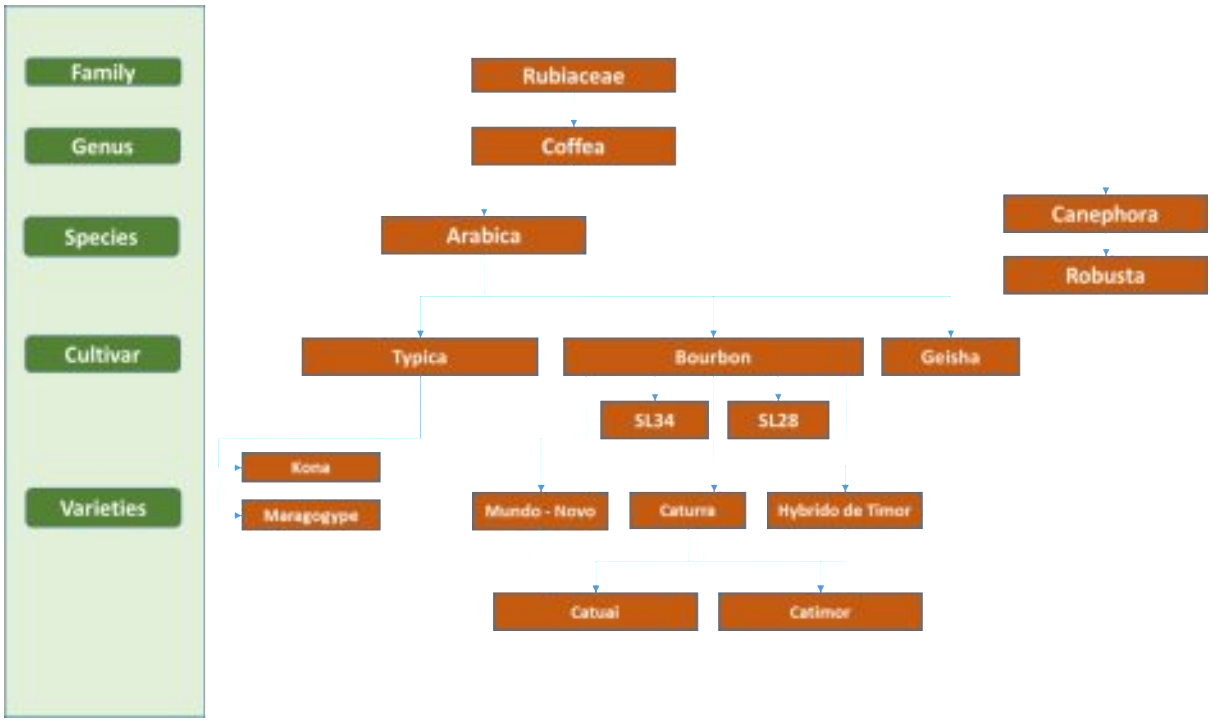
The genus *coffea* is a member of the Rubiaceae family, and is said to have over 100 species (124 recorded in 2012, revealed by microsatellite markers across Africa and the Indian Ocean). There are two main species of commercial coffee; *coffea arabica* and *coffea canephora* (robusta). All the cultivars and varieties of coffee currently grown in Malawi are of the *arabica* species.

Cultivars of *coffea arabica* are derived into two broad groups; Bourbon and Typica from which the varieties under production in Malawi are descended. However, later accession varieties such as Rume Sudan and Geisha are grown commercially worldwide (particularly Latin America) – genetically these are different.

Bourbon was developed by the French on the island of Bourbon, now Reunion, in the India Ocean. In general, Bourbon has slightly higher yields and is more robust than Typica. It has a broader leaf and rounder cherry (and green bean), a conical tree form, and erect branches. It has many local variants and sub-types, including Arusha, and the Kenya SL types. In general, Bourbon has potential for an excellent cup character. The cherry ripens quickly, but is at risk from wind and hard rain and is susceptible to major coffee diseases. Bourbon grows best at altitudes between 1100 – 2000masl and is the base from which many coffee varietals have been developed, many of which are now found in Malawi.

In contrast to Bourbon, Typica coffee plants have a conical shape with a main vertical trunk and secondary verticals that grow at a slight slant. Typica is a tall plant reaching 3.5-4.0 m in height. The lateral branches form 50-70° angles with the vertical stem. Typica coffee has a very low production, but has an excellent cup quality. A much smaller number of the Malawi varietals are descended from Typica coffee.

FIGURE 2: THE COFFEE 'FAMILY TREE' AND ORIGINS OF THE MAIN VARIETIES FOUND IN MALAWI.



Three of the dominant varieties of coffee under production in Malawi are Caturra, Catimor and Catuai; their main characteristics are described in brief below:

Caturra is a mutation of Bourbon discovered in Brazil, with high production and quality, but requiring extensive care and fertilisation. It is short with a thick core and has many secondary branches. It has large leaves with wavy borders similar to Bourbon. It adapts well to almost any environment, but does best between 1,500-5,500 feet with annual precipitation between 2,500-3,500 mm. At higher altitudes quality increases, but production decreases.

Catimor is a cross between Timor coffee (resistant to rust) and Caturra coffee, and was created in Portugal in 1959. Maturation is early and production is very high with yields equal to or greater than the yield of other commercial coffee varietals. For this reason the method of fertilisation and shade must be monitored very closely. The Catimor descendants are relatively small in stature, but have large coffee fruits and seeds. At low altitudes there is almost no difference in cup quality between Catimor and the other commercial coffee varietals, but at elevations greater than 4,000 feet Bourbon, Caturra, and Catuai have a better cup quality.

Catuai is a high yielding coffee plant resulting from a cross between Mundo Novo and Caturra. The plant is relatively short, and the lateral branches form close angles with the primary branches. The fruit does not fall off the branch easily, which is favourable with areas with strong winds or rain. Catuai also needs sufficient fertilisation and care.

The main varieties found under production in Malawi are as follows, with their basic characteristics described in Table 3.

- Catimor (Various populations 1 -5)
- Caturra
- Catuai (Yellow)
- Geisha
- K7
- Nyika
- Ruiru 11
- S. Agaro
- SL28 & SL34

TABLE 3: MAIN VARIETIES AND THEIR CHARACTERISTICS FOUND IN MALAWI

VARIETY	ORIGIN	GROWTH /HABITAT	PRODUCTION YIELD	PRODUCTION SYSTEM	TOLERANCE	SUSCEPTIBILITY	LIMITATIONS	STRENGTHS	CUPPING QUALITY
CATIMOR	Cross between Caturra and Hybrido de Timor	Semi-dwarf, compact foliage	Very high / moderate bean size	Highly intensive with heavy nutrient requirement	Coffee Leaf Rust (high), moderate resistance to CBD and some nematodes	Drought, over-bearing and subsequent dieback and alternate bearing	Has a weak root system and tends to "fall apart" in the row	Disease resistance and yield	Poor, more noticeable at high altitudes when compared with Caturra, Catuai and Bourbon over 4,000ft
CATURRA	Bourbon mutant (Brazil)	Semi-dwarf, dense foliage	Good / smaller bean size	Highly intensive with heavy nutrient requirement	Drought (moderate), warmer climates & varied elevations	Coffee Leaf Rust, CBD, and Fusarium	Vulnerable to disease and requires intensive management	Adaptable to a wide range of elevations	Good quality improves with altitude
CATUAI (YELLOW)	Cross between Caturra and Mundo Novo	Semi-dwarf, dense foliage with good vigour	High / moderate bean size	Can tolerate relatively low management	Drought and warmer climates	Coffee Leaf Rust, CBD, and Fusarium	Vulnerable to disease, late maturing	Able to withstand drought and higher temperatures	Good, improves with altitude
GEISHA	Ethiopia (also known as Gesha)	Paler in appearance, branches vigorously.	Low to moderate / small bean size	Can tolerate relatively low management	Coffee Leaf Rust and CBD (moderate) and Fusarium	Drought and higher temperatures	Lower yielding and drought prone	Withstands moderate disease break-outs, high cupping qualities	Excellent

K7	Single tree selection from Kenya	Spreading with drooping primaries	Average to high in lower elevations, higher temperatures	Medium management	Moderate resistance to CLR, some resistance to CBD, drought hardy	Fusarium	Only yields well at lower elevations where pest and disease prevalence are high	Some resistance to CLR and CBD	Good
NYIKA	Selection from Catimor 129	Semi-dwarf, compact foliage	High	Management and nutrient intensive	Moderate resistance to CBD and Coffee Leaf Rust	Drought, over-bearing and subsequent dieback and alternate bearing	Has a weak root system and tends to "fall apart" in the row	Disease resistance and yield	Fair, with increasing quality experienced with higher altitudes
RUIRU 11	Cross from Kenya	Compact foliage	High yields of good quality	Management and nutrient intensive	CBD and Coffee Leaf Rust	Generally good disease resistance	-	High disease resilience, high quality yielding	Good
S. AGARO	Ethiopia	Erect branching habit, open	Fair to good	Average management required	Fusarium (moderate), CBD and Coffee Leaf Rust (some tolerance)	Drought stress	Large inter-nodal spaces limit production relative to compact varieties	Relatively robust under disease pressure	-
SL28 / SL34	Bourbon Selection (Scott Laboratories – Kenya)	Tall, upright and open canopy	Moderate to good / large bean size	Management and nutrient intensive	Drought tolerant, prefers higher cooler climates	Coffee Leaf Rust and CBD	Susceptible to disease, prone to weather damage	Potentially high yielding and good quality output	Excellent cup quality

Note: As the amount of new genetic material entering Malawi over the past few decades has been minimal, there have been high levels of self-pollination. This has led to increased susceptibility to pests, diseases and drought and has lowered yields and cup quality.

In 2012 a selection of varieties were brought into Malawi from Portugal. These, along with locally selected varieties were put under evaluation and multiplication by a partnership between TraCSS, CAMAL and DARS. The evaluation and multiplication plots are situated at both Bvumbwe and Lunyangwa research stations. At the time of writing the trial was entering its third year with results beginning to emerge. For more information of the results of the varietal evaluation please contact CAMAL.

5. CLEARING AND LAND PREPARATION

Tillage, or the preparation of land for cultivation, is cost effective if it is well planned and therefore conserves as much water and soil as possible for production purposes.

5.1. MAIN AIMS AND OBJECTIVES

Planning should achieve the following four objectives listed in order of priority:

1. Maximum water infiltration and minimal soil movement.
2. Safe disposal of surplus run off water.
3. A good road system within the plantation.
4. Simplification of irrigation without prejudicing 1, 2 and 3 above.

5.2. PLANNING

The following should act as a guideline for land clearing and preparation.

5.2.1. ADVANCE PLANNING

Carry out Soil Analysis

The soil pH is of paramount importance and is often ignored. If the soil pH is incorrect, the balance of nutrient uptake becomes inefficient and the effectiveness of fertilizers is reduced. Take a representative soil sample (from 8 sub samples) 0.20 cm for pH and Phosphorus determination and label it. Analysis is carried out by the TRFCA laboratory). The presence of bracken, sword grass or the poor colour of various weeds can give an early indication of acidic soils. But the pH must be checked using a pH meter, and/ or soil samples analysed by qualified personnel. For information of how to take a soil sample see Section 11.1.2.

In the presence of acidic soils lime has to be applied at high rates. The level of magnesium present dictates what kind of lime should be used. If the problem is identified too late, then zinc, magnesium and calcium foliar sprays should be used instead.

Residual Herbicides from Previous Crops

There is the possibility of harmful carry over effects where certain residual herbicides have been applied to previous crops. An interval of 18 months is a minimum safe period between chemical application and planting.

Survey and Plan Layout

The appropriate system of earthworks for soil conservation, the promotion of rain infiltration and the regulation of run off need to be decided by skilled officers from the District Agriculture Office. They can aid in calculating expected run-off and use this to plan waterways, water bunds for storm water collection and roads on the farm appropriately.

5.2.2. TWO OR THREE MONTHS BEFORE PLANTING

1. Mow the grass by tractor. Remove scrub, grass, weeds and stubble.
2. Mark out the contours, water ways and planting lines. Planting lines ripped and holes dug ½ m X ½ m.
3. A herbicide spray can be used to control weeds especially couch grass, star grass, sword grass in the entire field.
4. Remove all roots.
5. The coffee planting station can be raised up slightly for drainage and frost control.
6. Continue to re-spray or weed as necessary in the months coming up to planting.
7. Planting shade trees should ideally be done one to two years before planting out the coffee. See section 8.5 for information on shade trees.

6. NURSERY PRACTICE

Nurseries are used to ensure that significant quantities of disease free and true to type coffee seeds are available at the required time. This supply allows for planting to take place at the correct time and for a variety to be introduced into a new location. Good supervision and management is a prerequisite for a successful nursery on the farm.

FIGURE 3: EXAMPLE OF NURSERY

6.1. THE NURSERY

To ensure ideal conditions for coffee growth there are some requirements for the nursery site and soil.

6.1.1. NURSERY SITE REQUIREMENTS

- To be fenced and protected from cold air.
- Suitable clean water available on site.
- Allow 5 m around the edge as a firebreak.
- 50% shade (top of the side walls covered and the bottom side left open for airflow). Do not use green shade netting as this can increase temperatures excessively.
- Avoid areas known to be susceptible to frost.

6.1.2. SOIL REQUIREMENTS

- Only use fertile free draining topsoil (top 25 cm).
- Use sandy/loam to sandy/clay/loam.
- Virgin soil has a higher organic matter content and is free of eelworm. Do not use soil from tobacco, maize and banana lands or vegetable gardens.
- Add well-rotted compost or manure to poorer soils: 1 part to 3 or 4 parts soil by volume.
- Harrow or mix in additives and sieve through a 5 mm x 5 mm mesh screen.
- Use a funnel with a 12.5 cm diameter spout to fill the pots so that when the soil settles after a good watering there is a 5-10 mm lip above the settled soil. 1 m^3 soil

fills 300 pots. The pots must be tampered to reduce air pockets before putting in the nursery bed; this also helps to keep the pots upright. There should be a maximum of 10 pots in a line for ease of management and support the edge of the bed with bamboo, soil or off cuts so pots do not fall over.

6.2. SEED SOURCING AND SOWING PRACTICES

Seed sourcing and sowing practices are currently a problem in Malawi and there is no certified seed in Malawi. CAMAL should be contracted for any requirement of seed. The supplier of seed should be visited and check the seed plot to ensure that the seed supplied is of a high standard.

A guideline on how to set up a seed plot on the farm can be found in Annex 3: A Guideline On How To Set Up A Seed Plot.

6.2.1. SOURCING SEED

Authority from CAMAL is needed to move seed (this system is used to reduce the spread of disease). Seed should be sourced from Registered Seed Growers List (SCEO or CAMA). Seed must be fresh when it is used and is only usable when it is less than 4 months old so it must be used within one season. Source seed is available from May-September but the beginning and end of the season should be avoided. Allowing for contingencies, 3kg of seed (assuming 4,000 seeks per kg) per hectare of land is required at the recommended spacing. However, 1,500 covas per ha require 1.5kg of seed or 2,000 covas per ha require 2kg of seed. To control Fusarium Disease, the seed may require a treatment of 1g Benglate (benomyl) per kg of seed (if it has not already been treated).

6.2.2. SOWING REQUIREMENTS

Sowing the seed requires good conditions for germination

Timing

- **Below 1,000m**: September/ October sowing seed for planting using, irrigation the following July/ August.
- **Above 1,000m**: August/ September sowing for planting using, irrigation the following July/ August.
- **Planting in rainy season**: December/ January for planting in November/ December. February can be too wet. Check the seed reaping date for viability.

Materials and layout for Sowing

- Pots are preferred to sleeves in general.
- Pots should be 25cm x 20cm lay flat or larger.
- They should be well perforated at bottom.
- Each bed should comprise 50 x 10 pots 1.3m wide and 6.5m long.

Sowing Method

1. Remove any weeds.
2. Ensure soil level in pots is 5-10mm from the top lip.
3. Place two seeds flat side down on soil surface of each pot near centre of pot and 2.5cm apart. Do this on the entire bed before covering with soil.
4. Push seed down 1cm below soil surface.
5. Cover with soil in the pot and firm gently with finger and thumb or add dry soil and press down gently if soil in pot is wet.
6. Water well after planting.

7. Mulching: Cover the soil surface of each pot with a light and fine grass mulch such as lovegrass - Eragrostis chopped into 2 cm lengths. Ideally the mulch should be sprayed with Confidor to prevent ants.

Watering

- **Equipment**: Use a watering can or hosepipe with fine rose or microjets suspended above each bed. The decision should be made based upon the size of nursery.
- **Sowing to germination**: A light watering daily and a good watering (soaking to the bottom of the pot) once per week.
- **Following germination**: Water less frequently but apply a good watering on each occasion. After watering the pot should be soft from top to bottom. Before watering the pot should have dried out and be becoming hard to the touch. Moss at the surface suggests over-watering and/or nursery may be too dark and damp.

6.3. SEEDLINGS

Fresh seed takes 6-8 weeks to germinate. You should always be watching for and removing weeds and you should scout daily for pests and diseases. Chemical control/ prevention could be used however chemical use should try to be avoided if possible. Two weeks prior to planting out drench with Confidor insecticide as per recommendations. Make sure that beyond 12 weeks there are no more than two plants per pot to ensure the plants grow at optimum rate but at first and second pair of true leaves, thin to one plant per pot and commence fertilisation. Before planting out plants should be 20-30 cm tall and 4-6 weeks before shade should be removed progressively. Any plants that are not true to type or are unhealthy should be discarded.

FIGURE 4: SEEDLING READY FOR PLANTING OUT

Pests

- Cutworm and dusty surface beetle: Use soil drench of a synthetic pyrethroid (e.g. Karate), or Thiodan 50WP.
- Slugs and snails: Use slug or snail bait, snail pellets such as Mersurol, or powdered tobacco scrap.
- Nematodes: A nematicide (seek latest available safe nematicides). If nematodes are seen in the nursery the affected plants should be removed.

For more information on pests please see section 14.3.

Disease

- Fungal infections: At cotyledon stage commence regular application of fungicide. E.g. Spray Kocide monthly at a rate of 100g to 15 litres of water.
- Fusarium: If Fusariam or Cercopora is seen, reduce water and immediately inform seed supplier. There is a very high possibility that it is seed borne and the quality of seed is compromised and suspect. In this case it should be destroyed.
- Dampening off: 90g of Baytan should be sprayed once and Thiram (60g to 15litres of water) should be sprayed weekly for 4 weeks. Thiram could be used in the 12th-16th week as a preventative measure.

7. GROWTH AND DEVELOPMENT[5]

Consistently high yields of coffee require a balance between vegetative growth (growth of the plants branches and leaves) and fruiting (reproductive growth). Too much growth can inhibit fruiting by providing too much shade. Too much fruiting on the other hand can cause dieback. Figure 5 shows key elements of a coffee plant growth system, highlighting the complexity of the plant and skill required to understand its growth requirements.

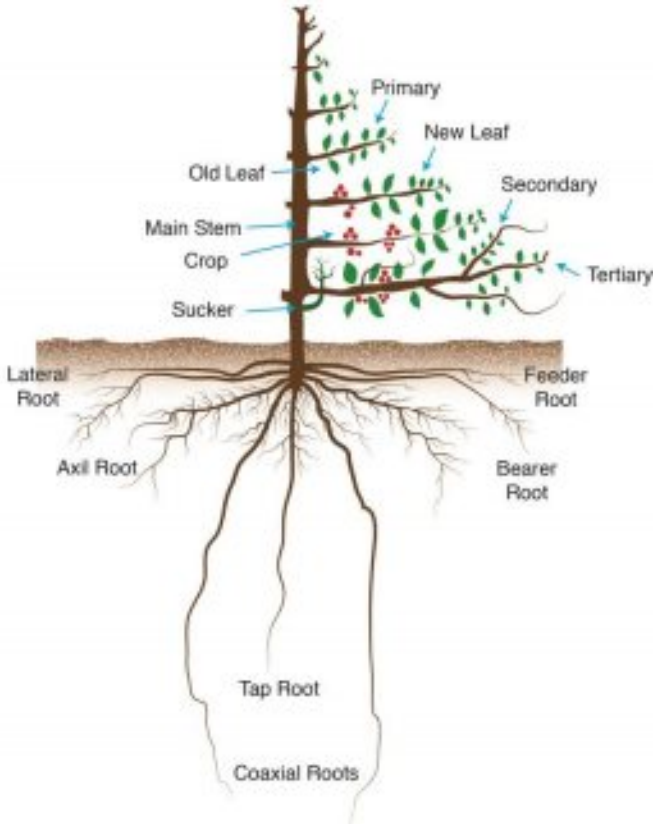


FIGURE 5: FULL COFFEE PLANT GROWTH SYSTEM[6]

7.1. VEGETATIVE GROWTH

The amount of light that reaches a primary branch and the pruning practices used determine the extension growth of a branch. However, growth decreases with age of the plant. Growth in the lower part of the tree may be inhibited by spacing.

7.2. REPRODUCTIVE GROWTH

Fruit yields are determined by the number of fruiting nodes produced (by vegetative growth the previous season), the number of fruits produced per node (reproductive efficiency) and by individual fruit mass. The fruit will arrive some 6-9 months after the plant produces its small white flower.

[5] Adapted from Allison, A. G., et al. (1987), "Coffee Handbook 1987", Harare: Coffee Growers Association. Pg 20-23

[6] Adapted from Allison, A. G., et al. (1987), "Coffee Handbook 1987", Harare: Coffee Growers Association. Pg 16

In the first two years, when fruiting is predominantly determined by the number of fruiting nodes, close spacing can increase yields. However, after this point (third crop onwards) reproductive efficiency becomes more important which is determined by access to sunlight. Therefore where high populations are planted, systems to remove trees or parts of trees as the crop matures need to be implemented. Optimal fruit mass can be improved through achieving adequate soil moisture.

7.3. ROOT GROWTH

A good understanding of coffee rooting patterns is important for irrigation and the placement of fertilisers and granular pesticides. Growth of the roots is most affected by nitrogen availability. However the key variable factors are soil type, mulching practices, irrigation, tree age, nutrition and plant spacing.

7.3.1. LIMITATIONS

- **Heavy or very compact soils:** The passage of heavy machinery through the coffee inter-row should be avoided or reduced to a minimum
- Gravel in the soil
- **Waterlogging:** Roots will not grow near permanent water tables.
- **pH below 4:** Aluminium and manganese can be a problem in soil that is very acid. Organic matter can offset some of the effects of a low pH.
- **Overbearing dieback limits root growth:** Such trees should be pruned to leave the maximum possible leaf area to give the root system a chance to recover

7.3.2. PRACTICES AFFECTING ROOT DISTRIBUTION

- **Mulching and shade:** The effects of these two treatments are similar as they both enhance root development in the top 25cm of soil and make axial roots, growing deeper, of less important.
- **Irrigation:** Excessive irrigation in the establishment phase means ultimate depth to which axial roots penetrate may be reduced and plant is less drought resistant.
- **Root pruning:** Pruned roots of healthy coffee trees will regenerate rapidly.

7.3.3. DENSITY OF PLANTING

In deep soils with higher plant populations axial roots generally penetrate to a much greater depth and have a higher intensity. However surface lateral root growth is restricted in the direction of neighbouring trees. Figure 6 shows root distribution of coffee tree planted in hedgerows. The amount of lateral rout growth is inversely related to the nearness of other coffee trees, though roots do interpenetrate to a degree.

Coffee planted in covas is markedly different with regard to root distribution, particularly for those near the surface. A cova system is where trees are planted in pairs next to each other (less than 0.15 m apart/ within the same hole). Figure 6 shows views of surface plate distribution of two and four tree cova respectively. The bold line represents the surface plate of an individual tree and its mainstem is indicated by the large dot. Growth of surface laterals is severely restricted in the direction of juxtaposed trees although lower lateral roots do cross over to a certain extent. Axial roots of coffee planted in covas grow much deeper than those of singly planted trees at similar plant populations. The preparation of a decent size planting station is of paramount importance to establish a healthy root system.

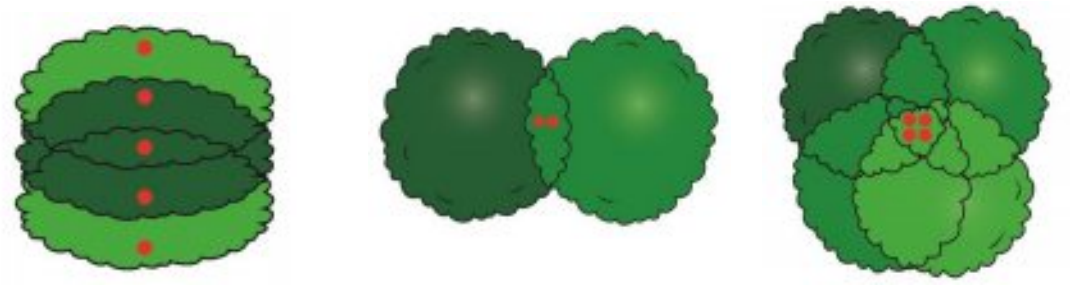


FIGURE 6. ROOT DISTRIBUTION OF COFFEE TREE AND SURFACE PLATE DISTRIBUTION OF TWO AND FOUR TREE COVAS[7]

[7] Adapted from Allison, A. G., et al. (1987), "Coffee Handbook 1987", Harare: Coffee Growers Association. Pg23

8. LAND PREPARATION AND PLANTING

This section covers planning an appropriate population (including spacing/ layout design) and planting methodology.

These elements are closely interlinked as choice over spacing and layout of plants directly impacts the overall plant population that can be achieved in a given area. To achieve an optimal yield, any decision with regards to population and spacing/layout must be made in light of the fact that plants compete for resources (nutrients, water and sunlight) and must be accessible for plant management practices to be completed. For smallholders it is advisable to use wider spacing.

8.1. SPACING AND POPULATION

Planting population or density (i.e. number of trees in a given area) will likely be influenced by a range of factors including:

- Size of the mature coffee tree – larger trees require a lower density.
- Feasible level of maintenance– higher density will mean more maintenance.
- Use of fertiliser– fertilisers boost tree growth so a lower density is required. [8]
- Manual versus mechanical maintenance.
- Chosen field layout and spacing (explored further in the proceeding sections).

Studies have shown that the optimal density for Arabica coffee in high–altitude equatorial zones is between 2,500 and 3,300 trees/ ha. Nearer to the tropics the density is generally between 1,100 and 1,600 trees/ha[9].

An important layout decision to make is whether to plant in covas or single hedgerows. For more information about planting in Covas or Single Hedgerows refer to Simply Coffee[10] or section 7.3.3 Density of Planting.

[8] OLAM, DE Foundation & Kuit Consultancy, (2004). *Plantation Establishment.* Amsterdam: DE Foundation.
[9] Hühne, M., (2012). *Coffee: Growing, Processing, Sustainable Production.* [2nd ed]. Weinhem: WILEY-VCH.
[10] Clowes, R., (2001). "Simply Coffee". Harare: Cannon Press

TABLE 4. SUGGESTED DENSITY, LAYOUT AND SPACING FOR ARABICA[11][12]

FARMING PRACTICES	ALTITUDE	LAYOUT	GOOD TO VERY GOOD SOIL FERTILITY OR FERTILISED COFFEE TREES		MEDIUM TO POOR SOIL FERTILITY OR NON-FERTILISED COFFEE TREES		AVERAGE SOIL FERTILITY	
			SPACING (M)	TREES (/HA)	SPACING (M)	TREES (/HA)	SPACING (M)	TREES (/HA)
Manual maintenance	High	Square	2.5 x 1.5	2660	2.5 x 1.2	3330		
		Rectangle	2.0 x 2.0	2500	1.75 x 1.75	3265		
	Low	Rectangle	3.0 x 2.5	1330	2.5 x 2.0	1666		
		Square	2.75 x 2.75	1320	2.5 x 2.5	1600		
Mechanised		Rectangle	3.0 x 2.5	1330	2.75 x 1.25	2430		
			2.74 x 2.74	1330	2.75 x 1.5	2430		
Using Fertiliser		Square					2.75 x 2.75	1320
		Rectangle					3.0 x 2.5	1330
Not using fertiliser		Square					2.5 x 2.5	1600
		Rectangle					3.0 x 2.0	1666

8.2. CONTOUR PLANTING

When a coffee plantation is on land with a slope of more than 5% the coffee trees should be planted along the contour (coffee rows should run at right angles to the direction of the slope). Anti-erosion measures such as contour ridges, contour bunds, contour ditches and vegetative measure of erosion control also run along the contour between the coffee rows in order to manage the rainfall run-off[13]. Contour planting is recommended for conservation and other management considerations such as energy use when spraying and more even application of water via irrigation systems.

FIGURE 7: GUATEMALA CONTOUR PLANTING UNDER SHADE

[11] Hühne, M., (2012). *Coffee: Growing, Processing, Sustainable Production.* [2nd ed]. Weinhem: WILEY-VCH. Pg 230.
[12] OLAM, DE Foundation & Kuit Consultancy, (2004). *Plantation Establishment.* Amsterdam: DE Foundation.
[13] Hühne, M., (2012). Coffee: Growing, Processing, Sustainable Production. [2nd ed]. Weinhem: WILEY-VCH. Pg 197

8.3. ORIENTATION

If the terrain is relatively flat or the general contour configuration will permit, an approximate North-South orientation allows a degree of mutual shading in the middle of the day and a similar distribution of height on both sides of the tree. Alternatively, to protect the tree from excessive sun in the afternoon an east-west row orientation is preferable.

8.4. WINDBREAKS

Coffee trees can be harmed by consistent exposure to strong winds and therefore it is important to shield the trees using windbreaks in areas that are wind-prone. If breaks are not naturally provided by vegetation, trees may need to be planted intentionally. The windbreaks must be planted at least 15 metres away from the coffee and should be grown in a row that is planted across the slope and perpendicular to the prevailing wind direction. They should be planted in the few years prior to planting coffee and should be allowed to grow higher than shade trees. Considering the length of time it takes for windbreak trees to grow to full maturity it may be sensible to plant alternative intermediary solutions (fast growing biennials or perennials in the meantime). The selected trees could include a mixture of short and tall trees to ensure a successful barrier is achieved. Pine trees, Gum trees and Cypress trees tend to deplete the fertility and water of the soil so it is not advisable to use these in close proximity to coffee.

TABLE 5. ADVANTAGES AND DISADVANTAGES OF WINDBREAKS[14]

ADVANTAGES	DISADVANTAGES
• Evapotranspiration losses can be reduced by up to 33% in sheltered coffee (stops trees drying out). • Large fluctuations in temperature are buffered. • Humidity within the trees maintained at a higher level. • Prevents leaf scorch and physical damage. • Some windbreaks may generate additional benefits e.g. fruit, mulch material, firewood.	• Coffee close to windbreaks may suffer from competition for light, moisture, nutrients. • Area used for windbreaks is lost for coffee production. • May cause an increase in the difference between air temperature at the farm during the day or at night. • High and dense windbreaks may become an inconvenient obstacle if certain kinds of management procedures are used.

8.5. SHADE TREES

In its natural environment coffee is a shrub which grows in the forest under the canopy of other trees and until around 40 years ago the majority of farms grew coffee under shade. However, in recent years new varieties of coffee have been developed for commercial growers which will thrive under full sunlight conditions with the intended advantages of increasing coffee yields and reducing the risk of fungal diseases especially of coffee leaf rust (Hemileia vastatrix). Therefore today, there is more of a debate about the necessity of using shade trees and it is generally considered important to make the decision based upon the conditions specific to the farm because in good coffee growing conditions the negative impacts can outweigh the advantages. However, global warming presents a risk to status quo temperatures and sunlight conditions for existing stock, and shade trees can be included in a climate-smart model. Advantages and Disadvantages of Shade Trees are listed in Table 6 below.

[14] Hühne, M., (2012). *Coffee: Growing, Processing, Sustainable Production.* [2nd ed]. Weinhem: WILEY-VCH.

FIGURE 8: GUATEMALA COFFEE UNDER GREVELIA SHADE

TABLE 6. ADVANTAGES AND DISADVANTAGES OF SHADE TREES[15]

ADVANTAGES	DISADVANTAGES
• In areas with higher than optimum temperatures, shade trees protect coffee from high solar radiation and limits evapotranspiration. • Limits weed growth. • Reduces decay rate of organic matter in soil. • Reduces plant metabolism encourages more regular flowering. • Higher populations of birds and other predators associated with the tree cover introduces natural pest control (such as of the coffee berry borer and leaf miners) and increases the number of bees to improve fruit set (following pollination). • Shade trees will help to stabilise soils in coffee plantations, reduce soil erosion and reduce water runoff all of which are beneficial for coffee production and reduce the risk of catastrophic crop failure. • Shade-grown coffee typically has higher diversity of flora and fauna. • Organic coffee has to be shaded. • Bean ripening is slowed therefore improving bean density and cup. • Enriches the soil through increased organic material (leaf fall/ twigs) and hence reduces dependency on chemical inputs. • Some leguminous trees are nitrogen fixing. • Protects against extremes in atmospheric and soil temperatures. • Provides increased protection against frost and strong winds. • Reduction of Cercospora spp. and attacks by White Stem Borer. • Contributes to conservation of biodiversity. • May generate additional benefits e.g. fruit. • Improved quality through slower ripening. • Reduces the effect of biennial bearing.	• Competes with coffee for nutrients and water. • Require regular lopping and thinning which is labour intensive. • Branches may fall due to lopping or high winds and damage coffee below. • Shade reduces photosynthesis activity and causes elongation of inter-nodes both of which result in lower yields. • Risk of Coffee Leaf Rust (CLR)

[15] Hühne, M., (2012). *Coffee: Growing, Processing, Sustainable Production.* [2nd ed]. Weinhem: WILEY-VCH.

Considering shade for temperature and moisture maintenance, with controlling risk of Coffee Leaf Rust (CLR), is a balance.

The chosen shade trees need to:

- Provide a homogenous canopy with few gaps and no undue leaf density.
- Intercept 20-45% of total light falling on the plantation.
- Must be deeply rooted, wind resistant, long living and fast growing.
- Well adapted to local conditions.
- Preferably provide consistent coverage year round.
- Must be able to withstand intensive pruning to provide organic mulch material.
- Must make sure selected trees are not host to pests.

Arabica coffee requires more dense shade coverage as compared to Robusta coffee. Shade trees should be planted at least one year before the coffee is planted, if possible.

Common species that are used as shade trees in coffee include:[16,17]

- **Grevelia**: very good for timber and firewood, wind break on boundaries (12m X 12m)
- **Leucaena**: fast growing, nitrogen fixing, rich animal feed, good biomass (4m X 4m)
- **Albizia**: improves soil fertility, nitrogen fixing, biomass
- **Calliandra**: fast growing, good firewood and fodder, nitrogen fixing, heavy leaf litter
- **Glicidia**: fast growing, nitrogen fixing and biomass
- **Kenya Croton**: fast growing and supplies a lot of litter for mulch

8.6. INTERCROPPING

Intercropping can be short-term (i.e. in the 2-3 years preceding the first harvest or in the 2 years following stumping of old coffee trees) or permanent (farmed for the duration) depending on the farmer's requirements. Temporary intercropping should be avoided if slopes are very steep (as it will encourage erosion), soil has low fertility, the chosen crop will host coffee parasites, the chosen crop will provide undue shading to young coffee plants or if soil nutrients extracted by the intercrop are not replaced through fertilisation.[18]

It should also be noted that planting other crops close to coffee lines can deplete soil moisture so the separation distances should be planned in advance and managed accordingly.

The choice of what intercrop to choose is made according to local climatic conditions, purpose of the inter-crop (permanent or temporary), the size of the farm, availability of the necessary resources and access to a stable market.

Temporary intercrop options would include plants such as Maize, bean, soya, cowpeas, Suggested spacing given this range of crops is given in the table. Cassava and potatoes have been thought to have an adverse effect on coffee growth.[19]

[16] Ssebunya, B., (2011). *9-13 Coffee: African Organic Agriculture Training Manual*
[17] Hühne, M., (2012). *Coffee: Growing, Processing, Sustainable Production.* [2nd ed]. Weinhem: WILEY-VCH.
[18] Ibid.
[19] Ibid.

TABLE 7. DENSITY AND SPACING OF INTERCROP[20]

CROP	DISTANCE FROM THE COFFEE TREES (M)		SPACING (CM)	
	YR 1	YR 2	BETWEEN ROWS	WITHIN THE ROW
Dwarf Bean	0.5	0.8	25- 30	20
Runner Bean	1	1.5	40- 50	15
Soya	0.6	1.0	30	15
Maize	0.6	1.0		15
Maize	2 rows	1 row	0.75`	30

Permanent intercrops could include Banana in the inter-row, or forest trees (planted in between the coffee trees in alternate rows to shade trees). Forest trees may be considered more suitable than fruit because they require less maintenance and provide less competition.

Soya beans

The main complication is that the coffee requires irrigation during the drying off period for soya. However, coffee can be irrigated by hose and basin and the soya can be cut and dried away from any sprinklers.

Field Beans

In some situations it has been noted that field beans should not be planted earlier than late February to avoid aggravating any frost problems, however this should be confirmed either through CAMAL or in discussion with other farmers in the area to confirm prior to choice of crop.

Maize

Maize has been trialled in hotter low yield areas as it can provide temporary shade during the early establishment period. Maize leaves should be removed where they are liable to chafe developing coffee leaves.

8.7. PLANTING OUT

Good planting practices ensure good drainage and also reduce the risk from disease and ground frost. As it is such an important task planting amounts to 80% of the major work because, as a result, all other operations fall into place. To achieve a good result all of the planting team must be clear on the chosen method before it commences. Once a decision has been taken on spacing, the land should be marked out with pegs. A string or measuring stick can be used to indicate the peg positions depending on the evenness of the ground. On slopes the method highlighted below should be used.[21]

Best results are obtained from planting out early in the season (July to August with irrigation). Practices which conserve moisture (e.g. autumn ploughing) are important if undertaking early planting.

The most appropriate equipment to use is a tractor ripper that will rip a straight coffee line. The tines of the ripper can be spaced according to the plant spacing. This will give good drainage and aeration to the plant. A hoe can be used to make the holes. A sharp and sufficiently long knife may be required for cutting plant roots.

[20] Ibid.
[21] OLAM, DE Foundation & Kuit Consultancy, (2004). Plantation Establishment. Amsterdam: DE Foundation.

When the plants are ready to be transported from the nursery to the field care should be taken. If it is very hot a wet hessian shade may be required. The pots must be wedged in tightly to avoid damage.

The suggested method for contour planting (at a spacing of 2.5 m x 2 m apart)

1. Mark the planting holes out by:
    a. Constructing a simple "A-frame" structure measuring 2 m high and 2.5 m wide at the point where legs are furthest apart. The horizontal support cross-piece should be marked at the central point. A string with a weight (e.g. stone) should be attached to the top of the A and allowed to hang freely.
    b. Starting from the bottom of the slope, "walk" the "A-frame" across the slope by rotating it from one leg to the other.
    c. Place a marker at each point on the ground where the pendulum lines up with the centre mark on the horizontal bar. Continue for the desired length of the contour line.
2. Locate the next contour line 2m up the hill from the first row.
3. Continue this procedure until the entire field has been marked out.

8.7.1. PREPARATION GUIDELINES

The instructions explained here should be used as guidelines only as there are other methods of preparation. Please consult the wider manual or other manuals for alternatives depending on location, topography, soil and varieties.

1. Dig the 40 cm area around the pegs marking out planting layout, mix the soil with the fertilizer, lime and manure, and then heap the soil around the peg like a molehill. This allows it to settle firmly into the rip line.
2. Add phosphate and/ or lime as recommended by the soil analysis in the topsoil and put some of the topsoil at the bottom of the holes 4-6 weeks before planting.
3. Planting holes should be dug ½m X ½m two months prior to planting out. The top soil must be put on one side of the hole and sub soil on the other side. The fertilizer, compost, manure, lime (if necessary) should be incorporated into the top soil and well mixed and fill the hole with the top soil using the peg to mark the centre. The sub soil can be spread on the outside. At planting a hole can be dug to fit the pot.

8.7.2. PLANTING GUIDELINES

The instructions explained here should be used as guidelines only as there are other methods of planting. Please consult the wider manual or other manuals for alternatives depending on location, topography, soil and varieties.

1. Plant coffee trees 2.5 cm above normal ground level.
2. Cool wet conditions are most suitable. In the absence of suitable weather, planting should take place only in the early morning and late afternoon.
3. The soil in the pots should be well soaked before planting and bent tap roots should be cut off above the bend.
4. Topsoil should be used to infill and subsoil used to scatter over the soil surface. Firm in the soil around the plant with hands.
5. Make a large (0.5 m radius) basin around the plant by pulling up soil.

6. Place a ring of mulch around the tree immediately after planting which should not be in contact with the stem of the plant. Ideally the entire row would also be mulched to reduce erosion and conserve moisture.
7. Apply an insecticide at monthly intervals to protect plant from dusty surface beetle and cut-worm damage.
8. A pre-emergent herbicide could be applied in bands down each side of the row.
9. Water plants as soon after planting as possible. Following this, be careful not to over-water young plants (a little and often is all that is required). If irrigation is available, irrigate as required.
10. The plastic pot should be placed on top of the peg which marked the planting station as this shows the pot has been removed.

9. PRUNING AND REJUVENATION

Pruning and rejuvenation are techniques that describe trimming or cutting back overgrown or dead branches and stems from the coffee plants to encourage new growth.

Tree management, through pruning and rejuvenation, is necessary to ensure that a tree's productivity does not decline until it becomes uneconomic. A pruning and rejuvenation regime forces the production of new bearing wood because it adjusts the amount and distribution of vegetative growth which affects light penetration through the canopy and hence floral initiation. It also achieves a degree of crop control.

9.1. TECHNIQUES

Pruning and rejuvenation techniques are one and the same thing that differ slightly in terms of degree and timing. Pruning is an annual operation and depending on circumstances, preferences and objectives of the farmer, the level of pruning may vary from little to a quite severe manipulation of tree shape and growth habit. Rejuvenation is only necessary when production starts declining towards uneconomic levels.

Pruning should be carried out when, as the coffee trees grow taller, the lower strata of the trees are less productive and, upon analysis, the bearing wood for the following season looks weak and short. This is important because rejuvenated coffee will be out of production for 1-2 years so it should only take place when the crop expectation in the coming season is poor anyway. In general this should be after trees have carried 4- 5 crops and after they have carried a heavy crop (i.e. after an "on" year when biennial bearing occurs). For best results it should be carried out between September and October which may mean that early ripening should be encouraged to ensure that the bulk of harvesting has been completed.

Factors such as condition of the tree, tree variety, labour availability and the incidence of disease, pests, and frosts are likely to have a marked effect on the system of pruning that is adopted.

9.1.1. EQUIPMENT

Each pruner requires a pair of secateurs and a pruning saw which are required for cutting back or removing stems. These should be kept sharpened and well oiled. They may need to be disinfected between trees to reduce the risk of spreading Fusarium Bark Disease.

Uprooting can be done by hand using a hoe although a contine or subsoiler may be required to loosen the soil first. All uprooted trees must be burnt to prevent it hosting other Coffee pests.

9.1.2. STEM CUTS

Cut back main stem to 2m once crop is off. Cut back primaries to leave two noes on each. All stem cuts should be at an oblique angle (i.e. non-right angle).

9.1.3. DE-SUCKERING[22]

Suckers should be removed regularly when there is new growth. This should take place before the wood hardens when they can easily be removed by hand. This process of thinning out young shoots and suckers is known as “handling”.

FIGURE 9: DE-SUCKERING AND HANDLING

Year 1 De-sucker to maintain a single stem system and avoid competition from suckers

Remove 'fly crop' fruit (early fruit which compete with strong plant/root development) as they appear.

Year 2 De-sucker to remove drooping primary branches that touch the ground. Cut back to nearest secondary branch

Remove secondary branches within 8 inches (20 cm) of the main stem

Remove all fruit as they appear (fly crop)

Year 3 Trees should be allowed to crop in the third year

Cap the main stem by cutting above a side primary shoot at about 5 ft (1.6 m) from soil level

De-sucker to remove drooping primary branches touching the ground. Cut back to nearest secondary branch

Remove secondary branches within 8 inches (20 cm) of the main stem

Maintain a maximum number of well-spaced secondary branches on each primary branch

Remove all dead, weak and spindly pest or disease damaged branches

[22] Adapted from E. Winston, J. Op de Laak, T. Marsh, H. Lempke Okkar Aung, T. Nyunt, K. Chapman (2005) *Arabica coffee manual for Myanmar*. Available at: http://www.fao.org/docrep/008/ae938e/ae938e07.htm

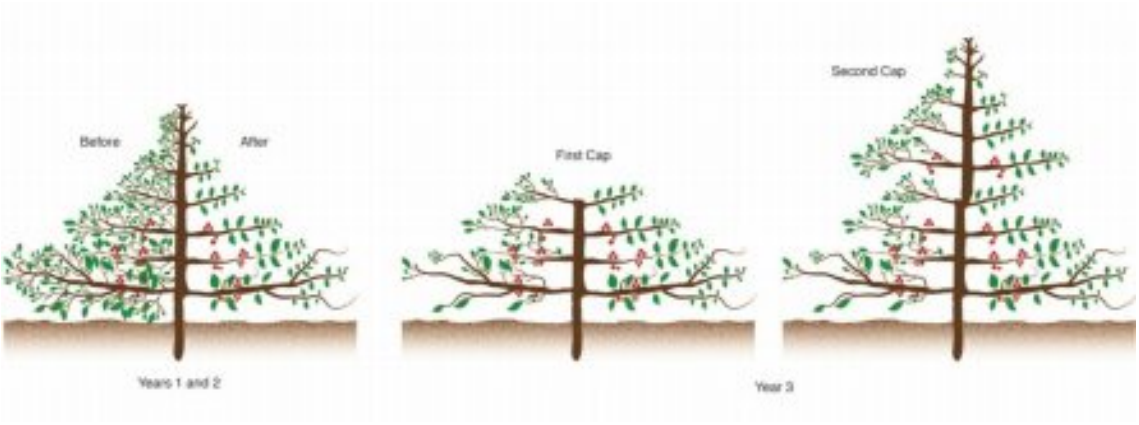


FIGURE 10: DESUCKERING

9.1.4. RATOONING

Ratooning is when a plant is cut down so that a shoot can grow from the stem and lower part of the plant. The decision to ratoon can be made on a field or individual tree basis. Note: Do not ratoon coffee if there are significant numbers of whit borer in the field.

Suggested method:

1. Cut stem down to below 30cm from ground level.
2. The stem must be sawn off at an angle to allow water to run off.
3. Paint the wound with copper and Jik mix (15ml copper and 20ml Jik in 500ml water). Cover the stem with coffee branches to avoid sun scorch and remove carefully when suckers appear in late November.
4. Well positioned suckers are those that will facilitate growth of the tree into the ultimate shape and will allow good room for growth. Suckers arising from the side of the prevailing wind are usually less likely to be broken off by wind
5. When suckers are approximately 2cm it is time to select 3 to 5 of the healthiest on the stems. At least 1 sucker should be left to grow from the rim or close to the rim of each cut to avoid die back. All those that grow 2cm below the top of the stump should be removed as these will have no support in the third year and the sucker will break off with the heavy crop.
6. In the next year, remove surplus shoots and repeat selection process again in January/February and select 2 suckers in the cova.
7. In the third, fourth and fifth years post ratooning, conduct skirting after harvest and before the rains, handle trees, and remove inward upward and downward growing branches.

FIGURE 11: RATOONED ROW

9.2. SYSTEMS AND PROCEDURES

In line with information above further detail on procedures depending on type and condition of tree is provided in the table below.

TABLE 8. SUGGESTED PROCEDURE BASED UPON TREE TYPE OR CONDITION

TREE CONDITION	PROCEDURE
When plants reach 3m tall or when planting tall varieties (e.g. SL28 and SL34)	• Capping may be used to limit plant height and to increase the number of stems. • Capping at hard wood stage should be done from September to October but nipping of the stem to control the apical dominance to maintain plant height is done normally when vegetative growth is high. It may reduce crop by preventing production of a new head of primaries.
Growing semi-dwarf varieties	• Cut back the trees to 0.4 m and choose 3-4 suckers to take over to the next cycle. • Leave these branches below the cut in the first instance.
Plant framework has degenerated to an umbrella shape	• No alternative but to ratoon trees by cutting them back to about 0.30 m. • Any existing branches below the cut should be left and the leaves within 0.2 m from the main stem should be cleared to allow better light penetration. • The suckers which subsequently develop should be progressively thinned out to leave the required number. • Coffee can be ratooned successfully to produce 3 to 4 good crops but the following requirements are necessary: the field must be healthy, the trees should be 6-8 years old and it must take place between August and October as soon as crop potential can be assessed.
If the lower side branches are healthy	• The trees should be truncated to 2 m and maintained at that height for two seasons and can then be ratooned to about 0.5 m in the following season. • During the period when the trees are held at 2 m, extra growth, vigour and production will be restored to that part of the tree. Then when the tree is too dense, the second cut back will ensure that only 4-5 well positioned suckers are left to thrive in the following cycle. • Branches below the cut should be left until the suckers are self-supporting.
Free growth system is used	• This is where one or two plants per station are allowed to grow until they are either, unproductive or unmanageable. These plants are then ratooned or replanted. • This system is popular because it has low labour requirements. Furthermore, under favourable conditions and good management, where dieback is prevented, a free growth or non-pruned system will out yield pruned coffee. • Under this system there is a tendency for yields to increase until the trees reach a height of three metres after which point the trees become increasingly vegetative and yield declines.
Where labour is skilled in handling and trees have a strong framework of primary branches	• Allow one or two outward growing secondary's to grow from each primary. • Each month remove surplus shoots, desucker and prevent any increase in height. • Handle trees in December and February • Ensure the new shoots are left to grow from 10-20 cm away from main stem to keep the canopy sufficiently open. • In the fourth or fifth year after planting, ratooning should be considered depending on the openness of the tree.

Pressure from disease and insect pests is high and the efficiency of spraying is low	• Skirting should be carried out. • It can be done once the trees have carried two crops. • It should be done after harvest and before the rains, then again in December and February
Primaries are touching the ground	• Skirting to be done.
Fusarium Bark Disease is present	• Remove plant and burn. The equipment used should be sanitized as risk of spreading the disease is very high.

10. MULCHING

In its natural environment coffee grows in a bed of forest litter. Its superficial root system is therefore adapted to function most efficiently under such conditions. On commercial farms we attempt to simulate these conditions by keeping the bare soil permanently covered with a layer of organic mulch material.

Mulch is most beneficial when done to trap soil moisture and to keep soil cool during the hot summer months. This could be done as the seasonal rains recede in February.

10.1. ADVANTAGES

Mulching is considered essential at least for the first two or three years in the land because:

- **It improves the yield:** It facilitates better regulation of moisture levels in the soil, thereby increasing soil moisture retention and improving surface water infiltration into the soil. The yield response to mulching coffee is greater for coffee grown on lands with steep slopes, shallower soils, coarse textured soils or soils with a crust or capping problem than from coffee grown on flatter, deeper, heavier textured soils. Such problems relate mainly to moisture conditions in the soil.
- **Costs of irrigation are minimised**: Because mulching reduces the watering requirements.
- **Protects the soil surface from erosion**.
- **More vigorous top growth and productivity:** Encouraged because building the topsoil fertility develops additional surface roots.
- **More economical and efficient of costly fertilisers**: These are conserved by mulching due to reduced surface run off and easier access to roots than on dry land.
- **Reduced risk of harm caused by variations in soil temperature**: Mulch reduces temperature variation in the soil and can protect young plants from frost damage if placed around the stem.
- **Controls weeds:** When used for prolonged periods. Therefore aids in supressing the cost of labour and herbicides in managing weeds.
- **Improved plant nutrition:** Builds up top soil fertility and improves uptake of nutrients through the general amelioration of soil structure and improved microbial activity. In particular, it improves the availability of plant nutrients and limits the excessive uptake of manganese which may build up rapidly to high levels in acid soils. It also increases the potassium level in the soil.

10.2. DISADVANTAGES

- **Increases the incidence of certain pests** e.g. leaf miner, termites and dusty surface beetle. Pesticides need to be applied.
- **Increases the fire hazard.** Some fire breaks, by not mulching certain rows, are advised.
- **Increases the risk of frost.** Although this is not a significant problem in Malawi, mulching could be delayed until September to avoid this problem. In some cases mulching can, however, be used to protect the stem from frost damage if managed carefully.
- **Costly process.** Especially with regard to the additional labour and land required. Although the economic return from the practice should outweigh this if the process is well managed.
- **Requires careful planning and management.**

10.3. MATERIALS

Many different materials have been found to be satisfactory for mulching some of which are discussed below.

TABLE 9. Suggested Mulching Materials

MATERIALS	SPECIFIC SPECIES EXAMPLES	ADDITIONAL NOTES
Indigenous grasses and cultivated pasture grasses	Guatamala Grass (*Tripsacum laxum*), Rhodes grass, veld grass, Napier grass, Sunn hemp, Vetiver grass.	Half a hectare of Guatemala grass will supply 1 ha of coffee. One or two hectares of Rhodes grass are required for one hectare of coffee and a minimum of three hectares of veld grass is needed for one hectare of coffee. One hectare of Napier at a year old should provide material to plant out 25 ha of coffee.
Composted coffee skins or hulls following ratooning	Any	When coffee is ratooned the branches and leaves could be used as mulch and only the mainstems would need to be removed from the land. Only appropriate if applied less than 5cm deep. ***Take care to examine this material before you apply it. If coffee has Fusarium Bark Disease do not apply the mulch to areas grown to coffee***. Suggested that this is applied to other crops.

10.4. PRODUCING MULCHING MATERIAL

Coffee farmers have two main options in order to produce mulch. Either of these methods could be pursued independently or a mixture of both techniques could be used.

Method 1:

Grow mulching plants in the same field by doing one of the following:

- **Guatemala grass** could be grown one or two years before planting. This rehabilitates the soil as well as producing an in-situ mulch at planting.
- Grow **sun hemp** or **rhodes grass** in between the coffee lines. This has to be managed as a separate crop. It will cut out some of the high weeding costs in the first two years.
- Grow **vetiver** for soil and water conservation and mulching in the interrows. The vetiver rows will be spaced depending on the slope. It is best not to grow vetiver in between the coffee as it has been shown to be detrimental to the coffee but can be grown separately.

Method 2:

Set aside a certain area of land for mulch production**.**

The mulch grass must therefore be managed as a separate crop and therefore consideration should be given to the requirements of the crop such as the need for regular weeding and fertiliser levels. Cut and bale the grass for mulching the basins of the first- and second-year-old coffee. Between one and four cuts are possible depending on the material chosen, rainfall and the level of management.

Method 3:

Source alternative mulching material from an external supplier such as rice husk or husk from Poultry Broiler unit.

10.5. APPLICATION

Coffee farmers have different options for the application of mulch.

10.5.1. MULCHING IN RINGS

A ring of mulch should be placed in a 0.5m circle just outside the dripline (not against the main stem) soon after planting out and each year for the next three to four years. This method ensures that weeds close to the dripline are controlled, herbicide spray drift is minimised, moisture infiltration into the rooting zone increases and the mulching material available is used economically.

On flatter lands place a 0.3m ring of mulch round the outside of the drip-line for the first two years making sure it is at least 10cm away from the stem. Mulch must be at least 15cm deep (settle to about 10 cm).

On steeper slopes place a 0.75m band of mulch along the lower side of the plant and along the drip-line for the first three years. Mulch must be at least 15cm deep (settle to about 10cm). This prevents erosion and encourages development of a terrace. A small trench at top side of the station, away from the drip line, is a good method to use to prevent run off.

TABLE 10. PROPORTION OF THE AREA MULCHED FOR DIFFERENT AGES OF COFFEE (ASSUMING A SPACING OF 3.0 X 2.4M)[23]

AGE OF COFFEE (YRS)	RADIUS OF DRIPLINE (M)	AREA OF 50CM RING OF MULCH PER COVA	PROPORTION OF THE TOTAL GROUND AREA MULCHED (1,389 PLANTING STATIONS/HA)
1	0.25	1.57	0.22 (22%)
2	0.50	2.36	0.33 (33%)
3	0.75	3.14	0.44 (44%)
4	1.00	3.93	0.55 (55%)

10.5.2. INTER-ROW MULCHING

If mulching materials are in short supply or where microjet irrigation is used, inter-row mulching could be used as an alternative 2 or 3 years after planting. Here the mulch is applied in strips in between the rows which are roughly 1.5-1.6m wide. These strips are still beyond the dripline and away from the plant stems. The mulch should settle to a depth of 10cm. Approximately 38 tonnes of dry material are required to mulch 1 ha of coffee and subsequent mulching should require less as it is mostly a case of topping up. The approach can be considered more economical because it requires considerably less mulching material and the results are almost as good. Timing of applying the mulch is important to save moisture.

10.5.3. SELF-MULCHING

After three or four years if the cova planting system and a high plant population are used, there is the potential for coffee to be self-mulching because the leaf litter from the coffee trees will provide adequate mulch.

[23] See p. 57 of Allison, A. G., *et al.* (1987), "Coffee Handbook 1987", Harare: Coffee Growers Association.

11. PLANT NUTRITION AND FERTILISING

For sustained productivity, coffee requires a high level of fertility and an intensive fertiliser programme is therefore essential.

11.1. ANALYSIS

Regular sampling of both leaf (annually) and soil (every three-four years) is usually done before the fertiliser is applied at the start of the new season. These analyses, together with expected yield levels are then used as a guide to determine the fertilisation of the next crop. It is suggested that this analysis is interpreted by a professional agronomist and a nutrition schedule worked out. This is critical for efficient use of Fertilizers and savings on related costs as opposed to a blanket application.

11.1.1. LEAF ANALYSIS

Timing

- Late December to early February is the best time to take leaf samples.
- They are generally taken once the trees start cropping and only before if the plant is showing signs of nutritional disorder.
- Best done at the expansion phase of the bean as this is when the tree requires most nutrients to perform satisfactorily.
- The level of the crop influences leaf levels of particularly nitrogen (N), calcium (Ca), magnesium (Mg) and potassium (K). For instance, a heavy crop reduces nitrogen and potassium levels and increases calcium values in the leaf. This must be taken into account particularly when coffee is bi-annually bearing and samples are taken late. This is not recommended after March.
- The uptake of nitrogen and potassium is particularly reduced under conditions of moisture stress. If coffee is planted in dry land do not take leaf samples when trees are under moisture stress.

Getting a Representative Sample

- Wherever possible only take leaves free of insect damage and disease.
- Leaf samples should not be taken from fields where foliar sprays have been recently applied as the samples will give an incorrect reading.
- If there is a good and a bad area take a separate sample from each area.
- Take leaf from each side of the tree.

Method

1. Take the third or fourth pair of new leaves on a bearing branch.
2. Take up to 100 pairs of leaves at random throughout a field (e.g. four pairs of leaves from a sample of 12 trees) that is between 5-10ha.
3. Use a paper bag for sampling as opposed to a plastic bag as plastic affects the results and label the bag. Samples should be kept out of direct sunlight.
4. Samples should be delivered to the laboratories as soon as possible after removal for leaf analysis. If they are not despatched within 24 hours to an approved reputable laboratory, they should be kept in a deep freeze until this is done.

11.1.2. SOIL ANALYSIS

Timing

- Soil samples should be taken in July. The first sample should be taken pre-planting. Soil samples should always be taken well before using the soil to grow coffee. This will ensure that the soil analysis will be available before planting. Consequently, the correct amounts of, in particular; lime and phosphate, can be properly incorporate into the soil before planting.
- It is also worth checking pH every year and having a full analysis every 3- 4 years.
- Samples must be taken after the rains have finished and the soil has fully dried out (unless the samples are required purely for pH determination and assessments of lime requirements).

Getting a Representative Sample

- To be representative, the sample must be a composite sample and must comprise many (10 or more) subsamples taken from different parts of the area.
- Significantly different soil types or those with very different management or cropping histories must be sampled separately.
- Minor variations must be ignored and abnormalities avoided. For example anthills, old hut sites, areas which are atypical of rest of site should be avoided.
- Sample must represent the full depth of topsoil.

Method of Soil Sampling

1. Soil should be taken from the rooting zone where both irrigation and fertilizer are applied (i.e. from around and under the drip line) because this is the feeding area.
2. Clear the surface of prunings, mulch and leaves which have not yet decomposed.
3. Using a spade, dig a “v shaped” hole at about 20 cm length. Cut a thin uniform slice over the whole plough depth (2 cm) and place in a clean container (e.g. bucket or sack) which has not been in contact with fertiliser, manure or chemicals.
   Alternatively samples may be taken using a soil auger which is a more accurate and quick method. But in newly ploughed lands when the tilth is fine and the soil is loose and dry it may be difficult to use an auger satisfactorily.
4. Remove any fibrous roots or stones from the sub-sample.
5. Repeat this process in at least 10 places. Choose the sample to take by moving in a diagonal or zig-zag line through the field.
6. When all sub samples have been put in the container, mix very thoroughly and allow to dry out to prevent moulds growing.
7. Mix again and take two ½ kg sub-samples and put into suitable clean containers or soil cartons. Clearly label.
8. Complete appropriate forms as fully as possible and despatch one of the two samples to a reputed accredited laboratory. Keep the second sample until you are satisfied with the result.

11.2. SOIL NUTRITION

The Law of the Minimum

Whilst the benefits of adequate availability of each individual nutrient are different, the overall rate of plant growth and coffee production is dependent on the least available nutrient; this acts as the constraining factor for production. This is known as the "Law of the Minimum" and it can be visually explained by the Barrel Analogy shown in Figure 15: Barrel Analogy. The barrel can only hold as much liquid as the shortest plank will allow. In the picture, the shortest plank is nitrogen showing that the low levels available of this nutrient constrain crop yield even though there are sufficient supplies of other elements such as sulphur or magnesium. Should nitrogen be added, potassium would be the next most limiting factor for production. [24]

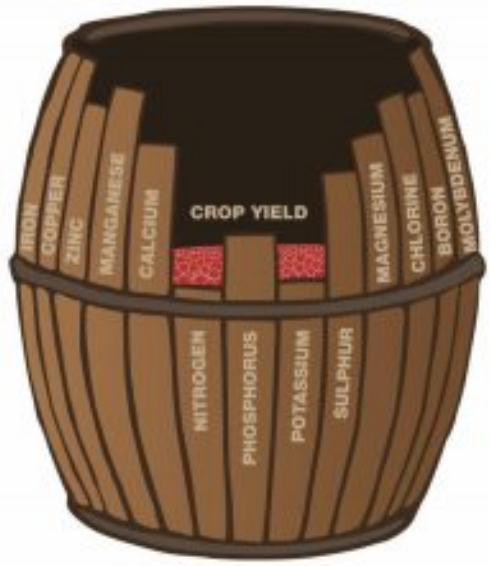


FIGURE 13: BARREL ANALOGY

11.3. FERTILISING

Fertilisation can be a means of providing and maintaining optimal quantities and combinations of ingredients with the soil to ensure that the plant is continually nourished. This section will give information on fertilisers available and applying the fertiliser.

11.3.1. APPLICATION

- Coffee roots are very susceptible to fertiliser burn during the field establishment period in the land. Therefore, do not apply against the mainstem but apply around the drip-line (the outside edge of the canopy) in the first two years as this is where the majority for the feeder roots are found. From the third year onwards apply under and around the drip-line, for example, by placing half the quantity under each side of the tree. It is important that fertiliser is broadcast evenly around the drip line and not banded.
- Lime and Phosphate should be worked lightly into the soil at the drip-line as they are less mobile than other substances.
- In high rainfall areas the same rate will apply except that it should be split into at least 8 applications.
- When applying the fertilizer to older trees it is easier to have one operator applying to one half circle of the tree and a second operator to the other half as this is less time consuming and more cost effective.

For more guidelines on fertiliser application see pages 62-66 in Allison, A. G., *et al.* (1987), "Coffee Handbook 1987", Harare: Coffee Growers Association.

[24] E. Winston, J. Op de Laak, T. Marsh, H. Lempke and K. Chapman (2005) *Arabica coffee manual for Lao-PDR* Chapter 4: Plant and Nutrition. http://www.fao.org/docrep/008/ae939e/ae939e06.htm

11.3.2. QUANTITY

- Decrease recommendations for coffee grown under shade or at high altitudes.
- Increase recommendations on very high yielding coffee in hot areas.
- Foliar-applied sprays are best done at low concentrations as recommended on the labels and must never be mixed with a copper spray round. It is important to note that Foliar sprays applied as a drench can be very dangerous and only the young leaves should be targeted. Crop loss at pin head stage can be high if too much water is used.
- The normal range of K, Ca, Mg values result in a 1 part K to 6 parts Ca to 2 parts Mg ratio which is more important than the amount per se.
- As a broad recommendation, apply 100 Kgs N for each Tonne of Green Bean harvested per Hectare plus 50 N for growth, using Compound J (N:P:K 15:05:20).

11.4. NUTRIENTS

For sustained productivity, coffee requires a high level of fertility and an intensive fertiliser programme is therefore essential. The following section provides some information on nutrients and diagnosing and treating deficiencies.

11.4.1. NITROGEN (N)

Importance

Provided that the soil is in good heart, good management is practised and favourable moisture conditions exist, the amount of available nitrogen has the greatest effect on attainable yield. Nitrogen from older leaves is efficiently and irreversibly transferred to developing fruit and younger growth. Higher rates of available nitrogen prevent leaf drop thereby maintaining the photosynthetic area at a maximum.

Optimum Range

2.5-3.0% or 40-60ppm

Diagnosing Deficiencies

If the translocation of N from older leaves to developing fruit goes too far, the older leaves are prematurely shed. This is particularly noticeable on heavily bearing laterals where the nodes with fruit more often than not lose their leaves. Leaves turn pale green/ yellow.

Healthy plant (left); deficient plant (right)

Available Forms

- Urea (46% N) It is the most readily available source. Application of 2.17kgs of urea will produce 1kg of N.
- Calcium Ammonium Nitrate (28% N) for acidic soils. An application of 3.57kg will produce 1kg of N.
- Sulphate of Ammonia (21% N and 24% S) for alkaline or S deficient soils. An application of 4.76kgs will produce 1kg of N, and 4.17kgs will produce 1kg of S.
- Di Ammonium Phosphate (P2O5 46%, 18% N). An application of 5.56kgs will result in 1kg of N.
- Potassium Nitrate (KNO3 or 13% N and 45%K)

Application

Field experience suggests that 6-8 split applications should be made during the season between August and April. This is particularly true of irrigated coffee on well drained soils. Heavy applications late in the season may induce the excessive production of side shoots from the nodes rather than flower buds.

Urea Spray grade Urea should be applied at a ½ -1% solution as a full cover. Applying Urea which is not spray grade can contain toxic levels of Biuret. Causes yellowing of leaves.

Potassium Nitrate A palliative spray at concentration of ½-1% may be useful under certain circumstances.

11.4.2. PHOSPHORUS (P)/ PHOSPHATE (P2O5)

Importance

This element has a stimulating effect on root growth and assists in hastening crop maturity.

Optimum Range

0.1- 0.2% or 50-70ppm or 60 - 80 mg/kg

Diagnosing Deficiencies

Symptoms begin as a slight mottled chlorosis of the older leaves. Later, older leaves became more chlorotic, with faint interveinal yellowing. At advanced stages, necrotic spots develop on the leaves and root growth becomes inhibited. Where the availability of phosphorus is low, sulphur is also usually low.

Early (left); advanced (right)

Available Forms

- Single Super Phosphate (SP, includes 19% P2O5, 12% S) Needs 5.26kgs for 1kg of P2O5. Also used to provide sulphur.
- Compound S (see 11.5). Also used to provide sulphur.
- Triple Super Phosphate (45% P2O5, 2.5% S) Requires application of 2.22kgs for 1kg of P2O5. Also used to provide sulphur.
- Di Ammonium Phosphate (46% P2O5, 18% N) Requires an application of 2.17kgs for 1kg of P2O5.

Application

Pre-planting: Where the soil is known to be acutely deficient, a broadcast application of 300-400 kg/ha SSP should be ploughed in deeply.

Or 75kg should be applied (144g/cova at 2,778cova/ha) by placing half (75g) to bottom of the hole and other half to the topsoil from within and around the hole. Mix in well and backfill the hole with topsoil.

If the soil analysis shows the P2O5 exceeds 30ppm then the inclusion of fertiliser in planting holes is deemed unnecessary and the amounts should be made up with extra top dressings.

Post-planting: Usually applied in one annual application in June-August. If SSP is used it is normally applied at in September or October.

11.4.3. POTASSIUM (K)

Importance

Potassium has been found to improve: yield, growth, fruit quality, disease resistance and drought and frost tolerance. Factors affecting potassium uptake by roots include:

- Soil moisture: Must be above 50% of available water capacity.
- Root growth, length and diameter.
- Weed competition
- Potassium buffer capacity of soil: The less weathered, the more it will fix potassium.

High levels of Mg and Ca in the soil can prevent the uptake of potassium (e.g. Mg:K ratio greater than 10:1 will induce K deficiency).

Diagnosing Deficiencies

The appearance of deficiency symptoms often coincides with the setting of a heavy crop. In the early stages it shows an interveinal chlorosis similar to that seen in iron deficiency. Then small necrotic areas appear on the leaf margins and these areas rapidly extend towards the centre of the leaf and towards each other, eventually coalescing. Before the leaves become completely necrotic, defoliation occurs.

Early (left); advanced (right)

Available Forms

- Muriate of Potash (Potassium Chloride). required in 1.67kgs/ ha for 1kg of K.
- Sulphate of Potash (Potassium Sulphate). 2.0 kgs of Sulphate of Potash (SOP) is required for 1kg of K.

Application

Large amounts of fertiliser are required to correct deficiencies.

Potassium should be applied in 6-8 applications between September and April. With early flowering varieties such as Agaro or in hotter areas, the first application should take place slightly earlier in August.

Local experience suggests that heavily bearing trees can benefit from monthly foliar sprays from January to end of harvesting.

11.4.4. SULPHUR (S) OR SULPHATE OF AMMONIA

Importance / intro

Sulphur is an important nutrient for plant growth, disease resistance, seed production and protein synthesis.

Optimum Range

0.1- 0.2% or >20mg/kg in soil

Diagnosing Deficiencies

Leaves turn pale green/ yellow in a similar fashion to nitrogen deficiency. General or feint interveinal chlorosis of all leaves and they fall prematurely. Plant stems become woodier and break easily and plant growth is stunted.

Advanced Symptoms

Available Forms

- Magnesium Sulphate
- Sulphate of Ammonia (21% N and 24% S). An application of 4.76kgs will produce 1kg of N, and 4.17kgs will produce 1kg of S.
- Single Super Phosphate (or SSP, includes 12% S). An application of 8.0kg is needed for 1kg of S.
- Triple super phosphate (2.5% S). 40kgs is required for 1kg of S.
- Sulphate of Potash (Potassium Sulphate, 18% S). A 5.56kg application is needed for 1kg of S.

Application

Apply 15-25 kg S/ha/annum as an insurance particularly if S not added at planting.

Magnesium Sulphate is applied as a foliar spray. mix ½-1kg with 100 litres water and apply as a full cover spray in a volume of 500-1,000 litres water per hectare.

Single Super Phosphate is normally applied in September or October.

11.4.5. BORON (BO)

Importance

Since boron is essential for cell division and since it has a very limited mobility within the tree, a deficiency principally affects the development or growth of new shoots and roots. Older trees which have been deficient for a long time may take years to recover.

Optimum Range

30-50 ppm or 40- 100mg/kg, 0.5-1.0mg/kg (sandy loams), 1.0 - 2.0 mg/kg (clay loams)

Diagnosing Deficiencies

The symptoms of deficiency occur more often on leached light textured soils. The newly formed leaves remain small and the leaf margin tends to be irregular and asymmetrical. Undersides of midribs can be distorted and exhibit “corkiness”. Deformed leaves and normal leaves can be found on the same lateral, indicating that the tree does not suffer uniformly from the deficiency. Care should be taken not to confuse symptoms with those from antestia bug damage or wind chafing.

Available Forms

- A mild boron deficiency can be corrected with 0.5% solution of 'Solubor'
- Borate
- Boron added to Compound S or Compound J

Application

Solubor Apply a foliar spray (i.e. 1 kg/200 litres of water or 20.5% Bo) at the beginning of the main growing period at the start of the rains. A second spray should be given in acute deficiency cases 3 months later.

Borate A soil application of fertiliser borate at 15g per tree every 2 years. Severe deficiencies may require higher and more frequent remedial applications.

Boron added to Compound S or Compound J Soil applied Boron at 0.05 – 0.1% is added to Compound S and Compound J.

Over-application: A toxicity of Boron makes old leaves hang downwards and leaf edges become blackened. New growth becomes hard and leathery.

11.4.6. ZINC (ZN)

Importance

Important for boosting plant height and the production of hormones and enzymes.

Optimum Range

9-30 ppm or 15 - 30mg/kg or 2- 10mg/kg in soil

Diagnosing Deficiencies

The first symptoms of a deficiency appear on the new growth as an interveinal chlorosis, with main veins remaining dark green. Leaves become stunted and may fold inwards and become narrower to form “boat shapes”. Pronounced deficiency results in 'rosetting' of the laterals. Individual branches may show the deficiency whilst others do not.

Available Forms

- Zinc Oxide (ZnO) Both effective and cheap.
- n.b. Zinc should only be applied when a real deficiency clearly exists because trials have shown that applied zinc does not always increase yields and in some circumstances can even depress yields.

Application

Zinc Oxide Applied as a foliar spray. Mix a concentration of 250g zinc oxide (78.6% Zn) per 100 litres water.

It is applied particularly in the first 3 years when roots are not fully developed and signs of zinc deficiency are common. Early treatment following diagnosis results in normal growth within 2-4 weeks.

Apply twice at a rate of 3kg/ha. The first application in November and the second in February.

Soil applications are not recommended because zinc is strongly absorbed in the first 5-1Omm of soil and less than 0.2% ever reaches the root zone.

11.4.7. MAGNESIUM (MG)

Importance

Magnesium helps chlorophyll development and seed germination

Optimum Range

0.2- 0.4% or > 1.6 mq/100 g, Ca:Mg ratio of 2:1 is normal but ratio can vary significantly.

Diagnosing Deficiencies

This nutrient is highly mobile within the tree and therefore the first symptoms appear in the older leaves. Symptoms are more evident during the fruiting period. The symptoms begin as chlorotic areas near the midrib, leaving a strip 5 mm wide of normal green tissue along the midrib. The midrib itself then becomes yellow. The interveinal chlorosis moves to the leaf margins and until the entire leaf (besides the midrib) becomes chlorotic.

Available Forms

- Magnesium sulphate applied as a foliar spray.
- Lime (CACO3) Where lime is required this can be achieved by the use of liming material containing a significant amount of magnesium.
- Dolomitic Limestone Where lime is not required apply dolomitic limestone.

Application

Magnesium sulphate Mix ½-1kg with 100 litres water and apply as a full cover spray in a volume of 500-1,000 litres water per hectare.

Dolomitic Limestone An application of 200 to 300kg/ha of dolomitic limestone should prove satisfactory.

11.4.8. ACIDIC (MANGANESE (MN) OR ALUMINIUM (AL)) AND ALKALINE (CALCIUM (CA))

Importance

Coffee can tolerate a wide range of soil acidity and yields are only affected where Mn (or Al) is available in toxic amounts. However if the soil pH is incorrect, the balance of nutrient uptake becomes inefficient and the effectiveness of costly fertilisers is reduced. Mn is an important element for photosynthesis and enzyme production. Ca is important for cell walls, root and leaf development, fruit ripening and fruit quality.

Optimum Range

pH: 4.9-5.6 in CaCl2/ 5.5-6.5 in H20.

Ca: 0.7- 1.5%/ 1.5 – 5.0 m.e. %, 3-5mg/100 g

Mn: 50- 150 ppm, 50-100mg/kg, < 50 mg/kg in soil

Diagnosing Deficiencies

Soil acidity due to a Ca deficiency appears as leaves becoming bronzed along edges and cupped down-ward. New leaves are often dead and eventual dieback of shoot tips ensues.

Alkaline soils (from a Mn deficiency) cause yellowing between veins with even small veins remaining green. There may also be necrotic cropping along the main vein.

Available Forms

- Lime (CACO3) Lime must be finely ground and have a neutralising value of over 90%. The type of lime used depends on what is affordable and the magnesium status of the soil.
- Dolomitic Lime contains magnesium. If soil magnesium level is below 0.2 mill equivalents apply half the lime as dolomitic.

Application

For application mix in with the soil in the planting hole. If the pH is very low broadcast and incorporate half over the whole area and then add remainder to the planting holes. Mix in well with the soil. One application required annually in June – August.

Lime (CACO3) If the pH is above 5.0 in calcium chloride no lime is added pre-planting. If pH 4.5 - 5.0 Add ½ - 1 tonne lime. If pH 4.0 - 4.5 Add 1- 2 tonne lime per hectare per annum.

Over-application/ Excessive acidity: On soils with a reddish colour (red dolomite and brown granite soils e.g. in Zomba and Lirangwe), manganese becomes toxic at a calcium chloride pH of about 4.6. Toxicity from Manganese results in yellowing older leaves especially on heavily bearing branches.

11.4.9. IRON (FE)

Importance

Iron encourages photosynthesis. A lack of iron is frequently noted in alkaline soils.

Optimum Range

50- 150 ppm/70-200 mg/kg/2- 20mg/kg in soil

Diagnosing Deficiencies

Iron deficiency causes yellowing between veins (interveinal chlorosis) and the production of amber beans.

Available Forms and Application

- Iron chelate can be applied in a foliar spray or directly onto the soil. The latter treatment is more expensive.
- The alkalinity of the soil can be reduced by applying sulphate fertilisers such as ammonium sulphate.

11.4.10. COPPER (CU)

Importance

Important for chlorophyll development and protein formation. Deficiencies are less common today due to the use of cupric fungicides to address leaf rust and Cercospora.

Optimum Range

5-40 ppm/16- 20mg/kg/0.3-10mg/kg in soil

Diagnosing Deficiencies

Young leaves die back and chlorosis sets in. Leaves often curl and shoots can be weak, restricted and rosetted.

Available Forms and Application

- Copper distributed at planting if adequate amounts not provided through fungicides.
- Copper sulphate applied in the nurseries.
- Over-application: Toxicity is often noted due to the excessive application of cupric fungicides for disease control. Toxic effects include darkening and termination of root growth, plant wilting, leaf drop and growth abnormalities.

11.5. FERTILISER COMPOUNDS

There are a number of compounds which are used to ensure good nutrition in the soils and include a number of the main elements (see section 11.4 above). Examples of options for use in Malawi are as follows:

- **Compound S (6:18:6):**

TABLE 11. THE REQUIRED KILOGRAMS OF COMPOUND S TO ACHIEVE 1KG OF N, P_2O_5, K_2O AND S[25]

FERTILISER	N	P_2O_5	K_20	S
Compound S	16.67	5.56	16.67	11.1

- **Compound J:** A mixture of straights: 15% N, 5% P_20_5, 20% K_20 and 9.6% S (sulphate of ammonia). The application should be split into 6-8 applications between August and April assuming that the coffee is irrigated.

TABLE 12: THE RECOMMENDED APPLICATION RATE BASED ON THE AGE AND CROP26

YEAR	KG/HA/ANNUM			
	N	P_2O_5	K_2O	S
1 year after planting	50	50	50-75	
2 years after planting	100	50	75-100	
3 years after planting, 2 years after ratooning	150-200	50	100-200	
More than 4 years after planting, 3 years after ratooning, 2 years after parrot perching	200-300	60	150-250	
1st year after ratooning or parrot perching	150	60	100-150	
Amount Required to produce 1 kg of N, P2O5, K2O and S	6.67	20.0	5.0	10.0

[25] P. 83 Tea Research Foundation, (1989). "Coffee Manual for Malawi 1989". Mulanje: TRF.
[26] P. 82 Tea Research Foundation, (1989). "Coffee Manual for Malawi 1989". Mulanje: TRF.

TABLE 13. SUMMARY RECOMMENDATIONS FOR FERTILISER APPLICATION[27]

PLANTATION AGE	NUTRIENTS KG/HA			SUGGESTED FERTILISER	TIME OF APPLICATION AMOUNTS KG/HA							
	N	PPS	KP		S	O	N	D	J	F	M	A
Year of Planting	100	80	100	Comp 'S' Comp 'J'	400	57	57	57	57	57	57	57
Second Year	110	30	120	Comp 'J'	75	75	75	75	75	75	75	
Third Year and Following	180	40	230	Comp 'J' AN M/P	200		150	 60 60	150	150 60	 60 60	150
Fourth and Subsequent Years	270	90	360	Comp 'J'	225	225	225	225	225	225	225	225

11.6. SMALLHOLDER FARMING

11.6.1. ORGANICS FERTILISERS

Organic fertilisers reduce dependence on artificial chemical products as they improve the soil, physical structure (soft and loose soil), chemical (increase nutrients) and biological (high population of beneficial microorganisms) composition. They improve the yields and quality of produce and its source of food for microorganisms. It reduces the cost of production and has long term effects on the soil of productivity. There are a number of technologies involving production and application of Organic fertilisers. The following organic fertilisers are produced and used by Smallholder Farmers.

11.6.2. BOKASHI

TABLE 14. A QUICK METHOD OF MAKING COMPOST MANURE

STEP	DESCRIPTION	REMARKS
1	**Materials to be collected** Collect the following materials for one heap	
	Materials absolutely necessary Animal manure: 3 pails Plant residues: 4 pails Virgin Soil: 3 pails Water: Necessary to activate microorganisms activities which decompose organic materials to make compost	Animal manure, plant residues, virgin soil and water are necessary for this process. If these others are not available composting can still be done.

[27] P. 61. Allison, A. G., *et al*. (1987), "Coffee Handbook 1987", Harare: Coffee Growers Association.

	Materials preferably added • Yeast rich materials: One or some of the following 1 Local beer residues(millet/or maize): Half a pail. 2 One portion of Bokashi previously made: 1 pail 3 Dry yeast for baking bread: Half teaspoon mixed with 500mls of water if possible add a spoon of sugar. 4 Banana peel, rotten fruits or other fruit residues: 1 pail soaked in water	Yeast rich materials give compost a quick effect.
	Materials added if available • Ash: half pail • Charcoal: Half pail; Charcoal should be broken down into small pieces to be mixed with other materials. It is a kind of microbes house	This is mainly for pH control in Bokashi. It also provides K and other minerals. However don't burn plant residues as N and C is lost which is very important in composting.
	This is the recommended proportion of materials, however this can be changed depending on availability of materials. The proportion of soil should not be more than 30% of the mixture even though soil is always available.	
2	**Collect Animal Manure** Animal manures are one of the sources that increase soil fertility as they are rich in nitrogen. Chicken or other bird droppings are the best source of stable nitrogen. Additionally they contain a lot of phosphate. Cattle manure are rich in nitrogen when they are fresh. When dry, nitrogen evaporates.	
3	**Collect Virgin soil** Soil is added because microorganisms from it decompose organic materials. Additionally, soil absorbs nitrogen in the materials and fixes it, which means it reduces the nitrogen loss in the process of making Bokashi.	
4	**Collect Yeast Rich materials** During the decomposition process, yeast takes nitrogen from the materials and uses it for their body growth. The nitrogen in the yeast body is mainly in amino acid form which is water soluble and as a result plants absorb and utilize easily. This means the effect of the compost appears relatively rapidly. On the other hand, this means that nitrogen in Bokashi is easier to leach out or to evaporate than in conventional compost. Yeast also contains rich vitamins which accelerate plant growth.	
5	**Collect and Prepare Plant Residues** The plant residues are maize and maize bran, sugarcane residues, tephrosia leaves, banana trunks etc. The plant residues contain C,N,K and other elements. These are good nutrients for plants, and energy source for microorganisms. They are decomposed into manure form which contributes holding appropriate moisture and improve soil physical characteristics. They also improve aeration of the heap, preventing compaction by its weight.	
6	**Mixing the materials** Mix thoroughly small portions of each material together.	
7	**Pour water using a Watering can** Pour water in order to have appropriate moisture content. Ensure that it's not too wet or too dry. To test moisture content, take a portion of the mixed materials in your hand and hold it firmly. When you release the palm, it has to be in a ball shape. But when shaken it breaks easily.	

8	**Heaping the mixed material** After adding the appropriate moisture, heap the materials. Do not compact the materials as this reduces free air circulation which is essential for the composting process. With appropriate moisture conditions, aerobic micro-organisms decompose compost heap more rapidly than anaerobic one.
9	**Cover the finished heap** Cover the finished heap with banana leaves to maintain the desired moisture content and also to prevent ultra violet light from killing the microbes.
10	**Keep appropriate temperatures** After 1-2 days, the temperature may increase to more than 60 degrees Celsius. Regrettably, this temperature kills the effective micro-organisms, therefore check the temperature of the heap to avoid temperatures reaching this level. To check the temperature, insert a knife into the heap. If hot to touch breakdown the heap in order to decrease the temperature. When the temperature reaches 30-45 degrees, put the heap back and cover it again. This should be repeated should the temperature go up again. Moisture should also be checked and if it is getting dry add water. Temperature and moisture checks should be done once or twice a day during the first week.
11	**Ready for use** After 2-3 weeks (depending on the situation) Bokashi is ready for use. Spread all the materials under shade in order to stop the decomposition. These materials are ready when they are dark in colour. If the decomposition process continues after this stage, nitrogen in the Bokashi changes into other forms that can a) easily evaporate, or b) that can be fixed into water insoluble form which makes extraction by plants difficult.
12	**Keeping Bokashi** Keep in a dry, shaded area. Avoid exposure to sunlight as it kills the microorganisms. Bokashi should be kept dry - if it becomes wet, decomposition starts again.
13	**Application of Bokashi** Bokashi is applied both as basal and topdressing. Remove the mulch around the dripline of the tree and apply Bokashi. Cover with mulch or soil so that sunshine does not kill the microorganism.
14	**Calculating Amount of Bokashi to Produce per Ha** One year old coffee: Volume of Bokashi=Amount of N/Ha /2.05% Volume of Bokashi=50kg/2.05% Volume of Bokashi=2,439kg No of Heaps=2,439kg/20kg No of Heaps=122
	Nutrient Content of Bokashi (Cattle Dung) Compost is 2.05% Nitrogen, 0.04% Phosphorus and 0.34% Potassium.[28]

[28] Chitedze Research Station Online: http://ring.ciard.net/chitedze-agricultural-research-station-department-agricultural-research

TABLE 15: PRODUCTION OF BOKASHI PER HA BASED ON TREE AGE (4,000TREES/HA)

TREE AGE	BOKASHI/HA	OTHER NUTRIENTS		RATE/TREE	NO OF APPLICATION	
		P/HA	K/HA		1ST	2ND
1 year	2,439kg	0.97Kg	10.48kg	0.6kg	0.3kg	0.3kg
2 year	4,878kg	1.95kg	20.98kg	1.2kg	0.6kg	0.6kg
3 year	7,317kg	2.93kg	31.46kg	1.8kg	0.9kg	0.9kg
4 year	9,756kg	3.90kg	41.95kg	2.4kg	1.2kg	1.2kg

11.6.3. CHINESE COMPOSTING

TABLE 16. A QUICK METHOD OF MAKING COMPOST

STEP	DESCRIPTION	
1	**Materials to be collected** Collect the following materials: • Plant residues such as maize stover, grass, legume materials , banana stems etc • Animal manure i.e. cow dung, chicken droppings. Chicken or bird manure have high nitrogen content than cattle dung. Virgin soil. Implements • Shovel, knife and watering can Chinese compost takes about a month to decompose, as opposed to conventional pit compost which takes about 3 months.	
2	**Preparing necessary materials** Collect all materials. Cut the plant residues into small pieces. The cutting process is ideal at this stage as the cutting increases the surface area at which the microorganisms work.	Virgin soils are recommended because they contain a lot of microorganisms which are important for the decomposition process
3	**Aligning the base for Manure** Clear the area for heaping the compost preferably under a tree or in a shaded area to reduce evaporation and rapid loss of nutrients.	The size of the area should be 75cm radius and the height of heap should be approximately 1.5m. If more than one heap is to be made, 2.5m should be observed from one heap to the next.
4	**Making manure heap** • Take 3 shovels of animal droppings and spread them in circular form. • Take the plant residues and spread them over the manure to a height of 15-20cm. • Take 3 shovels of manure and spread over the watered layer of compost. After this spread 2 shovels of virgin soil on top and sprinkle some water on it. This should be directly followed by another layer of 15-20cm of plant residues. • Continue doing this process by putting layer by layer of the materials mentioned above until a height of 1.5m is attained.	Water the residues thoroughly. 3 full watering cans are enough. Make sure the heap is made conical so as to avoid it from tipping over due to its weight. Make sure these heaps are made on the farm to reduce transportation labour.
5	**Turning the compost heap** • Turning of the compost heap should be done after 5 days from the day of making it. The outer dry layer should be put at the bottom of the next heap to be made.	The process in heaping during the turning is same as in the first heaping. It is the amount of water applied that is less.

	• Continue taking layer by layer of the old heap and putting it into another heap as described above. • The turned heap should also be conical in shape. Make sure there is adequate moisture since decomposition cannot take place without moisture. • Turning is done every 5 days for 6 weeks. The materials will be fully decomposed after 35 days giving an allowance of 1 week for those which were not fully decomposed. The finished composted material will be dark in colour.	However the first layer in turning should receive 3 watering cans of water since the materials were exposed to rapid evaporation. Animal manure should only be added in the first turning especially if it is noticed that a particular layer didn't have enough of it. If you add to that layer, more water should also be added to that particular layer to hasten decomposition.
6	**Checking the temperature** There should be some heat felt during the turning. The temperature tends to increase rapidly when the outside temperatures are high. This shows that microbial activity decomposing the residues is going on. So it is important to check the heat especially from the 3rd turning. There will be steaming smoke seen during the morning hours. This is also another sign of decomposition.	To check the temperature in the heap, take a panga knife or a good sized stick and insert it in the heap. Wait for a few minutes. Then take it out and feel it on your arm, and if it is hot, know that decomposition is taking place.
7	**Application to coffee** Follow the steps in Bokashi (Table 14. A quick method of making compost manure	

11.6.4. LIQUID ORGANIC FERTILISER

Chicken and bird droppings are one of the best materials from which to make manure as they contain high amounts of nitrogen, phosphorus and potassium. The nitrogen in the droppings does not easily evaporate as compared to cattle and other livestock dung, which is very advantageous.

TABLE 17. QUANTITIES OF FERTILISER

	N(%)	P (%)	K (%)
Chicken dropping (dry)	3.0	3.1	1.3
Cow dung (fresh)	0.3	0.4	0.1
Cow urine (Fresh)	0.8	0.1	1.5

Source: *"Manure Manufacturing Study (1981)", "Introduction of Manure Study, Second Edition (1960)"*

Differences in quantities of N, P, and K, (refer to the table above) are due to:

1. In the metabolism process, every animal produces toxic by-products, and ammonia which should be discharged. Mammals discharge ammonia in the Urine form, which easily evaporates. Birds discharge ureic acid with droppings, which is solid and difficult to evaporate.

2. Eating habit of each animal has influence on chemical component of their manure. Generally manure of carnivorous animals contain more N and P than herbivorous animals.

TABLE 18. CHARACTERISTICS OF FERTILISER[29]

Specification	Liquid fertiliser	Conventional Compost	Chemical Fertiliser
Time to make	1 week	2-3 months	-
Time to see the effect	Rapid	Late	Rapid
Duration of effect	Very short	Long	Short
Amount of fertility		>	Very high
Improvement of physical characteristics	Not effective	Effective	Not effective

This table shows the characteristics of liquid fertiliser, conventional compost and chemical fertilizer. The liquid fertiliser does not have an effect on improving the soil physical character and the nutrient effect is short-lived. Therefore it is important for farmers to complement liquid manures with other compost or forms of nutrition. As a result, liquid fertilisers should ideally be used in combination with other composts as top dressing.

[29] Adapted from *The Study on Capacity Building and Development for Smallholder Irrigation Scheme in the Republic of Malawi, Technical Manual*

TABLE 19. MAKING LIQUID FERTILISER

Step	Description	Remarks
1	**Materials to be collected** Collect the following materials to make liquid fertiliser: • Chicken or any other bird droppings • Container • Water	The container should preferably be able to contain more contents.
2	**Mixing the droppings in water** • Put droppings up to one third to half of the container • Fill the container with water. • Leave the container for one week for the droppings to dissolve into the water. • 200litres of liquid manure is enough for one application per hectare.	Nitrogen and Potassium in the droppings dissolves in water. Plants take the nitrogen in this form very easily. Thus the effect of Liquid fertiliser appears quickly.
3	**Applying Liquid Fertiliser** • Filter the dissolved dropping out with a piece of cloth. • Dilute the liquid fertilizer 5-10 times the volume of water • Apply the diluted fertilizer using a 250ml cup. • One cup is enough for one tree around the dripline. • This should be repeated 4-6 times in a growing season.	The residues in the container should be applied in the field or be used for compost making since it is rich in phosphate and could still contain nutrients that have not come out. Timing of application is same as for the chemical fertilisers.

11.6.5. TWIN N

Twin N are freeze dried microbes that supply crops with a natural form of nitrogen via the activity of the endophytic and soil nitrogen fixing. These microbes interact with the plants metabolism to fix atmospheric nitrogen in a plant available form. Twin N supplies nitrogen only. Therefore it is used as a top dressing to compost manure.

The Twin N package contains:

- A vial containing freeze dried Twin N microbes.
- A rehydration container with microbe food.

It is packed in a 1ha, 5ha and 10ha packs.

TABLE 20. MAKING TWIN N

STEP	DESCRIPTION	
1	**Rehydrating the microbes** • Fill the plastic rehydration container with 50ml or 100mls of **Non-chlorinated** water and shake to mix in the microbe food. • Remove the sealed lid of the vial of microbes. • Pour in some water from the re-hydration container and place a thumb over the top. • Shake to dissolve the microbes and pour them back into the rehydration container. • Repeat this until all the microbes in the rehydration container are dissolved • For a 10ha pack repeat this with the second vial. • Screw the lid on firmly and shake thoroughly for 30 seconds to 1 minute. Wait for 5 minutes then shake thoroughly again. The microbes are ready to mix into application tank to apply to the crop. • The Twin N solution can be kept in the fridge for 1 week. The solution should not be frozen.	
2	**Application to the crop** • Application methods need to deliver the Twin N solution into the moist root zone. Contact with foliage is not a problem but the bulk of the application should contact the root zone to maximize efficacy. • Apply using the sprayer and that this sprayer be dedicated for this purpose only. • Shake the tank regularly to re-suspend the microbes. • Apply the tank mixed microbes within 24hrs.	Do not mix with fertilizers or agrochemicals in the tank Do not use a sprayer which is used for applying chemicals. The chemicals will kill the microbes and this treatment will be rendered useless.
3	**Time of application** • Apply Twin N at the start of active growth when the soil is moist and at the end of the rainfall season when the roots are still active. • The application should be done in the early hours of the morning to avoid the heavy sunshine of the midday.	

12. IRRIGATION

The main purpose of irrigation is to supplement rainfall and thereby extend the growing season for increased yields. The irrigation scheme has to justify the capital cost as well as be practical in terms of the local conditions of the farm. There are a number of considerations that should be taken into account before deciding to use an irrigation system, including timing and physical considerations discussed in more detail below.

- Can the system apply sufficient water at the time of the year when the rate of use is at its peak for a mature crop? An irrigation system is seldom used at full capacity for more than a few months at a time but it must be capable of applying water at a rate sufficient to prevent severe water stress at times when demand is high.
- How much irrigation water will be required over the whole year? This is a less important factor when water is pumped from boreholes.
- How should the irrigation system be managed to achieve maximum benefit?

12.1. TIMING

- The dry periods after the seasonal rains have receded until the next rainfall are the key months for irrigation. In the winter months evaporation is lower so less frequent irrigation is required. However, in hotter and lower areas irrigation tends to be required throughout the year.
- A “drying off” period may be needed to stimulate flowering of the crop.
- Starting irrigation after good rainfall will ensure the whole estate is at field capacity (100% WHC) and it is important to start irrigation (using half set times) halfway through the cycle i.e. after 3 - 4 days on a 7 day cycle.
- When water is in short supply cut down water to trees that are not bearing, then on trees carrying a light crop. Ensure coffee in the first three main cropping years (3- 6 years after planting) and 2-3 years after ratooning get priority.
- For undertree systems, watering intervals should be shorter for maximum benefit.

12.2. PHYSICAL CONSIDERATIONS

Rainfall: Both the amount and the distribution throughout the year are important. The irrigation requirement should be based on average peak needs.

Evaporation (E0): The measured depth of water which evaporates from a Class A pan. This indirectly measures the amount of sunlight, temperature and humidity prevailing over the respective time period and the moisture required by the crop for optimum growth.

Evapo-transpiration rate (Et): Transpiration (evaporation of water from the undersides of the leaves) from the crop itself.

Conservation tillage: Following suitable conservation practices allows for the optimum use of rainwater.

Shade trees: These compete with the coffee plants for water. However, they also reduce the transpiration losses from the coffee plants.

Layout: In the cova system water use may be increased by 10% per cova.

Mulch: Mulching, especially in the first 3 seasons, ensures efficient use of irrigation water, increases crop yield and improves soil conservation. It also caters for power cuts, break-downs and the non-availability of spares. Failure to mulch increases irrigation

needs over the first four years by at least 15%. The impact of mulch on evaporation should be ignored when devising an irrigation scheme.

For detailed information on calculating the irrigation requirement for specific farms please see *Tea Research Foundation*, (1989). "Coffee Manual for Malawi 1989". Mulanje: TRF, Chapter 11.

Soil Moisture

Water should be applied to the crop when 50% of available moisture is depleted. However, Water Holding Capacity (WHC) varies with texture and classification of the soil e.g. clay soils: 70%, loamy sands: 40%.

TABLE 21. USEFUL MOISTURE CONTENT IN DIFFERENT SOIL TYPES[30]

% OF USEFUL MOISTURE REMAINING	LOAMY SANDS	SANDY LOAM	LOAM	CLAY LOAM
0%	Dry, loose single grained flowing through fingers	Dry, loose, flow through fingers	Powdery, dry, sometimes slightly crusted but easily breaks down into powder	Hard, baked, cracked some- times have loose crumbs on surface
50% or less	Still appears to be dry, will not form a ball with pressure	Still appears to be dry, will not form a ball	Somewhat crumbly but will hold together with pressure	Somewhat pliable, will ball under pressure
50 to 75%	Same as coarse texture and does not form a ball	Tends to ball 1mder pressure but does not hold together	Forms a ball, somewhat plastic	Forms a ball with ribbons out between thumb and forefinger
75 to 99%	Tends to stick together slightly and forms a weak ball under pressure	Forms weak ball, breaks very easily	Forms a ball and is very pliable, sticks readily if high in clay	Easily ribbons out between fingers, and has a slick feeling
Field Capacity	No free water on squeezing but wet outline of ball is left on hand	Same as loamy sand	Same as loamy sand	Same as loamy sand
Above field capacity	Free water appears when soil is bounced in hand	Free water will be released with kneading	Can squeeze out free water	Puddles and free water form on surface

As a general guide, assume 10-12mm water is held per 10cm depth of soil (i.e. 10% - 12% VN). For irrigation purposes the following depths and respective water holding capacity estimates should be used.

[30] P 39. Clowes, R., (2001). "Simply Coffee". Harare: Cannon Press.

TABLE 22. A GUIDE TO 50% OF WATER HOLDING CAPACITY[31]

AGE (YEARS)	DEPTH	WHC	50% WHC
1	0.25	30	15mm
2	0.50	60	30mm
3	0.625	75	38mm
4	0.75	90	45mm

In the first 2 years before the trees come into heavy production it is important to irrigate to a depth well below the root zone and to space irrigation intervals sufficiently apart. This ensures that the soil will dry out between irrigations from the surface horizons first whilst a more favourable moisture gradient will exist in the lower extremities of the root zone. Hence the development of deep roots is promoted.

The wetted area in the vertical plane will either be 'onion' shaped on soils with a good texture and water holding capacity, or 'carrot' shaped on coarse sands with poor water holding capacity. The shape (i.e. 'onion' or 'carrot') of the wetted area can be influenced a good deal by such factors as mulch organic matter, silt content or a gravel layer.

A soil auger is one of the most elementary and practical tools available to the irrigator to check soil moisture.

12.3. IRRIGATION METHODS AND SYSTEMS[32]

In the planning and design stages it is important to determine the crop water requirements so that the source and quality of water can satisfy the peak demands for the coffee. Planning must therefore ensure adequate water for the proposed hectarage and consider the potential for drought years.

To supply the irrigation system there needs to be a deliberation of the dam storage capacity required. Furthermore, if the water supply comes from a borehole the sustainability of the water yield must be analysed and its compatibility with the required irrigation rate confirmed.

Farmers must be aware of the advantages and disadvantages of each scheme but should also be aware that the success of any irrigation scheme is dependent on the management of that particular scheme. Careful consideration of capital outlay is paramount especially in the context of high interest rates.

[31] P. 73. Tea Research Foundation, (1989). "Coffee Manual for Malawi 1989". Mulanje: TRF.
[32] Pg. 323 – 326. Hühne, M., (2012). Coffee: Growing, Processing, Sustainable Production. [2nd ed]. Weinhem: WILEY-VCH.

FIGURE 14: IRRIGATION SYSTEM AT NGAPANI

12.3.1. SURFACE IRRIGATION

Surface Flooding generally requires flat land and for this reason is rarely used for growing coffee. This type of irrigation can cause restricted tree growth and low productivity due to serious erosion of the land.

Basin Irrigation can be used for coffee but has many disadvantages. The water around the base of the trees can get cold and lead to Fusarium Disease. This causes damage to the coffee tree roots and results in reduced productivity.

12.3.2. OVERHEAD IRRIGATION

The Drag Hose Sprinkler System is a system that is easy to operate and maintain. It is relatively low cost and in general clogging is not a problem. However there are some disadvantages such as high energy costs due to high friction of the hoses, high labour requirements compared to drip or centre pivot schemes and lower efficiency in relation to undertree irrigation (uses up to 30% more water). This method of irrigation also removes any protective fungicides that have been applied so can increase the susceptibility of the coffee to leaf diseases and Coffee Berry disease.

The Piddle system has relatively low capital costs and no or limited clogging should occur as the holes are fairly large in relation to drip irrigation. However it requires 4 men for 25 ha creating high labour costs and variability of flow due to low precision of the handmade perforations and if the field is not well planned initially

The Centre Pivot system requires access to a large area of land with relatively flat topography and a plentiful source of clean water. Installation of this system is low compared to other overhead and drip systems and its easy maintenance makes it more user friendly with low labour costs. Draw backs of the system are that it cannot operate in plots with shade trees and it is essential to mulch to prevent run off.

12.3.3. GROUND-LEVEL IRRIGATION

In general ground level irrigation methods do not wet the foliage of the coffee so that crop protection chemicals are not removed from leaves as they are with overhead irrigation methods.

The Micro Jets are less susceptible to clogging compared to drip irrigation and as it has a larger root surface wetting it is easy to inspect. However there are higher evaporation losses and it is prone to damage.

Drip Irrigation involves slow and low volume application of water to the coffee. There are a number of advantages and disadvantages. Advantages include: Low evaporation, increased efficiency of water use, low energy and labour costs, efficient fertilizer applications, cost of weed control is reduced, more suited to young coffee since can avoid unnecessarily wetting of the inter-rows. Disadvantages include: Clogging of the emitters, high capital costs, susceptible to rodent damage, salinity could be a problem so water quality should be checked and the water filtered. It requires periodic back-flushing and flushing out drip lines and it can be easy to over-water coffee in first and second years.

FIGURE 15: GROUND LEVEL DRIP IRRIGATION AT NGAPANI

12.3.4. WORKING EXAMPLES

On soils with good water retention (those of a depth greater than 1 metre and sandy loam or heavier): Consider using sprinkler irrigations of up to 50 mm net (60 mm gross) and basin or trickle irrigation of up to 250 litres per tree gross.

On shallower or sandier soils it would be more satisfactory to apply 30 mm net at 6 day intervals by over tree sprinkler irrigation, or 120 litres gross per tree at four day intervals by basin or trickle.

For coarse sands, daily irrigation recommended and a maximum interval of three days is recommended for heavy soils.

For a detailed example considering required quantities of water per hour, costing and plan for a piddle system see pages 42-45 in *Clowes, R., (2001). "Simply Coffee". Harare: Cannon Press.* For an example of calculating the number of required drippers per hectare see pp. 80 of *Allison, A. G., et al. (1987), "Coffee Handbook 1987", Harare: Coffee Growers Association* but generally three drippers per cova are needed for mature coffee.

13. WEED CONTROL

Coffee yields can be severely depressed by weeds, which compete for both water, nutrients and, when coffee is small, light. Weeds also harbour pests and diseases. Therefore a weeding programme is required to ensure that weeds to not become a significant problem.

A programme needs to be established to suit the individual farmer and ensure cost-effectiveness. The programme used will have to take account of such factors as topography, slope, the soil type, water availability and method of irrigation. Mulch provides the ideal form of weed control, but for both economic and practical reasons the level of mulch applied is seldom sufficient to afford full control. The use of either mechanical or chemical weed control is often unsatisfactory as the former method is likely to increase soil erosion while the use of selective herbicides may result in a build-up of herbicide resistant weeds. Weed control, therefore, generally requires an integrated programme involving mulching, as well as mechanical and chemical methods.

13.1. HAND OR MECHANISED WEEDING

Slashing

Weeds in the inter-row can be controlled by slashing and leaving them *in situ* for mulch. Regular slashing, every two weeks in summer and once a month in winter (May- August) in the inter-rows effectively prevents weeds from flowering, seeding and dispersing to coffee. Regular slashing of contours, waterways and roadsides is recommended.

Hand-pulling

Weeds within the drip-line, close to the main stem, and growing through the mulch should be hand-pulled to avoid damage to stem or roots. Hand-pull when weeds are small and before they have flowered. Hand-pulling on a two week round during summer and once a month in winter (May - August) is recommended. The number of weeds within the drip-line after the third season is greatly reduced by the coffee leaf canopy shading from above.

Inter-planting

Rhodes grass planted inter-line is a good weed control measure as well as providing mulch material when slashed. But the Rhodes grass must be managed as a separate crop.

Suggested Equipment

Hoes: May be used for light weeding but their use can cause serious soil compaction and encourage erosion.

Vine forks: Ideal for controlling perennial weeds and producing a good cloddy (rough) surface. They are recommended for breaking up a compacted soil surface.

13.2. CHEMICAL WEEDING

Suitable herbicides sprayed around the drip lines are advantageous because they can simplify management of coffee plantations.

Concentration and Calibration

- Always read the labels carefully for detailed instructions on the quantity of herbicide and recommended volumes to be used.
- Additions such as wetters and stickers should only be made when recommended.
- Sprayer calibration should also be checked regularly. Details and methods of calibration are normally included in the operation manual applicable to the

equipment being used. Main thing to remember is to calculate rate per "sprayed hectare" and not "land area" for calibration purposes.
- Regular maintenance of the spraying machines is vitally important.

Application of Pre-emergent Herbicides

- In the first year place a band of pre-emergent herbicide along each side of the row to control weeds within the rooting zone. Do not spray herbicide in a ring around the plant because this results in over-application. Care is needed to prevent overlap and missing areas in the rooting zone. Apply soon after planting to weed free soil which is moist or irrigated after application.
- Use flat fan nozzle on sprayer. The chosen swath is dependent on the nozzle characteristics and height of nozzle above the ground but in general a narrow swath will save the cost of the chemical.
- It may be advisable to change the materials used each year to prevent a build-up of specific weeds and herbicide residues in the soil.
- Extreme care should be taken in their use on sandy soils.

Application of Post-emergent Herbicides for Coffee more than 3 Years Old

- Use in combination with slashing to control weeds in the inter-rows.
- Clean water (free of silt and organic matter) must be used for the application of herbicides.
- Flat fan nozzles should be used for overall application. Use a cone nozzle for spot application. Swath depends on nozzle characteristics and height of nozzle above weed canopy.

13.3. TIMING

- The control programme should start before planting when perennial grasses must be eradicated.
- During the early establishment phase the programme must control weeds which may compete with the young trees.
- Clean weeding during the rains is not necessary and it is beneficial to leave the weeds in to help prevent erosion.
- During the dry months it is imperative to continue weeding as this will prevent seeding. But it should be done with a greatly reduced labour force.

13.4. WEED CONTROL BY WEED TYPE

The following section gives examples of weeds and how to control them.

13.4.1. PERENNIAL GRASSES

Perennial grasses include those such as Couch grass, Kikuyu grass and Paspalumspp. It is important that these grasses are eradicated before planting any new coffee.

There are two main options to assist with the removal of Couch grass however it is important to note that couch grass should not be hand-pulled, as this will cause it to spread further.

Mechanical: At the end of the rainy season when little moisture is left in the soil, mow and burn the grass; then deep plough within two days. Then use additional cultivation to kill the grass by desiccation. As temperatures start to rise, a recommended herbicide can be used on any regrowth.

Herbicides: Glyphosate for dense stand of grass/ Fluazifop butyl/ double application of Dalapon for small patches. The rate of Glyphosate to eradicate couch grass is 300 mls in 15 litres water and use a fine spray . Do not use Glyphosate spray in young coffee for the first two years.It is preferable to use Fusilade to spot spray couch grass in young fields at a rate of 300 mls in 15L water.

13.4.2. SPEAR GRASS (IMPERATA CYLINDRICA)

From experience in Malawi, chemical treatment is the most effective way of controlling spear grass and Glyphosate has been more successful than Dalapon in treating the weed.

13.4.3. NUTSEDGES (CYPERUS SPP.)

The two nutsedges which infest coffee in Malawi are yellow nutsedge (*Cyperus esculentus*) and purple nutsedge (*C. rotundus*).

Chemical control of Yellow Nutsedge

- Pre-emergent: Controlled by applications of metolachlor.
- Post-emergent: Control involves using glyphosate or MSMA.

Chemical control of Purple Nutsedge

- Post-emergent MSMA application may give reasonable results.
- Sequential use of glyphosate at 6l/ha alternated with tank mixes of a suitable safe alternative to paraquat and wetting agent with a suitable residual herbicide, but this could be very costly.

13.4.4. ANNUAL GRASSES & BROADLEAVED WEEDS

These grasses / weeds can be controlled through either mechanical or chemical management as follows depending on available resources:

Mechanical: Can be controlled at an early stage of growth with light cultivation. In some cases (e.g. between rows of newly planted coffee or on steep slopes) control of weeds by slashing is desirable.

Chemical: Treatment with a residual herbicide with foliar activity (ametryne or diuron) or without foliar activity (oxadiazon, oxyfluorfen, simazine, terbuthylazine or metolachlor) could be used. The rate of application depends on the age of the coffee, the weed spectrum and soil type.

14. INSECTS, PESTS, NEMATODES AND DISEASES

Coffee that is grown in Malawi has the potential to be affected by a wide range of pests and diseases. A summary of the relevant pests and diseases are outlined in this chapter.

14.1. FACTORS AFFECTING SEVERITY

The severity will depend on the following:

The health of the tree: If the tree is unhealthy, the effectiveness of controlling any pest or disease is reduced.

Weather conditions: Weather conditions vary from season to season and spraying routines must be adjusted accordingly e.g. in very hot conditions, insecticide spraying should be done early morning or late evening.

Variety of coffee grown: The chosen variety can have a big impact on the range of insects, pests, nematodes and diseases that impact the trees. Each variety can also have differing levels of impact depending on growing conditions, geography and topography, so requires strong consideration at the earliest possible stage.

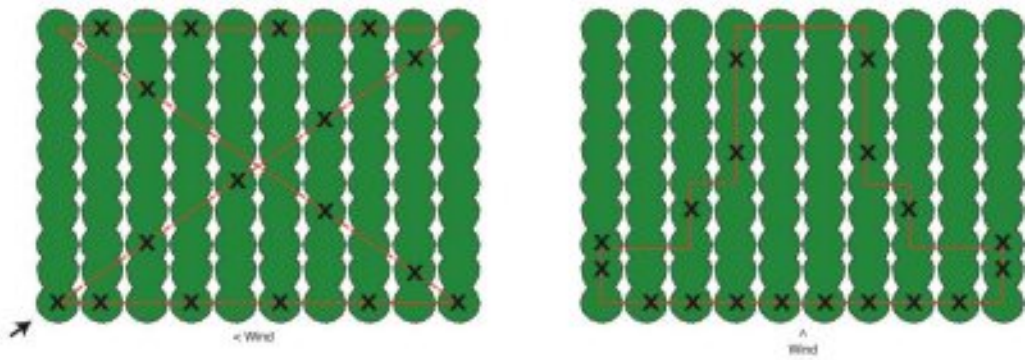
Quality of scouting: Careful scouting can save up to three or more insecticide sprays per annum.

Application method and selection of fungicides and pesticides.

14.2. SCOUTING

Scouts must have good eyesight, be able to read and write and be trained to recognise and record pest and disease levels. They will need to have their work supervised and checked. Each field should be scouted weekly throughout the year because pests and disease can develop quickly in Malawi even throughout the winter months. As a general guide use one scout per 50 hectares of coffee which is equivalent to 10 hectares/day on a five day week.

The *Zimbabwe Coffee Manual 1987* suggests 2 methods for scouting a 10 hectare plot: scouts should enter a plantation and move through the land either using either “a. stepped traverse system” in close spaced coffee or “b. diagonal traverse system” in widely spaced coffee. A total of 40 trees should be scouted and usually a greater proportion of trees scouted in problem areas such as the windward side of the plantation. Each of the trees should be examined for pests and diseases.



a. b.

FIGURE 16: SCOUTING ROUTE IN A 10HA PLOT

Start with general scouting to obtain an overall impression of the pests/diseases present (use markers) and areas of land affected. Then quantify levels of pests/diseases which are likely to require treatment.

The dates of each chemical treatment and dosage should be recorded for each field so that scouting levels can be related to control.

Preventive control is recommended to reduce plant losses. However, careful scouting can also result in successful treatment once an outbreak occurs. Scouting is essential as preventive treatments do not last.

14.3. PESTS

14.3.1. CONTROL

Chemical insecticides should only be used if pest levels rise above the economic threshold, or if past experience indicates that they will rise to the economic threshold. It is unwise to adopt the attitude that no insect pests should be permitted in a coffee plantation. Low numbers of a pest rarely result in economic depression of yields, and their presence allows the maintenance of parasites and predators which will usually prevent the pest from increasing to damaging numbers.

14.3.2. ORGANIC PRODUCTION[33]

It is important to note at this stage that certain non-chemical treatments can often be important for controlling pests and diseases. For example, natural enemies of coffee pests can be encouraged on the farm to ensure that the populations are kept at bay naturally. The populations of the enemies can be boosted through growing coffee amongst a variety of different plant species (e.g. under shade trees) as the diversity allows for a different organisms to thrive. Alternatively, intensive cultural management practices can be rewarding. For instance regular removal/ burning of infected plant material, regular picking (fortnight in heavy fruiting period and monthly at other times), pruning (to allow for clean and thorough picking), and collection of fallen beans from the ground allows for effective manual sanitation. Additionally, moving organic materials (e.g. mulch) between areas/ farm plots should be prohibited.

Some methods unique to the protection of seedlings could also be used. Natural sprays (black jack, tephrosia or neem extracts) can be used for prevention of coffee berry borer or otherwise nets can be used to create a protective boundary around the seedlings.

14.3.3. THRESHOLD LEVELS

The threshold levels indicate the pest level which would require control to prevent economic loss of crop. It is used as a general guide for spraying. The threshold level varies with the type of pest and also with the age of coffee as shown by the table below.

There is no tolerance for pests like borers which must be scouted for and controlled as soon as possible. Other pests such as stinging caterpillar in young coffee, scales and mealybug can cause serious infestation of individual trees.

[33] Ssebunya, B., (2011). *9-13 Coffee: African Organic Agriculture Training Manual.*

TABLE 23. THRESHOLD LEVELS VARYING WITH TYPE OF PEST AND AGE OF TREE[34]

AGE OF COFFEE YEARS	LEAF MINER MOTHS	ANTESTIA NYMPHS/ADULTS	LEAF EATING CATERPILLARS	CAPSID BUGS
1st	2-5	1-2	1	4
2nd	5-10	1-2	2-5	4
3rd	10-20	1-2	5-10	4
4th+	20+	1-2	10-20	4

A more detailed sheet for the economic thresholds of pests is given in the Allison, A. G., *et al*. (1987), "Coffee Handbook 1987", Harare: Coffee Growers Association. (p. 95).

Contact CAMAL for more information on identification of pests in Malawi.

14.3.4. ANTESTIA BUG

Identifying the Insect

The adult bug is 6-8 mm in length, shaped like a shield and has dark brown, orange and white markings. Young nymphs are of a similar colour but are much smaller and do not have functioning wings.[35] A potentially very serious pest causing blackening of flower buds, shedding of immature berries, rotting of beans within the cherries, and fan branching as a result of the death of the terminal buds.

Scouting

The bugs tend to hide amongst the berry or flower clusters. Eggs tend to be present in groups of about 12 on the underside of leaves.

Scout early morning or late evening. Select a few trees with antestia and place a sheet under the tree and spray it with a pyrethroid then shake the tree after a few minutes and count nymphs and adults. Egg dusters (12 eggs) are also clearly visible. If the top of the egg is off and the inside is black the eggs have hatched.

Coffee has a wide range of pests but has been aggravated by over spraying thus killing off beneficial pests as well as those that are harmful. Antestia is one of the main pests which has increased due to over spraying, which highlights the need for good management. The Actara systemic insecticide controls Antestia and Leaf miner significantly.

14.3.5. LEAF MINER

Identifying the Insect

Leaf miner adults are 3-4mm long white nocturnal moths which lay tiny eggs on the upper leaf surface either in small groups or in a row along the main vein. Upon hatching, the flat white caterpillars emerge and bore into the leaf. Often the resulting mines appear as brown blotches on the upper side of the leaves which coverage to form one larger mine as the boring continues. The blotches cause a reduction in the active leaf surface and the leaves are usually shed prematurely. The mature caterpillars (around 4-8mm long at 2-5 weeks old) come out of the mine and pupate in an H-shaped cocoon on fallen dead leaves or on the underside of leaves on the tree.

[34] P. 95. Tea Research Foundation, (1989). "Coffee Manual for Malawi 1989". Mulanje: TRF.
[35] http://www.infonet-biovision.org/default/ct/140/crops

Scouting

As referenced in Table 23 the threshold level of leaf miner varies with its age.

14.3.6. GIANT LOOPER

Identifying the Insect[36]

The caterpillars are best identified for how they move in a "looping" motion. They vary in colour from pale grey to dark brown. Young caterpillars usually eat pits on the upper leaf surface whilst more mature caterpillars (5cm long) feed on the margins and leave a jagged edge. The caterpillars always prefer tender young leaves but berries and flower buds may also sometimes be attacked.

The adult is a moth with a wing span of up to 5cm. Again they vary in colour from light grey to dark brown but often have dark grey markings. They lay light green/ blue eggs in the cracks in the bark.

14.3.7. WHITE BORER

Identifying the Insect

The adult white coffee borer beetle (also known as the "stemborer") is roughly 3cm in length and they have a dark brown/ grey body with white wings that get darker near the edges. They also have very long antenna.

The adult beetles actually cause far less damage through feeding off the tree bark than the eggs and larva. The female beetles lay the eggs on the tree trunks usually near the base. The larva then digs into the trunk and main roots of the tree and pupates in the chamber that's created. This process causes young trees to die and older trees to wilt, turn yellow and produce a reduced crop. The adult is a moth with a wing span of up to 5 cm. Again they vary in colour from light grey to dark brown but often have dark grey markings. They lay light green/ blue eggs in the cracks in the bark.[37]

Scouting

White borer are generally more of a problem at lower altitudes (below 1500m) or on shallow/ eroded soil in shaded areas. The main areas to check for attack are at the base of the stem where scouts should look for exit holes for adults and fibrous shavings.

White Borer has become a serious pest in the coffee industry after the banning of Dieldrin. It has been known to wipe out entire plantations. The recommended treatment to minimize borer outbreak is: 20 Kgs lime in 200 litres water plus 200 mls white pva paint and paint the main stem up to 30 cms. Apply before emergence of the borer, probably December – April. Affected trees must be removed and burnt immediately.

14.3.8. STINGING CATERPILLARS

Identifying the Insect[38][39]

Latoia vivida is the variety which has most commonly been recorded in Africa. The pest can cause defoliation of coffee. The caterpillars are translucent green with a line of orange dots

[36] http://www.infonet-biovision.org/default/ct/140/crops
[37] http://www.infonet-biovision.org/default/ct/140/crops
[38] Hill, D. S., (2008). *Pests of Crops in Warmer Climates and Their Control.* Springer Science and Business Media.
[39] Waller, J. M., Bigger, M., and Hillocks, R. J., (2007). *Coffee Pests, Diseases and Their Management.* Wallingford: CABI.

in pairs running down the back with rows of spines (bristles) on each side. Importantly, the caterpillars are covered with protruding hairs which sting if they come into contact with human skin. The young caterpillars make small pits on the underside of the leaf whilst the older caterpillars feed at the leaf edge leaving it jagged. The pupation takes place in an oval white cocoon, 14mm long, which is stuck to the tree branch.

The adult moth that emerges has green forewings and yellow/ brown hindwings. The total wingspan is about 3cm. The green/ yellow eggs are hatched on the underside of leaves and overlap like tiles.

Scouting

Scout for damage to leaves and also for signs of black droppings (e.g. stinging caterpillars and loopers).

14.3.9. CUTWORM & DUSTY SURFACE BEETLES

Identifying the Insect

Cutworms are the larvae of soil-living species of moths and can have a negative effect on a number of agricultural crops. The larvae attack plants at the base usually at night. They most commonly affect very young coffee plants.

The dusty surface beetle and its larvae are well known agricultural pests. The larvae are especially attracted to germinating seeds whilst the adult beetles feed on the young leaves or may "ringbark" the stem at a low level. Look under mulch and in the soil for the oval shaped and flattened beetle 9.5mm long and dusty brown in colour with ridges along the back (wing covers). Treatment should involve drenching the mulch, soil and stem with a persistent chemical.

14.3.10. MEALYBUG AND SCALES[40][41]

Pests which are part of the Coccoidea family are otherwise known as "coccids". Of these insects, scales insects and Mealybugs are of a particular threat to coffee plants. These small insects feed on the plant by extracting the sap. Therefore, the insects cause depletion of the plant's necessary nutrients and it may fail to grow or produce fruit with the necessary vigour. Ants are a good indication of mealybug and scale activity as they feed on any additional sap that escapes, whilst sooty mould (a fungus) is a late sign of the insect's being active.

MEALYBUGS

Identifying the Insect

Mealybugs can attack either the aerial parts of the plant or the roots. The damage caused is usually revealed by the leaves wilting, turning yellow and falling from the tree. The tree may also bear less fruit. For root mealybugs, the nymph and adult winged females cause the most damage to the trees and they are small (4mm), oval, dusty white insects which, unlike scales, can move freely on the plant as they mature. The white mealybugs are usually hidden beneath the fungal mat. A pesticide such as Furadan, Dursban or Mashal 10% granules can be applied to the root (10g per tree).

[40] Rutherford, M. A., and Phiri, N., (2006). *Pests and Diseases of Coffee in Eastern Africa: A Technical and Advisory Manual.* Wallingford: CABI.

[41] www2.tap-ecosur.edu.mx/mip/Publicaciones/pdf/Coffee%20pests%20and%20their%20management.pdf

SCALES

Identifying the Insect

A number of self-descriptive scales attack coffee e.g. black/brown scale *(Parasaissetia nigra),* brown (helmet) scale *Saissetia coffeae,* green scale *(Coccus alpinus),* white waxy scale *(Ceroplastes brevicauda),* star scale (yellow fringed scale) *Asteroleca nium coffeae.* Brown scale most common in Malawi. Scales will probably be found on the underside of leaves, near the tips of shoots and occasionally on the coffee berries. Regular inspection is needed to ensure that infestation can be identified at an early stage. Cut off badly affected branches and leave under the tree to encourage parasites. Skirt trees and control ants (e.g. stem banding). Spot spray with a suitable oil to avoid killing parasites and predators.

Scouting

Scout for damage to leaves and also for signs of black droppings (e.g. stinging caterpillars and loopers).

14.3.11. TERMITES[42]

Identifying the Insect

Exact characteristics may vary depending on species but most common in Africa are macrotermes, microtermes, nasutitermes or odontotermes. Soil burrows are an obvious sign that occurs off the plant. These mounds reduce cultivated areas and inhibit cultivation. Termites also eat the dead bark on healthy trees (usually close to the base) which is normally harmless but if the tree is weak for some reason (e.g. drought) then the termites may penetrate the tree to the living wood and kill the tree.

14.3.12. RED TORIK AND GREEN TORIK

Identifying the Insect

The eggs are laid on the upper surface of the leaf in groups of 200-250 eggs. The eggs are yellow and overlap like tiles. The larvae are long (up to 25mm) and thin and both spin a web. They can be found webbed between tow leaves or in clusters of fruit. Red tortik is a larger version of the berry moth and the tortrik caterpillars are very active when disturbed. The larvae feed on both leaves and green cherries. The moths are brownish and shield shaped; the hind wings of the female green tortrik are orange in colour. Moths are 6-13mm long.

14.3.13. JELLY GRUB

Identifying the Insect

White scale like eggs are laid singly on both sides of a leaf. The larva is a slug like bluish green blob 13mm long when mature. The adult is brown with darker patches on the forewing with a wingspan of about 25mm. Jelly grub eats out rounded regular shaped holes which become irregular as they increase in size.

14.3.14. FRUIT FLY LARVAE

Identifying the Insect

Fruit fly commonly attacks the pulp of ripe cherries. The white maggot which tapers at the front end and is up to 8.5mm long is often seen during pulping. Invasion of ripe cherries does not cause any crop loss. The adults are orange/brown fly with mottled wings 4.5mm long. The fruit fly attacks young expanding frit causing them to drop.

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[42] J. N. Wintgens, (2009). "Coffee: Growing, Processing, Sustainable Production" [2nd Ed.]. Hoboken: Wiley-VCH

14.3.15. SNOUT BEETLE ADULT

Identifying the Insect

Flightless, snouted, 8mm long beetles which attack coffee leaves. They feed by night and are not easily seen. They hide under leaf litter or mulch. Normally black but species vary in colour – some translucent greeny/blue. Feed on leaf edges.

14.3.16. BLACK BORER

Identifying the Insect

The 20 mm long black "beetle" tunnels (6 mm diameter) obliquely up the stem. Several beetles may occupy one tunnel and up to six tunnels can be found going up the stem. Scout for "sawdust" close to the base of the tree. Often occurs close to natural forest.

14.3.17. BERRY MOTH LARVAE

Identifying the Insect

The eggs are scale-like and are usually laid singly on or close to the fruit clusters. Eggs hatch in about a week into reddish translucent larvae which spin a silken web around the cluster of berries and most berries in the cluster are likely to be attacked (hollowed out) and eventually turn brown. The larva is fully grown (13mm long) within two weeks; it is then inactive for 4 days before it drops to the ground to pupate in an envelope formed between two leaves. The golden brown moth with a 13 mm long narrow and pointed wingspan can often be seen flitting about in the late evening or early morning. Crop loss can be very high and a number of sprays are required. Careful scouting for moths and eggs required once flowering occurs and whilst fruit are on the tree. Silken webbing over fruits in a cluster indicates presence of berry moth. Later clusters of brown fruit are characteristic of berry moth. Up to 20% crop loss has been observed.

14.3.18. YELLOW HEADED TIP BORER

Identifying the Insect

Young larva bores into the shoot tip and down the branch and sometimes into and down the stem producing holes at regular intervals along the branch and stem. The adult has long black antennae and is 25 mm long. Body is brown and head, thorax and part of the wings are yellow. Outbreaks often occur close to natural forest.

Scouting

Scout when dry for shavings and droppings. Scout for wilting branch tips particularly at mid-day or early afternoon and for flute holes; also wood shavings and droppings. Borers normally come in at the middle to the top of the tree. Commonly found in coffee growing adjacent to natural trees or forests.

14.3.19. CAPSID BUGS

Identifying the Insect

The nymph is pale green and pear-shaped and sheds its skin five times until 6mm long and an adult. The adult is green or brownish. The wings bend sharply downwards about halfway along so that they cover the abdomen. The adults and nymphs feed on flower buds which blacken with the exception of the style (centre of flower) which remains healthy and elongates and remains white. The stigma (top of style) is black and club like.

14.3.20. LACE BUG

Identifying the Insect

The nymphs, which have knob-like projections on the head and body, grow to 2 mm in length. The adult grows to 4 mm in length and has lace-like wings. The nymph does most damage. Nymphs feed on the lower side of the leaf causing yellowing in patches. The eaten area is also covered with spots of shiny black liquid excreta.

14.3.21. COTTON SEMI LOOPER

Identifying the Insect

Eggs are 0.6 mm in diameter, shaped like a sea urchin and pale yellowish with fine radial ribs and are laid singly on the upper surface of the leaf. The larva is a green looper up to 53 mm long when mature. It "loops" along because it only has three pairs of legs in the front and three pairs at the back with a legless area in the middle. The adult has brown forewings washed with bronze and with two conspicuous gold spots. It can cause serious defoliation very quickly as the Looper eats leaves.

14.3.22. LEAF SKELETONISER

Identifying the Insect

Dome shaped yellow green eggs 0.5 mm in diameter are laid singly or in small groups usually on the underside of the leaf close to the midrib. The greyish white larva with many pimple-like projections on its body feeds from the under surface of the leaf leaving the veins and upper epidermis intact, hence its name. The adult is a grey and brown moth with a wingspan of 13mm. The moth is often seen on the leaf during the day with the hind legs drawn back alongside the body and the narrow forewings held at right angles to the body like short stubby oars. It is easily recognized by this characteristic pose. Serious outbreaks have occurred in Malawi. Can cause serious defoliation particularly in the lower part of the canopy.

14.3.23. BERRY BUTTERFLY

Identifying the Insect

The eggs which resemble minute sea urchins are laid singly and are stuck to the side of the berries. The green and brown 19mm long larva bores single holes into the sides or ends of large green berries. Later the berries go brown and the edges of the holes bend up to form a distinct rim. The male butterfly has wings which are grey below and nearly black with some broad orange or yellow patches above whereas the female has wings which are grey on both sides. Hollowed out fruits with no webbing. Edges of the holes bend upwards.

14.4. DISEASES

There are a number of good practice methods that should be considered when looking at ways of preventing diseases in coffee, these are highlighted below:

- Always use certified, disease free, seed and use disease resistant cultivars where possible.
- Highly fertile soils will produce stronger trees that are more resilient.
- Scout regularly to ensure early detection of disease problems.
- Pruning and de-suckering will increase airflow and reduce humidity around the plant. After pruning, before moving to the next tree, sterilise tools used in the operation.
- Ensure infected plants or parts are removed and destroyed.
- Always move from healthy to heavily diseased parts of the plantation during normal agronomic operations and make sure no equipment or materials are moved from infested to healthy areas.
- Ensure that the plantation is spaced correctly for efficient spraying (e.g. enough space is left between rows for access by tractor/ mist blower where spraying at scale is possible) and, if necessary, trees should be pruned to allow for good spray penetration.
- See Chapter on "spraying" for good practice methods. But most important is that method achieves good spraying penetration, coverage and a turnaround time of 3 weeks.
- Follow all legislative measures relating to disease prevention.

The common diseases affecting coffee in Malawi are outlined and described below.

14.4.1. COFFEE LEAF RUST (HEMILEIA VASTARIX)

Signs and Effects

Yellow/orange pustules (spots up to 20mm diameter) on the under-surface of the leaf. Only 2-3 pustules per leaf are required to produce severe defoliation on heavily bearing coffee. Can cause dieback and biennial bearing.

Spread

Moist humid conditions (21-25˚C) are ideal for the spread of leaf rust. The spores are light and easily dispersed by wind, rain splash, mechanical means (e.g. pickers) and insects. They infect the leaves through the stomata on the lower leaf surface.

Infection

Most severe outbreaks occur between February and June, and also in August and September. However, outbreaks can occur at any time in Malawi because winter is not severe enough to prevent rust pustules from growing and developing.

Young leaves are very resistant to attack in comparison to more mature, fully expanded leaves.

Rust outbreaks are most severe under shade and on heavily cropping trees.

The period from infection to sporulation (latent period) may vary from two weeks to several months.

Scouting

Remove a sample of leaves or assess (by a rating) the number of leaves with active pustules. Scout the underside of the leaf in the bottom, middle and top of the tree.

14.4.2. FUSARIUM BARK / WILT DISEASE (FUSARIUM LATERITIUM VAR LONGUM)

Signs and Effects

Seedling blight: The cotyledons of infected plants may fail to unfold, the stem becomes necrotic and the seedling dies. Alternatively, light to dark brown, smooth edged lesions occupying matching positions on the unfolded cotyledons appear. These lesions contain irregular concentric rings in various shades of light to dark brown. Gradually, over several months, these lesions enlarge and may reach the stem of the seedling causing death. Those infested seedlings that survive, and which may have shown signs of infection, continue to grow normally, but later produce the collar rot symptoms which are particularly prevalent once trees commence cropping.

Stem: Plants wilt. Scraping off the bark just above ground level would reveal a characteristic well defined elongated brown/black lesion surrounded by light green healthy tissue. Pinkish white spores often seen around the lesion. The mainstem is also often constricted because the lesion eventually encircles the stem and all the branches above wilt and die. Signs are similar to those produced by a white borer ring-barking the stem at the base.

Leaves: Some older leaves turn yellow/ brown and curl downwards for a few weeks before turning black and dying.

Fruit: The apparently healthy fruit near to the infection tends to yellow/ redden prematurely before the fruit eventually falls off.

Spread

Primary spread is by seed and secondary spread is by insects, pickers, pruning and rain splash.

Infection

Fusarium infection in the berries may be caused by foliar spraying at a high concentration. The foliar spray burns the stalks and prevents nutrients reaching the berries.

Scouting

The first visible signs often occur during hot dry periods or when the tree first carries a crop and the tree is under crop stress. Always scout carefully for secondary infection (i.e. branch, fruit, sucker and stem - above the collar) adjacent to where plant losses have occurred. Inspect for signs of collar infection i.e. scrape away the bark on the mainstem at the base of the sucker for signs of a characteristic elongated black lesion. Scout carefully for signs of sucker infection especially on ratooned coffee.

Shade trees and not having basins around the coffee trees reduces the outbreak of fusarium, as having basins around the tree encourages the cold air to collect in the basin and affects the cambium thus leading to fusarium.

Foliar sprays could also affect the cambium if sprayed incorrectly and thus encouraging Fusarium and CBD especially on the berries.

14.4.3. COFFEE BERRY DISEASE (COLLECTOTRICHUM COFFEANUM)

Signs and Effects

Leaves: Similar brown lesions on leaves to those found in brown blight. Lesions usually found at leaf margins.
Fruit: A small sunken dark brown or black lesion on green berries grows to invade the entire berry. Infected berries either drop or remain-in a mummified condition on the branch. The bean (seed) is usually destroyed. Can result in severe loss of crop if not controlled at an early stage. *n.b. Cercospora can be mistaken in May/ June for CBD.*
Stalks: Lesions may also occur on young berry stalks, causing them to be shed before lesions are visible on the berry itself, or on the flowers under very wet conditions.

Spread

Spores from the bark of young branches and infected fruits, are transmitted downwards within the tree by rain or irrigation and from tree to tree by pickers, insects and birds. Long distance transmission is from moving CBD infected nursery plants to a new area. The optimum temperature for spore germination is 22˚C.

Infection

Most likely to happen in March/April due to temperatures. Wet warm humid conditions favour the development of this disease. Mature berries are less affected that the immature. Fruits are very susceptible to CBD infection during the expansion phase (6 – 20 weeks after flowering) and again during the ripening phase (30 weeks to actual harvest). This means that late crop from the previous season (ripe fruits) can easily infect the early crop in the next season (young expanding fruits).

Scouting

Regular scouting is necessary.

14.4.4. CERCOSPORA LEAF SPOT (CERCOSPORA COFFEICOLA)

Signs and Effects

The brown eye spot on the leaf is a circular brown spot not more that 5mm diameter with a greyish lesion. A severe infection can cause defoliation if not controlled in time. The fruits on these trees often suffer from sunscorch and Cerospora and Colletotrichum are often present on the fruit. The sunken lesion resembles CBD but damage is superficial and restricted to the outer flesh only.

Infection

Severe outbreaks can occur in the nursery or in the field particularly when plants are subjected to stress (moisture, nutrition).

14.4.5. ROOT ROT (ARMILLARIA MELLEA)

Signs and Effects

The fungus attacks the roots of many woody plants. It occurs in isolated patches. Trees lose vigour, wilt, and then die. Leaves turn yellow in the process and lateral growth dies back. A creamy white mat of mycelium (fungal threads) can be seen below the bark. This fungal mat has a characteristic mushroom smell.

Infection

The infection spreads through root contact.

14.4.6. WARTY BERRY DISEASE

Signs and Effects

Infected berries develop grey/white scabs and warts which later turn brown. The bean inside usually shrivel and rot. Under moist conditions the fruit are covered with a furry mass of grey spores. Flowers can also be attacked. Crop loss is usually negligible although in severe cases it can cause immature berries, leaves and twigs to die.

Infection

Grows ideally in warm and humid conditions. More prevalent at high altitudes under dense shade and after a prolonged wet spell.

14.4.7. DAMPING OFF

Signs and Effects

Young seedlings develop a constriction and become necrotic at ground level and then die.

Infection

Caused by various fungi (e.g. Rhisoctonia and Fusarium but not the species which causes FBD). May be due to overwatering or planting a nursery when excessive rainfall occurs especially when there is inadequate drainage and dense shade.

14.4.8. WEAK SPOT

Signs and Effects

Small, not more that 2mm diameter, translucent yellow spots like pin pricks often surrounded by a brown halo. Suspected to be associated with leaf drop.

Infection

Presumed to be a fungal disease which could be associated with insect damage.

14.4.9. DISEASED BEANS (NEMATOSPORA CORYLII)

Signs and Effects

It causes a brown/black discoloration of the bean and results in coffee being downgraded.

Infection

Invades beans attacked by antestia bug.

14.4.10. SOOTY MOULD

Signs and Effects

Leaves, berries and twigs attacked by scales, mealybugs or ants become covered with a superficial, sooty, black mould, which grows on the honeydew by the insects.

Infection

Caused by the presence of aphids and scale insects on the plants.

14.5. PHYSIOLOGICAL DISORDERS

A number of other problems for coffee plants are considered to be physiological disorders, a number of these are considered below along with some of the key signs too look out for when scouting.

14.5.1. SUBERIZED BERRY

Although widespread, this disorder is of unknown cause and rarely of economic significance. The brown, corky areas which occur on the berries cause no damage to the bean, except where the condition has developed early in the formation of the fruit.

14.5.2. BERRY SCORCH

Browning of the berry caused by frost or cold dry winds. Excessive amounts of disulfoton from spillage can cause expanding fruits to go a chocolate brown colour and for leaves to go yellow.

14.5.3. LIGHTNING DAMAGE

A circular patch of a few to 20-30 trees which wilt from the top down. Scrape away the bark from the main stem. It should be reddish-brown colour which blackens later.

15. SPRAYING

Spraying is the method used to apply the correct dosage of chemical uniformly over the target area at the right time and in the most efficient and cost effective manner.

15.1. PRACTICAL ADVICE

Water: Water is a carrier and the volume used depends on the target area and the droplet size (smaller droplets require a lower volume). Water must be clean and filtered to prevent blockages and ensure that chemical activity is not reduced. Water may be less suitable where evaporation is very likely (and hence oil could be used instead to prolong droplet life).
Uniform coverage: This may be difficult to achieve on older coffee because of the arrangement of branches and density of the foliage. Air assistance (e.g. a mist-blower) may be needed to ensure droplet penetration and handling the trees regularly (four times throughout the season) will ensure that the canopy is kept open.
Target zone: It is important to know where you are targeting as this will affect the chosen spraying method. For example foliar applied insecticides and fungicides must reach the leaves but covering the fruit and branches (e.g. for FBD/ CBD treatment) requires higher volumes. With regards to herbicides, pre-emergent herbicides target the soil whilst foliar applied substances must reach the weeds.
The target area for foliar is on the young leaves only. Do not drench the plant as it could reduce the crop by burning the stalk on the developing beans. Use a fine nozzle 1 man day = 3 Ha
Timing: In some cases it must be reactive and in response to a need to be effective. Therefore good scouting is required.
Climatic conditions: Do not spray under hot conditions as burning can occur and the foliar will be less efficient.
Quality checks: Remember to conduct regular checks (including pressure performance, uniformity of spray, leakages and swath width) to ensure accurate and consistent coverage.
Dosage rate and chemical selection: Refer to other relevant chapters for guidance as well as the information provided on the product labels.

FIGURE 17: CHEMICAL SPRAYING

15.2. NOZZLES

There are different size nozzles available for various operations. They determine the droplet size, spray pattern and spray angle. Droplet size in particular has implications on volume, cover, penetration, drift and loss from evaporation (smaller water-based droplets more readily evaporate). Therefore droplet size is important for effectiveness and decisions on nozzles should be made with due consideration.

15.2.1. CONE NOZZLE

Solid or hollow cone nozzles are used in nurseries and in the land to apply insecticides and fungicides to the foliage. They may be used for full coverage or spot spraying.
The cone nozzle has two parts:

1. The nozzle tip with a circular orifice (1-3 mm diameter orifice is normal).
2. The swirl plate or core which swirls the liquid around before it reaches the orifice. For insecticides and fungicides, the swirl plate must be suited to producing small droplets.

These nozzles produce good atomisation at low pressure of 200-300 kPa (2–3 bars).

TABLE 24. HOLLOW CONE TIPS[43]

NOZZLE TIP	PRESSURE (KPA)	FLOW (LITRES/ MIN)	APPLICATION RATE (LITRES PER HECTARE AT 5KM/H (APPROX. WALKING PACE))
Disc-core 2-13	300	0.32	104
Disc-core 2-23	300	0.39	127
Disc-core 3-23	300	0.47	153

[43] P. 33. Clowes, R., (2001). “Simply Coffee”. Harare: Cannon Press.

15.2.2. *FLAT FAN NOZZLE*

These nozzles are used for applying herbicides. They produce less atomisation and less drift (hence larger droplets at lower pressure).

TABLE 25. FAN-JET NOZZLES[44]

NOZZLE TIP	PRESSURE (KPA)	FLOW (LITRES/ MIN)	APPLICATION RATE (LITRES PER HECTARE AT 5KMIH/WALKING PACE)
Pink	150	0.282	74
	200	0.326	85
	250	0.365	95
Light brown	150	0.424	111
	200	0.490	128
	250	0.548	143
Orange	150	0.566	148
	200	0.653	170
	250	0.730	190
Red	150	0.849	221
	200	0.980	256
	250	1.095	286
Blue	50	1.131	295
	200	1.306	341
	250	1.460	381
Yellow	150	1.413	369
	200	1.632	426
	250	1.820	475
Lime green	150	1.697	443
	200	1.960	511
	250	2.191	572
Royal Blue	150	2.828	738
	200	3.266	852
	250	3.651	952

15.2.3. *POLIJET NOZZLE*

The Green Polijet nozzle is a good general purpose nozzle. As described in the Malawi Coffee Manual 1989 (on page 159), the Green Polijet nozzle can reach a swath of 60 or 80cm depending on whether it is at a height of 20 or 30cm (respectively) above the canopy. Herbicides are often sprayed using Polijet nozzles.

15.2.4. *NOZZLE LIFE*

This is limited because some substances (e.g. copper and zinc) are very abrasive and therefore output (litres per minute) and spray pattern should be checked for damage. Some materials like brass, wear more easily than other materials such as ceramic tips. Replacing worn nozzles will ensure that expensive chemicals are not wasted.

[44] P. 33. Clowes, R., (2001). "Simply Coffee". Harare: Cannon Press.

15.2.5. CALIBRATION

Calibration is the process of standardising the spraying process so that it is accurate. The calibration needs to be checked regularly (especially from January to May because the leaf area increases rapidly during this time).

15.3. NURSERY SPRAYING

Requirements: Knapsack sprayers with cone nozzles (1-2 mm orifice) which have a swath width capable of spraying half or one third the width of the bed in a single pass. It is advisable to keep records of how many knapsack sprayers are filled in one day, as this will indicate the efficiency of the operation as well as checking that all the chemicals are going on to the field.
Pressure: Use the high pressure setting where possible for smaller droplets and better penetration.
Height of nozzle above canopy: Normally must be 25-50 cm above the top leaf canopy. This influences the swath width and the amount of chemical applied.
Walking speed: A steady speed of 1 m/sec is acceptable. Alternatively using the operator's normal speed can be used to calibrate the knapsack as described in section 15.2.5.
Dosage rate: Based on concentration.
Volume: Approximately 150-250 litres of water should be applied per hectare.
"Full cover spray": This is often recommended and it means that the plants have been coated with small droplets but these droplets should not be quite big enough to combine and run off (as this results in loss of chemical to the soil).

15.4. FUNGICIDES AND INSECTICIDES

The use of a high pressure of over 200 kPa will ensure good atomisation and therefore the production of small droplets. This also helps with spray penetration. Fungicides and insecticides usually have to be sprayed separately because:

1. Fungicides are required for general cover over the entire bush but insecticide sprays normally have to be targeted on a particular area and a full cover spray is not appropriate (e.g. when systemics are used for the control of leaf miner, or when the stem must be sprayed for the control of borer or antestia bug).
2. Insecticides can be used at a lower volume of water/ha.

15.5. HAND SPRAYING

A single spray to each side of the tree will probably suffice during the first year in the land. After that, as the covas gets larger, then half the cova is sprayed on the walk up the row and half on the walk back down the other side. The sprayer must spray up one vertical swath and down the next until each side is sufficiently covered. For consistency, the nozzle must be moved up and down at the same rate and it must be kept at a constant distance from the tree (25-50cm depending on the swath required).

15.6. MECHANICAL SPRAYING

Tractor Drawn Sprayers

The nozzles are usually provided with the unit and the pressure setting must be operated as per the manufacturer's instruction (but it is usually above 1000kPa). The speed may vary between 3.5-4.5km/hour depending on the density of the leaf canopy. The main objective is to create an air and droplet mixture in the canopy.

The time to spray one hectare (without stopping) can be calculated as follows:

$$\text{Time Required (minutes per Ha)} = \frac{600}{\text{Row spacing (m)} \times \text{km/hr}}$$

Using the litres sprayed per minute through the nozzles, the volume applied is calculated:

Volume per Ha = Time Required x Application Rate (litres per min)

Mist Blowers

Most mist blowers are not suited to spraying coffee above 1.5m height so curved vertical boom extensions must be fitted to ensure good coverage at the top of the tree.

Nozzle Orientation

The nozzle orientation must be appropriate for the branching angle. This means that the spray must be directed into the tree and parallel to the branching angle. For example, in the first year on young trees, the nozzles must point down and into the trees.

Closely Spaced Coffee

If rows of coffee trees have been planted within 2.2 m of one another then the coffee may reach the stage where it touches across the row. In this case, only sprayers with air assistance such as motorised mist blowers can be used for spraying because hydraulic nozzles do not have the required space to be effective and chemicals may be wasted. In general closely spaced coffee is not recommended as it has proved to create a lot of problems.

16. HARVESTING

Harvesting is the process of picking the ripened fruit (berries) from the coffee trees. Coffee berries ripen progressively and may be picked at intervals of 10-15 days over a period of several months. Harvesting normally begins as early as February and extends as late as September in Malawi; the bulk of the crop being reaped between May and August.

16.1. FACTORS AFFECTING YIELD

There are a number of factors to be considered during harvest that can have an impact on the yields gathered, such as:

Method of picking: Pickers need training in the best techniques so that they can be most efficient.

Rate of ripening: Highest output is obtained when the main ripening flush occurs.

Number of cherries per kilogram: The higher the number of cherries per kg, the greater the potential return per picker per day and the more pickers required per hectare.

Cherry to parchment/ green coffee ratio: Cherry: parchment ratio varies between 5.5: 1 and 6.0: 1. Cherry to green coffee is approximately 7:1.

As a general guide: 100 ha of bearing coffee yielding 3 tonnes per hectare will produce 18 tonnes cherry per ha at a ratio of 1:6.

16.2. TIMING OF HARVEST

To obtain good quality, coffee berries must be picked at the correct stage of ripeness which is approximately 40-45 weeks after flowering. When the cherry is *very* ripe it is easy to pick, thus increasing productivity and ensuring better quality coffee. Effective pulping is also largely dependent on lubrication from fully ripe cherries. Coffee at a uniform stage of ripeness will ferment uniformly and allow more precise control over fermentation times.

The cherries should be blood red (or pinky yellow for varieties such as yellow Catuai and yellow Caturra) and easy to squeeze between finger and thumb.

Geisha and Agaro have small and uneven sized fruit which ripen first. SL28 and K7 ripen next then, finally, Catimor and Caturra.

Cherry selection is the first and key determinant in the quality potential of coffee during the final processing stage. For the production of speciality quality coffee in Malawi the selection of perfectly ripe coffee cherries is central to this quality potential.

Segmenting a farm into uniform blocks helps control optimum cherry selection. This is most commonly done by variety, age of trees, or altitude since these are key factors in determining the timing of ripening. Giving these blocks numbers, names or codes within a farm helps manage labour organisation as well as lot separation of processed coffee. Blocks are monitored regularly for yield estimation, cherry development, and level of ripeness. This provides information on when to pick and how many people are needed to effectively carry out the harvesting.

For co-operatives, working with farmers to understand how their smallholding fits into the flow of ripening for the whole group helps to manage this. Requesting specific varieties for delivery to the washing station on certain days is also crucial in managing lot quality through to the end consumer.

In Malawi selective picking is the most common practice in place. The number of picking rounds carried out on farms varies. Commercial quality farms will carry out three rounds

plus a 'last pass'. Farms geared towards optimising potential quality and accessing speciality markets will usually carry out six or more picking rounds plus a 'last pass' selection. By carrying out a higher number of rounds the pickers can be very selective in picking only ripe coffee, leaving partially or almost ripe coffee ready for the next round of picking. The number of rounds necessary can be calculated by ensuring all coffee plants can be picked every 8 – 10 days during the season.

There is a cost implication of adding in extra picking rounds but when carried out correctly, the income benefits from the higher quality crop will outweigh this added cost.

Uniform picking is extremely important for uniform processing because density, water content and sugar content will vary by ripeness. This will affect the later processing and potential quality of the coffee.

The exception to this is the end of the season when the 'last pass' will strip all remaining coffee off the trees. This is a crucial stage for plant maintenance and disease prevention. This final picking involves clearing the coffee plants of all remaining crop at the very end of the season.

Employee or family training at the beginning of the picking season is important in setting quality standards. Ripe and unripe cherries look and behave differently in a number of ways so areas to cover in this field based training include:

- The colour of ripe coffee is fully homogenous across the whole cherry
- Ripe coffee is easier to pick
- Ripe cherry is harvested as an individual fruit between finger and thumb and removed by a twisting motion
- Unripe coffee often brings the stalk with it
- Ripe coffee will pulp between a finger and thumb easily
- Ripe coffee is sweeter than unripe coffee when tasted
- Different varieties have slightly different appearance when ripe
- Yellow fruiting varieties appear orange to pinkish orange when fully ripe depending on cultivar

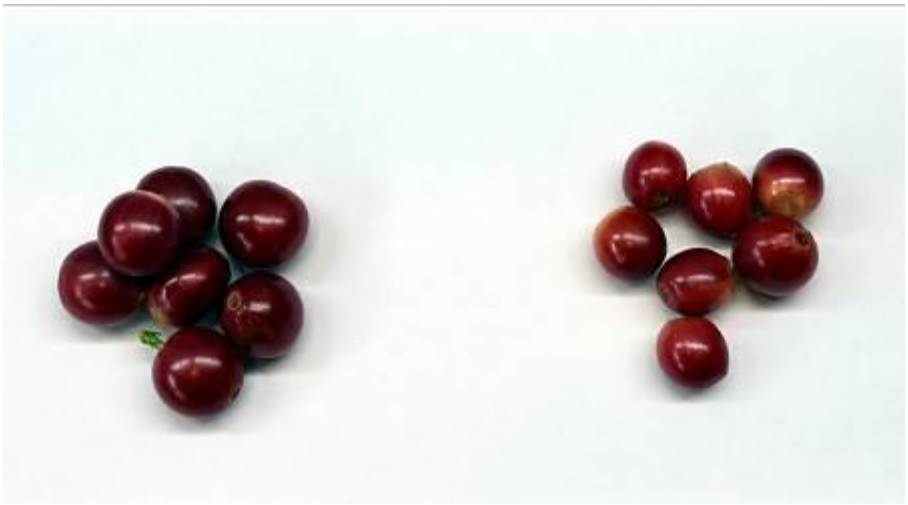

FIGURE 18: RIPE CHERRIES (LEFT) AND APPROXIMATELY 10 DAYS OFF RIPE CHERRIES (RIGHT)

Checking the quality of pickers early in the season using the classification method outlined in 'Cherry Sorting' below helps determine if further training is required and identifies areas for improvement.

At a more complex level some tools can be used to understand the exact level of ripeness of coffee.

The sugar content of handpicked coffee can typically vary from 17 – 25%. This can give a wide variation in potential quality. To have more control over quality one method is to measure the sugar content of coffee cherries using a Brix meter. They are particularly useful for:

- Consistently maintaining quality standards through the picking season
- Training picking teams on the range of acceptable quality standards of cherry ripeness
- Optimising the ripeness of yellow fruiting varieties
- Separating levels of ripeness for selection in preparation for alternative processing methods.

FIGURE 19: USING A BRIX METER

Brix meters can misread if there has been rain or mist in the previous twenty four hours because coffee will absorb moisture and reduce the actual sugar level. Because of this only use them to measure coffee sugar levels during periods of sustained dry conditions.

Good practice with Brix meters is to measure the fruit juices of 10 similar cherries and making a decision based on the average sugar level.

FIGURE 20: CHERRY RIPENESS SELECTION

16.3. PICKING METHOD

Pickers must be taught to pick with both hands simultaneously, each hand picking from either side of one branch. They should start from the top of the tree, close to the mainstem, and work outwards until they reach the end of the branch before moving down to the next. All branches must be checked for ripe fruit.

Each cherry should be picked individually, held between finger and thumb, and picked with a twisting action to ensure it is separated from the stalk (this means stalks are likely to flower and produce again, and that pulping can happen without irritation from stalks). Some coffee farmers also harvest two to three cherries at a time by using the finger as a wedge and rolling the thumb over the cherries and twisting the bean slightly with the finger. If harvesting with a lot of stalks this indicates the picker is pulling the cherries off as opposed to rolling his thumb.

FIGURE 21: COLLECTING PICKED CHERRY IN A BAG PRE-SORTING

The picker should only transfer fruit to the bag once hand is full and the base of each tree should be checked for fallen fruit before the picker moves on to the next tree. Fallen fruit which are not properly ripe (i.e. are still green, brown or black) should be kept separate for sun drying. Therefore pickers need another small bag on them for this fruit.

Preferably each picker should have their own line or lines of trees. If the trees are very tall (such as the SL 28 variety) ladders are probably required.

16.4. PICKING POCKET

Each picker should have a pocket, made from polythene or hessian, which they tie around their waste using an attached cord. The picking pocket method means that fewer labourers are required per day to collect the same quantity of fruit.

A wire in the top if the pocket and two stones in the sides of the top seam (with top seam rolled down on top) should keep it slightly open. It should hold seven or eight kilograms of cherry when it is full.

To prevent the reaping pocket from being over-filled, a larger bag could be moved from tree to tree as well which is used to hold the fruit emptied from the picking pocket.

FIGURE 22 – COFFEE PICKING POCKETS[45]

[45] P. 127. Allison, A. G., et al. (1987), "Coffee Handbook 1987", Harare: Coffee Growers Association.

16.5. LABOUR REQUIREMENTS

Labour requirements will vary from place to place, depending on the altitude and the general age of the plantation (ie. the older the coffee the later the harvest). Average daily pick will range between 30-50kg cherry per day with 3- 5 labourers required per day per hectare over the main harvest period. The first harvest in February/March is always of poor quality and harvesting should be treated as a cleanup i.e. ripe, over ripe and if the few under ripe cherries should be harvested (this ensures that the second harvest is of a good standard).

TABLE 26. ESTIMATIONS FOR LABOUR REQUIREMENTS FOR 1 HA[46]

MONTH	PERCENTAGE	CHERRY (KG)	AVERAGE PICK	MONTHLY LABOUR REQUIREMENTS	NO. OF ROUNDS PER MONTH	NO. OF PICKERS/ MONTH
April	2	360	25	14	2	7'
May	5	900	30	30	2	15
June	10	1 800	40	45	2	23
July	30	5 400	80*(100)	67 (54)	2	33 (27)
August	35	6 300	80 *(100)	78 (63)	2	39 (31)
September	16	2 880	60 *(80)	48 (36)	2	24 (18)
October	2	360	25	14	1	14
Total	100	18 000	61,8 (70,8)	296 (256)	13	155 (135)

One junior supervisor should be responsible for 30-50 pickers who are part of one or a number of picking teams. Output quantity and quality should be analysed for each specific team and also the individual lines of trees so that the source of any problems can be easily identified.

Before weighing, the quality of each picker's coffee must be checked (e.g. for too much unripe fruit and whether stalks have all been removed). The workers should pick over any coffee that is not properly picked (i.e. remove green fruit, stalks and extraneous matter). This will deter bad picking as well as ensuring the quality of cherries to be pulped.

Payment is based on the labour wage regulations (information on this is available through CAMAL) but remuneration and bonuses can be used to give incentives to workers to increase productivity. In the mid-season when the majority of fruit is perfectly ripe, the employees are paid according to the amount of fruit that they harvest. At an early or late stage of ripening, pickers are usually paid a specific sum because there is not sufficient coffee to warrant payment per quantity picked, however the payment is usually given based on a threshold level of fruit being gathered.

16.6. WEIGHING

Weighing points should be positioned so that pickers do not have to carry picked coffee long distances. Weighing should commence early enough to ensure that pickers do not have to wait around with full bags of coffee, and so that pulping can also get underway. It should be a continuous process throughout the day.

[46] P. 49. Clowes, R., (2001). “Simply Coffee”. Harare: Cannon Press.

16.7. CHERRY SORTING

Immediately after picking coffee should be kept in the following conditions to prevent fermentation or spoiling:

- Bags or silos for a maximum of 8 hours before processing
- At temperatures of no more than 40°C and in the shade

Once picked, cherry sorting is a method commonly used to refine the quality of picked cherry when it is received from the fields. This sorting of the day's crop further refines the quality management process in preparation for secondary sorting. A range of strategies are employed by farms and co-operatives to sort cherry delivered to the washing station

FIGURE 23: CHERRY SORTING

An effective way of organising qualities of coffee is to:

1. Draw 100g or 1kg incoming cherry
2. Classify as:
    - Green
    - Unripe
    - Immature
    - Ripe
    - Overripe
    - Raisin
3. Group this classification into quality sections of A, B and C grade e.g. An example 'A Grade' could be "Contains at least 90% fully ripe, and has 0% green cherries and 0% raisins"

This is a very effective method of maintaining picking quality in the field when used with portable hand scales. Individual organisations can set their own quality standards within these categories. An example form with two completed examples can be seen below.[47]

[47] Adapted from Speciality Coffee; Managing Quality Edited by T. Oberthűr et al (2012)

Cherry Picking Quality Assessment

Field Check: Weigh 100g	Wet Mill Check: Weigh 1kg

- Weigh cherry from a bag of picked cherry
- Categorise the sample into the grades below
- Reweigh each category to work out percentages
- Check the picked quality against the target standard

	Sample Ref					
Category	**1**	**2**	**3**	**4**	**5**	**6**
Green						
Unripe		5%				
Immature	10%	25%				
Ripe	85%	65%				
Over Ripe	5%	5%				
Raisin						
Total	***100%***	***100%***				
Final Category	A					
Action	**Pass**	**Re-sort**				

FIGURE 24: CHERRY PICKING ASSESSMENT EXAMPLE

Once classified, further re-sorting of cherry either by hand or by machine before processing is also commonplace. By hand, this re-sorting requires labour, time and space to ensure that all product is prepared for secondary processing. Improved picking quality in the field will result in less time re-sorting. The method is to empty a delivered sack of cherry onto the sorting medium of either spare mobile wire beds or clean, dry tarpaulins. Workers then identify cherries that fall outside of the agreed quality standard for separate processing. Prior to processing, the different grades of cherry are weighed and recorded.

In order to make the above process less time consuming, a picking supervisor should be checking throughout the day for quality control wherever possible.

For larger commercial farms machinery for resorting is available. Mechanical sifters/hydraulic separators will remove foreign bodies, over-ripe coffee and floaters, while washer separators will sort small unripe fruit from fully ripe coffee.

Specifically potential qualities from this separation could be defined into A, B and C grades where:

A grade – speciality quality potential

B grade – commercial quality potential

C Grade – commercial to low commercial quality potential

Marking blocks for sorted, A, B and C qualities helps manage process flow at the wet mill. From this stage these lots will be separated all the way through the supply chain to end

consumer. High quality ripe coffee cherry will yield more weight than partially ripe coffee after processing and produce less milling defects if managed correctly.

16.8. WASTE REDUCTION

Cold winds or frost can stop coffee berries from ripening and may even cause physical damage. For example temperatures below 5 degrees centigrade will cause ripening of the fruit to be bright yellow. These may be pulped but they should be kept separate. Similarly, frosted, ripe coffee may be pulped if it is picked before it dries out.

If semi-ripe damaged fruit dry out to some extent they may be soaked in water for 12 hours and then pulped. Again, they should be kept separate. Severely damaged, or dry, fruit should be sun dried and treated as 'mbuni'. Over-ripes can be re-soaked overnight, pulped and then classed as double pass.

A process known as "stripping" is done at the end of the season when the picking efficiency becomes very poor. At this point all the ripe and unripe fruits from the tree are picked to be sun dried and sold as unwashed coffee or hulled on the farm and sold as green coffee.

17. PROCESSING

A major goal with a processing unit is to have a range of coffee products that meet the needs of different customers and manage the environmental impact of the wet mill in a sustainable manner.

Different processing methods will have a different cost basis and a cost of production analysis for all methods carried out is important for effective marketing and sale of finished products.

17.1. LOT SEPARATION AND IDENTIFICATION

Quality of coffee is determined during plant growth. Quality cannot be gained but can be lost during processing. Effective lot separation throughout processing maintains quality potential and identifies all unique coffee lots through the system to the end buyer.

Identifying lots with as much information as possible has a number of advantages and helps in:

- Detailing information required for third party accreditation
- Quality feedback to farming and harvesting
- Process refinement at the wet mill
- Identifying lots with potential for high value market segments
- Aiding blending and lot management at the dry mill
- Providing marketing material for end buyers

FIGURE 25: DAY LOT IDENTIFICATION AND CODING FOR THE SPECIALTIY MARKET

Information collected at farm units or washing stations can include:

- Date Code
- Farmer or Plot Code
- Third Party Certification
- Cherry Selection Grade
- Lot Variety
- Lot Size

- Post-harvest Process Used
- Hours Fermented – if applicable
- Hours Soaked – if applicable
- Drying Time
- Drying Medium
- Screen Size – if applicable

17.2. WHICH CHERRY FOR WHICH PROCESS?

Climatic conditions at the wet mill will impact on which processes are possible and how this is carried out. Beyond these environmental factors the range of products and associated value and flavour profile are determined largely by the initial quality of harvested cherry. The level of ripeness leads to big differences in moisture content, anatomy, and chemical composition[48]. Identifying coffee into different homogenous categories and processing accordingly improves overall efficiency.

Partially ripe and green unripe coffee can develop off taints and black beans as a result of elevated drying temperatures. When processed as natural processed coffee the risk of defective beans and fermented or immature cup notes is higher. This coffee is best pulped and either processed as washed or pulped natural coffee[49].

17.3. WASHED PROCESS

The goal of washed process is to remove the pulp and the mucilage surrounding the coffee bean prior to drying and is the most common method for post-harvest processing used in Malawi. This process requires the most resource inputs in terms of water, electricity and equipment and the technical knowledge needed.

Depending on factors including altitude of growing and level of ripeness of the coffee cherry the mucilage content in Arabica can vary from 16 – 22%.

Fermentation times will vary substantially from wet mill to wet mill and can fall between a range of 6 to 72 hours. Some factors that can cause variations to occur are:

- Higher ambient temperatures and humidity will speed up fermentation
- Thicker mucilage will speed up fermentation
- Ripe coffee cherries will have a higher concentration of peptic enzymes and will ferment faster
- Higher temperatures and thicker mucilage
- Dry pulped coffee will ferment faster than wet pulped coffee
- Wet fermentation is slower than dry fermentation
- A smaller weight of de-pulped coffee will ferment slower
- Smaller coffee seeds will ferment faster than larger ones

It is important to manage quality on a daily basis and know exactly where production issues are happening. A similar form to the picked cherry assessment can be used at the wet mill by analysing 100g of de-pulped coffee in the main channel for any possible issues. Split the selection into:

- Small Cherries
- Skins

[48] Handbook of Coffee Post-Harvest Technology Edited by F. M. Borem (2014)

[49] Amino Acids Profile in Unripe Arabica Fruits Processed by Wet and Dry Methods by F.M. Borém et al (2008)

- Greens
- Brokens/Whites
- Sound

Amend machinery settings accordingly and also picking quality the following day for feedback loop

Vital to successful washed processing is hygiene control at the wet mill. Coffee processing is a food production area and should be treated as such. Once any post fermentation channelling and washing has been completed, the wet mill team carry out a full clean down of:

- All pulping equipment – removing any skin or bean residues with pipe cleaners and wire brushes
- All pre and post fermentation channels
- All fermentation and soaking tanks

Prior to production starting the wet mill manager is then responsible for walking through the whole process flow checking machinery, channels and tanks for any residues or remaining beans. Once they are happy that the system is clean they can sign it off for production.

FIGURE 26: ANALYSING PULPER DEFECTS

17.4. TIPS ON GOOD PULPING[50]

17.4.1. PULPER DISCS

Coffee pulper discs must have a rough surface for pulping clean parchment coffee. Worn discs can be roughened using an angle-grinder to deepen the grooves, followed by eutectic welding. It may be cheaper to purchase new discs. If the disc is in good condition, an old file can be used as an electrode at 100 to 110 amps, and this will roughen the disc. Worn discs cause;

[50] Clowes, R., (2001). Simply Coffee. Harare: Cannon Press Pg 61-62

- Too many skins in the fermentation tank
- Coffee can be bruised which causes loss of quality. This occurs when the operator moves the breast-plate too near the disc trying to remove the skin.
- Coffee cherry blocks at the feed end of the pulper

17.4.2. BEARINGS

The bearings need to be in perfect condition i.e. no side play at all. Any adjustments made to the pulper when bearings are not perfect will be useless.

17.4.3. KNIFE

The knife must be in good condition and should be one hacksaw blade gap for the entire length of the knife. Check for wear in the middle section of the knife.

17.4.4. BREAST PLATE

The breastplate must be 8 mm from disc. (Biro pen or pencil or 19-mm Gedore Spanner).

17.4.5. NYLON FINGER

Nylon fingers should be set about 5 - 6 mm away from the disc.

If there is a lot of un-pulped small bean:

- Increase the tension on the fingers
- Move the fingers in slightly

If cherry blocks with normal feed, move fingers out. On certain makes of pulpers, the rib can be built up or replaced for better pulping. Baines pulpers have fixed fingers mounted on the plough.

17.4.6. COFFEE GRADER

On the coffee grader, a siphon feed system will reduce skins in the fermentation tank. A 12-mm punch plate produces better grades than the square mesh screens, and is cheaper to maintain. It is advisable to drill out the last section of screen to 13 mm. This will allow the AA and 'elephant' coffee beans to go into the first grade.

TABLE 27: DISC PULPERS: FAULTS AND REMEDIES

FAULT OR SYPTOMS	POSSIBLE CAUSE	REMEDY
Many berries passing through pulper without being pulped	• Plough set too far away from disc • Cherry of incorrect ripeness	• Adjust plough to a closer setting • Take more care in picking
Nipping of breaking of beans and/or fragments of beans being passed through with the pulp on the back sheet	• Plough set too close to disc • Knife set too far away from disc • End Float of disc shaft • Cherry is of incorrect ripeness	• Adjust plough to wider setting • Adjust knife to a closer setting – 1.5mm or less clearance is required • If due to worm bearing they must be replaced.
Whole beans being passed through with the pulp on to the back sheet	• Knife set too far away from disc	• Adjust knife to a closer setting - 1,5 mm or less clearance is required.
Excessive amount of pulp being delivered with pulped coffee	• Rate of feed into the pulper too high • Disc surfaces have become polished	• Reduce feed rate until satisfactory delivery is obtained. • For quick temporary improvement, etch disc surface with hydrochloric acid • For longer lasting repair surfaces should be sand blasted. New discs required.
Flow of coffee ceases, or almost ceases	• Foreign material, such as leaves or twigs, have entered the pulper causing a blockage • Feed rate too high • Over-ripe coffee being pulped • Undue delay between picking and pulping	• Stop machine and clear the blockage, if necessary removing the breast plate to do so • Cut off the feed altogether until machine clears itself, then continue to feed at a reduced rate. If the lowest possible feed is excessively high, attention should be given to the disc surface • Take more care in picking • Pulping to be carried out on the same day as picking whenever possible • Increase water flow
Intermittent ringing sound coming from disc pulper	• Knife or knives set too close • Loose disc shaft • One of various cover plates fouling discs • Slots in hopper not correctly aligned • Hard object trapped	• Adjust knives to a wider setting of 1,5 mm • Check bearings • Adjust • Adjust, usually by means of a screw in the pulper side frames • Remover

FIGURE 27: CLEAN AND WELL MAINTAINED DISC PULPER AT WASHING STATION

17.4.7. MUCILAGE REMOVAL METHODS

There are three main methods of removing mucilage. Of these the dry and wet fermentation methods involve a biological fermentation caused by the enzymes pectinases and pectase[51]. Mechanical mucilage removal, often termed eco-pulping, involves a physical stripping of the mucilage from the bean.

Prior to all fermentation methods some pre-grading of de-pulped coffee by size produces a more homogenous fermentation mass. Once fermenting, the acidity of the coffee mass falls from approximately 5.5 to as low as 4.1pH. Mucilage can be washed clean at a pH of 4.6 and wet mills will typically work between a range of 4.6 and 4.1pH depending on internal standards and specifications. Negative sensory attributes can develop when pH drops below 4.0.

Dry Fermentation[52]

The basic process is:

- Coffee is weighed prior to pulping
- Floaters are removed via a washer separator or floatation
- Coffee passes through a pulper
- De-pulped coffee is transferred to fermentation tanks.
- Lot details including the start time of fermentation are recorded on the appropriate tank(s)
- Water used for transfer of the coffee is drained from the tanks.
- The mass of de-pulped coffee is levelled into an even bed.

[51] Coffee: Growing, Processing, Sustainable Production (2009) Edited by J. N. Wintgens

[52] Coffee Manual for Malawi Edited by M. St.J. Clowes et al (1989)

- These are then covered for the period of fermentation. This prevents the top of the coffee drying or rain falling into the tank.
- After 12 hours the coffee should be turned using a wooden paddle and stamping of feet (wearing gum boots). Water is sometimes added and then removed to assist with turning; however this can increase the fermentation time and may interfere with quality.

Dry fermentation can take anywhere between 12 – 40 hours depending on environmental conditions, mass size and coffee quality. Checking for fermentation must be done in the early morning, as if the fermentation process is complete, the sooner the coffee is washed and graded and put out to skin dry the better for quality.

Rub Check: A handful of coffee is rubbed between two hands under running water or in a bucket of clean water. If coffee is "gritty" and not slippery, fermentation is complete.

Stick Check: The handle of a channelling paddle is pushed into the fermenting coffee and immediately pulled out. If this is tested five times and the holes remain for 30 seconds or more then fermentation is complete

pH Check: Methods exist where the pH of the bean mass can be checked to ensure that mucilage has been degraded and that fermentation has not continued too far. This can involve the use of electronic meters or specially designed pH measuring sticks.

FIGURE 28: DRY FERMENTATION

Wet Fermentation

The wet fermentation method uses between 5-10 litre of water per kg clean green coffee more than dry fermentation but has benefits in terms of consistency of fermentation, bean appearance, and cup profile (see 'Impact on Cup Quality') below. This method is slow and whilst the conversion of sugars to acids is more efficient at the beginning of fermentation, the process slows considerably towards the end[53]. If fermentation times become extended and there is a risk of developing negative sensorial attributes, water up to a temperature of 40°C can be used for this method[54].

- Coffee is weighed prior to pulping
- Floaters are removed via a washer separator or floatation
- Coffee passes through a pulper
- De-pulped coffee is transferred to fermentation tanks
- Lot details including the start time of fermentation are recorded on the appropriate tank(s)
- Water used for transfer of the coffee is drained from the tanks
- The mass of de-pulped coffee is levelled into an even bed
- The tank is then refilled with clean water to 2cm above the coffee level
- The tank is covered with a framed tarpaulin. This prevents rain falling into the tank.

It should be noted that wet fermentation is usually only used in the last day of fermentation and early the following morning before the coffee is washed and graded. This method has not been recommended due to reduced quality of the coffee as mentioned previously, however improved quality coming out of Ethiopia, Kenya and Central America suggests otherwise.

Wet fermentation typically takes between 20 – 60 hours depending on environmental conditions, mass size and coffee quality. If fermentation extends beyond 72 hours the formation of 'stinker' beans increases[55]. To ensure fermentation is optimised the later stages are checked regularly at hourly intervals by either: Recycled water can be used which can reduce time but the pH and number of time water can be used should be monitored. Water with a pH below 5 should not be used.

Rub Check: A handful of coffee is rubbed between two hands under running water or in a bucket of clean water. If coffee is "gritty" and not slippery, fermentation is complete.

pH Check: Methods exist where the pH of the bean mass can be checked to ensure that mucilage has been degraded and that fermentation has not continued too far. This can involve the use of electronic meters or specially designed pH measuring sticks.

Mechanical Removal

Mucilage can also be removed from coffee by friction and upward flow mucilage removers are the most common type on the market. These machines have a vertical drum pulper that feeds pulped coffee into an endless vertical screw. Agitators in this screw rubs the coffee beans against each other, removing the mucilage. Water use and environmental impact of this process is much lower.

This type of machine can allow for a bypass of the mucilage removal if honey process coffee is required.

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[53] The Importance of Field Processing to the Quality of East African Coffee by A.E. Wootton (1965)

[54] Coffee: Growing, Processing, Sustainable Production (2009) Edited by J. N. Wintgens

[55] Espresso Coffee: The Science of Quality Edited by Illy and Viani (2005)

FIGURE 30: A PENAGOS ECO-PULPER

FIGURE 29: MUCILAGE OUTPUT FROM ECO-PULPER

Basic process flow is:

- Coffee is weighed prior to pulping
- Floaters are removed via a washer separator or floatation
- Coffee is de-pulped and mucilage removed
- Coffee is passed either to a fermentation tank or directly to the raised beds
- Lot details are recorded on the appropriate tank(s) or raised beds
- If coffee is passed to the tanks, the small volume of water used for transfer of the coffee is drained from the tanks
- The mass of de-mucilaged coffee is levelled into an even bed.
- These tanks are then covered overnight. This prevents the top of the coffee drying or rain falling into the tank. Care must be taken as to what material is used to cover the coffee as the coffee could become tainted, such as with the use of hessian cloth or old fertilizer bags.

If mechanically removed mucilage is soaked for 24 hours after processing no bio-chemical reaction takes place. Instead the centre cut is cleaned via minor fermentation, and improved appearance resulting from a process similar to a post fermentation soak takes place.

17.4.8. CHANNELLING

Grading channels are usually made of concrete and designed to:

- Remove any remaining mucilage from coffee as it leaves fermentation
- Separate wet parchment into grades by density

The process involves:

- Wooden slats should be 7cm deep and placed at strategic intervals along the grading channel. Use 2 to 3 slats on top of each other to slow the grading process and allow sufficient time for floaters and skins to be removed.
- The coffee is released into the channel.
- Skins and floats are removed first, flowing over the wooden slats which act as weirs.
- Heavies are held back against wooden slats across the channel which act as weirs

- Wooden paddles are used to move coffee against the flow to facilitate grading as it flows over the paddle.
- This process also washes remaining mucilage away Slats are added or removed as grading progresses. The objective being to get all lighter coffee to be at the far end whilst keeping heavies at the top end.
- After 3 sections of the grading channel have been graded, remove the top slats to allow further grading to occur and check the quality, and complete the procedure by allowing the coffee to move nearer to the discharge (this will save time and water).

FIGURE 31: CHANNELLING

17.4.9. SOAKING

After fermentation and channelling coffee can be soaked for a further 24 – 48 hours if required. This is done to:

- Improve bean appearance by whitening the centre cut and removing silverskin.
- Improve appearance of coffees where mucilage was removed mechanically
- Remove some minor bitter compounds including polyphenols
- Delay movement to raised beds for drying if no bed capacity is available without deterioration of coffee quality

However, this requires a further 5 – 10 litres of fresh water (which can then be recycled) so there is a labour and environmental impact.

17.4.10. DRYING

Wet parchment has a total moisture content of approximately 65% and the goal in drying is to achieve 12% total moisture in a controlled manner over a period of approximately 10 – 12 days. It is important that skin drying is done in one day to prevent tainting and therefore maximize quality. For this reason coffee is best washed and graded early morning and put onto drying tables.

The drying stage for all coffee can be split into three phases:

- A lag phase
- A linear period of maximum change
- A deceleration phase

The starting lag phase is easiest to manage with washed coffee compared to other processes because moisture reduces relatively quickly compared to natural process coffee, and the mass is easier to move

FIGURE 32: SORTING WET PARCHMENT

than honey process coffee. However, it should still be closely monitored. High quality raised beds are the most efficient medium for drying washed process coffees and the process flow is as follows:

- Spread the coffee lot across the raised bed to a height of 2-3 cm across the width of the raised bed.
- Once flattened the first task is to remove all defective beans and residual skins from the coffee mass. Defective beans are easier to remove on the first day of drying because they are easier to detect. Correct grading channel techniques will reduce hand picking of defective beans which will be in the third grade.
- Turn the coffee every 15 – 20 minutes.
- After moisture content reaches 30% it is skin dry.
- During the hottest part of the day (11am to 2pm) parchment should be piled into a ridge and covered. This prevents mass temperatures rising too high and promotes moisture equalisation through the coffee lot. If the coffee is regularly turned it is not necessary to cover, but labour must be available during the lunch hours to turn the coffee on the drying tables. A hand rake is a useful tool for this operation.
- During periods of rain and at night cover the coffee with plastic sheeting or tarpaulins to prevent re-wetting.
- For optimum quality the maximum temperature of the drying coffee should never exceed 35°C. Quality deteriorates when the drying coffee mass exceeds 40°C.
- Split parchment is a sign that the coffee has not been turned on a regular basis especially from 12 midday to 2pm.
- Removal of defects continues over the full drying period.
- Drying mass should never exceed 3cm in depth when the coffee is drying from 25 to 12% total moisture.
- Washed parchment produced in a clean environment will turn a light bright yellow hue as it dries.
- The total drying time is usually between 10 – 12 days, however, the number two's and three's should be thicker on the drying tables after skin drying so that 10 to 12 days drying can be achieved and avoid over-drying.
- Once the total moisture reaches 11%-12% the coffee can be weighed and stored.

FIGURE 33: COVERING DRYING TABLE AT END OF THE DAY

17.4.11. IMPACT ON WATER USE

Understanding how to efficiently use water at a wet mill is central to good processing practice. Reducing water use by process management and recycling where possible reduces the volume of residues needing further treatment. A summary of recycling options are:

- Use recycled water for floatation/washer separating
- Use recycled water for pulping
- Use recycled water for fermentation
- Use clean water for channelling
- Use clean water for post fermentation soaking
- Fermentation times and cup quality will be altered by the amount of recycling taking place so ongoing assessment in relation to product quality is recommended

Good wet mill management included the monitoring of water used per kg clean green coffee. Depending on the machinery type and process control this will vary from 30 litres per kg with fully washed coffees using a vertical disc pulper to as little as 1.5litres per kg with ecological mechanical mucilage removal.[56]

Waste Water

Waste water from coffee processing can damage local eco-systems and must be treated prior to release into the wider environment. Total and suspended solids are higher in water used for wet processing and the pH is lower than clean water.

Prior to water filtration all solid organic matter should be removed by sieves and composed separately with residue coffee pulp. The remaining water is then transferred by pipe to a pond system.

Pond Systems

Treatment of wet mill waste water will reduce the bio-chemical load of coffee by up to 94% depending on system efficiency. The usual layout of 5 to 6 ponds is as follows:

First Stage Anaerobic Settlement Pond: Two ponds are designed as follows

- Pipe bringing flow in from coffee processing at top
- Rectangular beds are more efficient in reducing bio-chemical load
- Site beds and ponds as far as possible from the coffee processing unit and away from housing.
- Compact the base of the pond with a layer of argillaceous material
- The capacity of the filtration bed should be twice the volume of one month's processing water
- Pond depth when full should be 1 – 2 m to aid evaporation.
- Add lime to this first pond to improve correction of the output pH of water as it travels through the system
- Outflow pipe at bottom corner.

[56] Impact of ''ecological'' post-harvest processing on the volatile fraction of coffee beans: in green coffee by By O. Gonzalez-Rios et All (2006

FIGURE 34: FIRST STAGE FILTRATION OF A POND

Second stage Filtration: A series of three or more secondary filtration ponds below the initial water treatment are necessary to clean the water further before release into the surrounding ecosystem. Design of these is the same as the anaerobic pond apart from the depth can be shallower at 0.5 - 1m.

Organic matter settles on the bottom of these ponds as sludge, and decomposes producing water, methane and carbonised gas.

- Inflow pipe from anaerobic pond
- Rectangular beds are more efficient in reducing bio-chemical load
- Remove sludge on the bottom of ponds every 5 years
- Solids from water filtering can be used as organic fertilizer
- An overland flow facility can be built into the system in case of excess capacity
- Outflow pipe to further filtration

Testing of water quality on an annual basis is recommended. Testing at the end of the harvesting and picking season will assess the maximum environmental impact of the wet mill on the local eco-system.

FIGURE 35: FINAL STAGE FILTRATION OF A POND

17.5. PULPED NATURAL OR 'HONEY' PROCESS

The pulped natural process was developed in Brazil and has spread in use to many parts of Latin America. In recent years it has also become commonly known as the honey process, especially within high value market segments of the coffee industry.

Traditional washed process coffee origins have adopted this method as a means of reducing overall water consumption, diversifying the product range of a wet mill, and as a method of accessing alternative market segments. Because the level of fructose and glucose are markedly different, sensory attributes of these coffees show a higher perceived sweetness when compared to traditional washed process coffees. Yields of red cherry to clean green coffee will also be higher for honey processed coffee because of the retained soluble solids.[57]

While it may seem a simple process when compared to the washed process, there are important technical challenges to address curing processing.

17.5.1. CONTROLLING THE PROCESS

Cherry selection is similar to that of the washed process and access to a floatation tank or washer separator is important to remove beans of low density and poor quality.

Producers can modify flavour and taste profile of the coffee if they use a mechanical mucilage removal pulper. This allows the producer to control the percentage of mucilage removed during processing and typically anywhere from 0% to 70% of the mucilage can be removed. This will markedly change cup profile and the decision to keep or remove mucilage is also linked to the availability of infrastructure needed to dry the coffee.

If water for pulping is recycled it is recommended that primary water is used instead for pulped natural coffee to prevent the risk of fermentation. This water can then be recycled.

Day one process flow of honey process coffee is:

- Record the weight of cherry to be de-pulped.
- Remove floaters.
- De-pulp the coffee and pass to the drying bed.
- Coffee should be levelled to a depth on one bean on a raised bed.
- Mark drying beds with lot traceability information and the date when drying was started.
- Coffee is left undisturbed for the first 16 hours.
- Re-clean the coffee to remove skins, brokens and greens immediately after pulping.
- If de-pulped coffee is levelled onto the raised bed by 2pm then three hours drying can take place before covering with non-tainting protective material to prevent rain or moisture forming on the coffee.

17.5.2. DRYING

The risk of developing dirty and fermented off taints in honey process is high due to the increased sugar content and sticky nature of the mass when compared to washed process coffee. Effective skin drying reduces the risk of these taints so the day following pulping is the most labour intensive and critical to process success. High quality raised beds are the most efficient medium for honey process coffees and the process flow is as follows:

[57] Sugars in green Coffee Beans – Important Aroma Precursors and Their Correlation to Post Harvest Method by B.Bonnlander et al (2006)

- Remove the protective covering from the coffee.
- Mounding the coffee into 2-3 cm high rows and then immediately turn and flatten the mass to one bean depth every 15 minutes.
- Ensure that coffee does not clump together as the mucilage dries onto the parchment.
- Repeat this process until the coffee no longer clumps together (approx. 35% total moisture and after 4 – 5 hours).
- Increase the drying depth to 2cm. This will take up approximately 35% of the initial raised bed space.
- Turn the coffee every 15 – 20 minutes.
- After moisture content reaches 30% the drying mass can be thickened to facilitate optimum drying and prevent mass temperature rising too high.
- During the hottest part of the day parchment should be piled into a ridge and covered. This prevents mass temperatures rising too high and promotes moisture equalisation through the coffee lot.
- Drying mass should never exceed 3cm in depth when the coffee is drying from 25 to 12% total moisture.
- Depending on the environmental conditions and drying curve the parchment will be golden coloured through to red.
- The total drying time is usually between 10 – 12 days.
- Once the total moisture reaches 12% the coffee can be weighed and stored.

FIGURE 36: SKIN DRYING HONEY COFFEE UNDER SHADE

17.6. NATURAL PROCESS

17.6.1. CONTROLLING THE PROCESS

Critical to the success of the natural process is the separation of coffees in to similar levels of moisture content ripeness, and size. This is because coffee of the same size and moisture content will dry consistently and more uniformly, thus having the potential to produce quality coffee. Specifically perfectly ripe cherry has a total moisture content of 65% and over ripe to raisin coffee can have a moisture content as low as 35 %.

The first stage of natural process coffee is therefore to homogenise the cherry quality by:

- Remove stones and foreign matter.
- Remove raisins (nearly dry) and over ripe fruit – Keep these together.
- Remove unripe fruit – keep together and pulp.
- Remove small fruit.

This can be done with equipment such as a hydraulic separator or by hand sorting. Once initial sorting has been done coffee is passed directly to the drying table for final quality control and drying.

FIGURE 37: LAYING OUT RIPE CHERRY FOR NATURAL PROCESS

17.6.2. DRYING

Drying natural cherry follows similar principles to that of parchment coffee but drying times will be extended because of the larger size of whole coffee fruit compared to parchment, and the presence of the skin. The main lag in drying is during the first 1-3 days[58].

The risk of fermentation is critical in the natural process. A period of three to four days stable dry weather is required for the natural process because extended drying times as a result of wet or humid conditions can increase the risk of fermentation. Covered green-house driers can also be used if weather patterns do not fit the ideal. Design of this type of drier should facilitate low humidity to prevent spoilage and prevent temperatures rising above 35°C for optimum quality[59].

The Simple process flow for quality natural coffee is:

- Record the weight of cherry.
- Mark drying beds with lot traceability information and the date when drying was started.
- Cherry should be levelled to a depth on one cherry on a raised bed.
- Cherries are left undisturbed for the first 24 – 36 hours.

[58] Guidelines for the Prevention of Mould Formation in Coffee by FAO

[59] Drying Rate and Quality of Natural Coffee By F. M. Borém et al (2012)

- Once ripe cherry has been spread onto the raised bed it is then re-cleaned to remove any remaining cherries that are over ripe, under ripe, or split.
- These are then processed separately or with grade B or C cherry depending on their quality.
- If cherry is levelled onto the raised bed by 2pm then three hours drying can take place before covering with non-tainting protective material to prevent rain or moisture forming on the cherry.
- After the initial 24 – 36 hours drying the coffee cherries should be turned once every 15-20 minutes.
- After moisture content reaches 30% the drying mass can be thickened to facilitate optimum drying and prevent mass temperature rising too high.
- During the hottest part of the day cherry should be piled into a ridge and covered. This prevents mass temperatures rising too high and promotes moisture equalisation through the coffee lot. If labour is available and conditions allow then stirring can help avoid the need to pile up the coffee and cover but at night the coffee must still be piled up and covered.
- Drying mass should never exceed 5cm in depth when the coffee is drying from 25 to 12% total moisture.
- The total drying time is usually between 14 – 21 days.

FIGURE 38: DRYING CHERRY ON DAY 15

17.7. DRYING MEDIUMS

Drying coffee is a critical factor in quality. At a basic level drying ensures that coffee remains sound and free from mould during storage. At a more detailed level the medium used for drying and way the drying takes place has an impact on quality.

Temperature and time are two key variables to monitor when drying coffee. As the coffee dries monitoring temperature becomes more important because the coffee becomes drier and more susceptible to temperature change.

Drying capacity management at the wet mill facilitates effective process flow. Bulk densities, total moisture content, and drying time range for processed coffees prior to drying are as follows[60]:

TABLE 28. DRYING TIME FOR PROCESSED COFFEES

COFFEE TYPE	BULK DENSITY	TOTAL MOISTURE	ESTIMATED DRYING TIME
Ripe Cherries	616 kg/m^3	60%	14 – 18 Days
De-Pulped Coffee	846 kg/m^3	55 – 60%	10 – 12 Days
Wet Parchment	665 kg/m^3	50 – 55%	10 – 12 Days

17.7.1. RAISED BEDS

Raised beds traditionally were a method used throughout East Africa but are now being used globally because of quality driven results. This has led to several recommended design changes over recent years but the main variables of drying depth, air humidity, drying medium and partial shading remain central to success.

The basic quality management parameters for raised bed construction are:

- Raised beds should be completely level and of a width of 1.5 – 2m.
- Ideal height is approximately 1m.
- A base of non-permeable HDPE (high-density polyethylene) materials allows for optimum airflow and is both taint free and long lasting.
- Jute and Bamboo are not recommended as dying mediums because of the risk of off taints and improper drying
- The supporting base material should be very taught and free from dips.
- Completely flat structures with a 4cm lip at the sides and end are the most efficient in space management and bed depth homogeneity.
- Elevated shading with non-permeable HDPE (high-density polyethylene) can be installed to regulate drying curves.

FIGURE 39: RAISED BED DESIGN

FIGURE 40: CLOSE UP OF RAISED BED

[60] Coffee: Growing, Processing, Sustainable Production (2009) Edited by J. N. Wintgens

Daily routine is as follows:

- Mark drying beds with lot traceability information and the date when drying was started.
- Initial drying depth and pattern for the first 24 to 36 hours varies by process.
- Optimum drying depth for quality of washed process coffees is 2 – 4cm61 depending on capacity issues.
- 2cm is preferred for control over high quality washed and honey process coffees.
- Coffee should be turned with a hand rake every 15- 20 minutes to even the drying pattern.
- Covering coffee between 11am -2pm regulates drying and improves cup profile.
- Defects including brokens, greens and skins are easiest to remove during skin drying.
- Any dips in the drying bed lead to inconsistent drying depths and poor quality.
- Any coffee falling to the ground should be bulked with mbunis and off grades.
- Avoid rewetting and cover the coffee with non-permeable material if it rains62.
- At night coffee should be mounded into the centre of the bed and covered with non-permeable material to prevent moisture absorption and possible mould growth.
- Coffee is ready to store once it reaches 12% total moisture.
- Record the weight of parchment as it enters the store.

FIGURE 41: HAND RAKING PARCHMENT

Cup profile deteriorates significantly when depths increase beyond 4cm because drying is inconsistent. A simple way to check depth is by placing the index finger into the drying coffee mass. Optimum depth for quality of parchment is up to the first joint after the finger.

[61] The Quality of Wet Processed Arabica Coffee as Influenced by Depth of Parching and Covering Period during Drying by S. Endris, B. W. Senbet (2006)

[62] Guidelines for the Prevention of Mould Formation in Coffee by FAO

FIGURE 42: CHECKING COFFEE DRYING MASS DEPTH. THE COFFEE IN THE PHOTO IS TOO DEEPLY SPREAD

17.7.2. PATIOS

Patios provide a way of drying coffee with low energy cost and low maintenance need, but the initial construction cost is higher than raised beds and a large space is required. They should be built in a place that maximises sun and wind. Do not build them in shaded areas or low areas where temperature inversions may occur.

Different materials can be used but a critical factor is using an impervious surface. Common options are concrete or thin layer asphalt. Drying coffee directly on the ground is not recommended because it leads to mould formation and poor sensory attributes. Drying on tarpaulins laid on the ground is not recommended.

Preventing re-wetting is very important, particularly in the prevention of OTA[63]

Patios often have elevated temperatures compared to raised beds because the impervious surface absorbs heat through the day. However, the airflow is poorer and this must be taken into account when managing drying patterns. This means that during the early stage of drying for both parchment and natural process coffee the maximum depth is one bean. Deeper layering will extend the lag phase, risking mould growth and producing undesirable cup results.

Coffee drying on patios is managed by a worker walking with a rake backwards and forwards through the coffee, following their shadow to maintain straight lines. After the moisture has reduced to 30%, a regular process of increasing depth of the mass while raking takes place. This is as follows:

- Parchment Coffee - 2cm on day 2 - 3cm on day 4
- Whole cherries - 2cm cherries on day 3 - 3cm on day 5 - 5cm on day 7

As with other methods covering from heat of the day, regular turning at least once every 15-20 minutes, and moisture equalisation are important in order to dry coffee correctly. This results in a drying time for coffee within the following ranges:

[63] Guidelines for the Prevention of Mould Formation in Coffee by FAO

- Natural Process: 15 – 20 days
- Parchment Coffee: 10 – 12 days

Patios will also retain heat longer at night.

17.7.3. SOLAR DRYERS

Solar dryers are an advance in controlling the drying environment and can be used in conjunction with either patios or raised beds. If cold damp weather is a problem these are good solutions. Allow for natural process to be completed in environments where drying would be extended beyond 20 days, thus developing negative cups. Airflow control is critical and there must be a vent at either end or the roof. Temperature control and monitoring is recommended if possible and Greenhouse shading netting can be used to regulate temperature.

17.7.4. MECHANICAL DRYERS

A number of mechanical driers are used globally, and the most commonly used are rotary dryers. The design of these is a slow moving horizontal cylinder loaded with coffee that has warm air blown through the cylinder.

These dryers are useful for:

- Fast and controlled pre-drying to 30°C.
- Controlled finishing drying.
- Periods of wet weather because they allow drying to continue.

Risks associated with these dryers are:

- Drying coffee quickly at high temperatures impacts negatively on both initial cup profile and long term shelf life stability of green coffee.
- The maximum temperature for the bean mass when producing speciality coffee is 40°C.
- Coffee can tainted by smoke so the heat source must be controlled and non-direct
- Airflow has to be managed.

FIGURE 43: MECHANICAL ROTARY DRYER

17.7.5. PARABOLIC DRYERS

Parabolic dryers (sometimes called greenhouses) are a technology advance in controlling the drying environment and can be used in conjunction with either patios or raised beds. These dryers are a clear polythene surround with either a curved or triangular roof over the coffee.

If cold damp weather is a problem these are good solutions because drying is faster and re-wetting prevented. However, too fast drying is a major risk so airflow and temperature control is critical to success if parabolic dryers are used. Venting at either end of the dryer and the use of nursery shade netting during hot parts of the day can be used to regulate temperature in a simple way. For effective temperature control and humidity monitoring, data logging is recommended if possible.

18. STORAGE[64]

Once dried the quality of coffee remains stable for many months if kept in the correct conditions.

When building storage for parchment or cherry green coffee a number of considerations need to be considered to maintain the product quality. Basic building parameters are as follows:

- Buildings face an east-west, north-south plan with long sides on east-west and short sides of the building where the sun travels most through the day.
- Avoid low humid areas for any warehouse location.
- The store should be well ventilated.
- There is a constant temperature and humidity not exceeding 22°C and 60% RH.
- Foundations are insulated and weatherproof.
- Thermal insulation is built into the design.
- Buildings are structurally sound, pest proof and free from leaks.
- A sealed, waterproof and impervious concrete floor.
- Avoid natural light to retain product quality. Where artificial light is used it should be shatterproof lighting.
- Monitor temperature and humidity of the store in several places.
- Contract a pest control programme on site.

When storing coffee within the warehouse place bags:

- On dry, clean and sound pallets.
- At least 0.8m away from walls.
- In dark condition the majority of time.
- Away from doors and windows that open regularly.
- Keep at least 2m from the top of a coffee stack and the ridge of the roof.

18.1. BAG TYPES

Do not store parchment or dried cherries in jute because it leads to a fast deterioration of cup quality and can taint. Studies have shown that hermetic big bags offer an excellent method of preserving quality over extended periods in storage.[65]

Big bags need a forklift truck (ideally gas or electric powered to limit fumes in the warehouse) and as such require significant capital investment. Where this is not possible, storage in grainpro bags is preferential. If using grainpro bags, these can be placed inside jute to improve coffee stack stability.

18.2. LOT SEPARATION

Lot separation, identification and monitoring quality changes over time are essential elements of good stock control. Keep the best quality lots at the opposite end of the store to poorer, possibly defective off grades to prevent taints. Assess coffees on a monthly basis to determine if physical and sensorial characteristics are maintained.

[64] Green Coffee: Guidelines for Storage and Transport ISO 8455:2011(E)

[65] Evaluation Of The Sensory And Colour Quality Of Coffee Beans Stored In Hermetic Packaging By Borem et Al (2012)

During transport to storage bagged coffee is covered to prevent contamination or weather damage. Once coffee arrives at a warehouse all lots must be checked for moisture content and for signs of pests or infestation.

Coffee is a hydroscopic food and can absorb both moisture and taints from the surrounding environment. For this reason it is always stored separately from materials with strong odours. These can include:

- Tobacco
- Spices or herbs
- Defective coffees
- Chemicals or fertilizers
- Engine fumes

18.3. STORAGE PERIOD

Milling coffee directly after processing produces known problems. Astringent cup profile is common and colour can fade quickly. Conversely, coffee quality in both cup score and appearance is improved if it is given a resting period of three months before milling[66]. Cup quality is maintained for longer periods beyond three months if coffee is stored in parchment form (for washed or pulped natural coffee) or dried cherry (for natural processed coffee) and it is important to keep coffee in this form until the final preparation for market.

[66] The Importance Of The Resting Period In The Coffee Grain Aspect And Beverage Quality By M. Y. Rendon et Al (2010)

19. LABORATORY QUALITY CONTROL

Laboratory quality control of coffee at the farm or co-operative level is a key tool in understanding the quality being achieved by processing units, where problems exist, and where opportunities for improvement lie. The potential value of coffee being produced by a farm or co-operative washing station can also be estimated during quality assessment, and a range of different products defined for sale to global clients.

Understanding the principles of sample assessment carried out in a cupping lab, what equipment can be used to assess coffee, and knowledge of how to set and maintain standards of assessment set the foundations for an ongoing effective quality assurance system. Such systems yield a better understanding of the coffee products on a farm or co-operative. This allows in turn for refined product development whereby product segmentation can be controlled, new innovative products can be developed and profiled, and new markets accessed.

19.1. LABORATORY DESIGN

A well designed coffee analysis laboratory allows for the effective analysis of various elements of coffee quality to the standards being tested without impacting on the generated results in any way.

The SCAA have defined a basic laboratory standard. In addition challenges and standards to consider for laboratory design include space allocation, working environment and equipment discussed in detail below.

19.1.1. SPACE ALLOCATION

A number of factors that should be considered in space allocation are:

- Building size capacity for all elements of the support functions that allow the testing to take place including storage and cleaning
- Separation of roasting from cupping and green area to prevent sensorial impact
- Division of different tests, both physical and sensorial
- Allocating sufficient space for all sensory tests to be carried out comfortably based on the number of people working in the space
- Allocating sufficient space for equipment
- Siting a laboratory facing northwards in the northern hemisphere or southwards in the southern hemisphere

19.1.2. WORKING ENVIRONMENT

The working environment should be a light non-reflective neutral coloured non-invasive space with non-absorbent surfaces for sensory analysis. It is important to maintain a clean odour free workspace on a daily basis. For effective sensory analysis lighting should meet requirements of ISO 3664 and environment temperature should be 21 - 25°C and 45 – 55% relative humidity.

19.1.3. EQUIPMENT

It is important that the health and safety needs of the equipment is managed and there is utility planning including adequate capacity of electric load, gas flow and water resource. Water should meet the SCAA water quality standards.

When planning the equipment needs of a coffee laboratory, storage of equipment as well as working space for analysis should be taken into consideration. Many pieces of equipment

including roasters and espresso machines have a relatively high electrical load and specific needs for gas. This should be designed in at the build stage to ensure all equipment is fully functioning.

Many tools that support coffee sensory analysis in a laboratory need regular calibration in order to yield relevant results. The working tolerance of all equipment varies from manufacturer to manufacturer and this is an important consideration when purchasing laboratory equipment. The tolerance of a machine will ultimately define the accuracy of the laboratory.

In addition, cleaning and maintenance schedules should be prepared for all equipment to keep it in fully working order. This is especially true of high risk equipment such as roasters and equipment where hygiene standards impact directly on sensorial analysis such as grinders, cupping vessels, and brewing equipment.

TABLE 29. GENERAL SUMMARY OF EQUIPMENT COMMONLY FOUND IN A COFFEE LABORATORY

GENERAL	GREEN COFFEE	ROASTING	CUPPING/SENSORY
Plumbing - water	Huller	Roaster	Cupping Bowls/Glasses
Plumbing - gas	Sizing screens	Colour Meter or Colour Tiles	Cupping Spoons
Electricity - lighting	Total Moisture Content Meter	Digital Timers	Digital Scales to 0.1g accuracy
Electricity - equipment	Water Activity Meter	Profiling Software	Digital Timers
Green coffee sample storage	Density Meter	Sample Trays	Coding
Green coffee sample analysis	Black Light		Espresso Machine
Roasting room allocation	Digital Scales		
Cupping room space allocation	Sample boxes/Tins		
Office space allocation	Vacuum Packer		

19.2. GREEN COFFEE ANALYSIS

On receipt to the warehouse there are a number of physical green coffee tests to carry out. This is to check if the coffee lot is safe for storage and also what its intrinsic quality is. Sampling should be done as soon as possible and the sample drawn of any coffee for testing the sample must be representative of the total lot. This is done by bulking small samples taken from a number of bags in the coffee lot. Standards vary globally as to the number of bags to take samples from but guidelines generally recommend:

- 10% of bags for homogenous lots from a farm or farm block
- 20% of bags for lots made up of a number of farmers

Once a coffee is sampled there are a number of physical checks that can be carried out before a sample is roasted and cup tested. These are discussed in more detail following sections.

19.2.1. SIZE

At the dry mill coffee is graded into homogenous sizes. This is important for physical appearance and more importantly for roasters because coffee of the same size and physical conditions will roast consistently.

TABLE 30. GLOBAL SCREEN STANDARDS

SCREEN NUMBER	10	12	13	14	15	16	17	18	19	20
ISO Dimensions (mm)	4.00	4.75	5.00	5.60	6.00	6.30	6.70	7.10	7.50	8.00

19.2.2. APPEARANCE

The colour of coffee varies depending on a number of quality factors. Beyond colour changes as a result of process variations there is an optimum colour range for the appearance of green coffee. An even blue-green colour is generally considered to be the ideal target. Too light a sample can indicate negative factors like aged coffee, variable colour can indicate poor drying, and too dark a colour can indicate negative factors like high moisture content.

19.2.3. DEFECTS

A defect is "anything that diverges from a normal bean inside the lot and that can be produced in the field, or during the harvest, processing, transport and storage" (Teixera and Teixera 2005)[67]. These defects provide the basis for quality classification systems. Classification systems involve counting the types of defect present and the number of these defects present in a representative sample of coffee. This defect count is scored, with scoring working on the principle that some defects are likely to lead to more severe cup quality problems than others. After a physical analysis cup testing will also identify the presence and type of off-taints in the coffee.

All coffee should be graded first to the standards outlined by the Coffee Board of Malawi. Beyond this grading, high value markets will often ask for coffee to be graded further to meet either globally recognised standards such as the SCAA system or internal company specifications. Ultimately, high value markets are looking to source coffee as free from defects as possible.

TABLE 31. A SUMMARY OF KEY PHYSICAL DEFECTS, THEIR CAUSES AND IMPACT ON CUP QUALITY[68][69]:

DEFECT NAME	CAUSE	IMPACT ON CUP
Black/Partial Black	**Agricultural** • Blackening from over fermented pigment • Over ripe coffee fallen to the ground • Unripe coffee fruit picked has a Carbohydrate deficiency **Processing**	**Medium to high impact on cup** • Ferment or stinker taste • Dirty • Mouldy • Sour phenolic taste

[67] Espresso Coffee: The Science of Quality Edited by Illy and Viani (2005)

[68] Arabica Green Coffee Defect Handbook by SCAA

[69] Coffee: Growing, Processing, Sustainable Production (2009) Edited by J. N. Wintgens

	• Unripe coffee dried at high temperatures • Poor drying/re-wetting	
Mould	**Agricultural** • Fallen coffee collected for processing **Processing** • Faulty humidity and temperature conditions during storage and transport	**Very high impact on cup** • Mouldy/off flavour • Loss of all aromatic and taste characteristics • Health risk
Fungus Damage	**Agricultural** • Left over cherries in harvest sacks • Picking fallen cherries **Processing** • Poor cleaning of fermentation tanks • Delay from processing to drying • Storage in high humidity and temperature • Poor colour sorting in dry mill	**Medium to high impact on cup** • Ferment or stinker taste • Dirty • Mouldy • Sour • phenolic taste
Sour	**Agricultural** • Picking over-ripe or fallen cherries **Processing** • Water contamination during wet processing • Over recycling water in wet processing • Dirty fermentation tanks • Over-fermentation from slow drying • Storage with too high moisture content • over-fermentation in the fruit still attached to trees during humid conditions	**High impact on cup** • Stinker cup in extreme cases • Sour, winey or acetic acid characteristics
Insect Damaged	**Agricultural** • Berry borer attack **Processing** • Poor removal of berry borer damage in dry mill • Storage weevils	**Medium to high impact on cup** • Ferment or stinker taste • Dirty • Mouldy • Sour/ phenolic taste
Chips/Pulper Nipper	**Agricultural** • Picking un-ripe coffee **Processing** • Too much pressure from pulpers during pulping • Processing un-ripe coffee through pulpers • Poor dry mill machinery	**Medium impact on cup** • Chemical and ferment off-flavours • Reduced aromatics • Reduced acidity • Scorching during roasting

	calibration	
Shells/Ears	**Agricultural** • This is a naturally occurring phenomena, caused by genetics	• Shells may char and produce burnt or charred flavour
Floater	**Processing** • Partially unknown cause • Improper storage or uneven drying are the suspected causes	**Medium impact on cup** • Reduced flavour and acidity
Frost Damaged	**Agricultural** • Frost	**Medium to high impact on cup** • **Minor damage** leads to a loss of aroma and flavour, a decrease in mouthfeel intensity and quality • **Major damage** leads to strong off-flavours
Immature	**Agricultural** • Unripe cherries harvested **Processing** • Failure to remove unripes during processing	**Medium impact on cup** • Increased bitterness and astringency • Grassy, straw-like or greenish flavours
Withered	**Agricultural** • Stressed trees due to drought • Underdeveloped fruit • Poor fertilization **Processing** • Poor density separation	**Low to medium impact on cup** • Loss of acidity • Reduced flavour characteristics • Weed-like or straw-like
Crystallised	**Processing** • Excessive drying temperatures of over 50°C	**Low to medium impact on cup** • Beans break during roasting • Loss of acidity • Reduced flavour characteristics
Mottled/Spotted	**Processing** • Faulty drying • Re-wetting • Broken parchment	**Medium impact on cup** • Reduced acidity • Reduced flavour and aroma • Slight mouldy or sweaty off flavour
Old/Past Crop	**Processing** • Extended storage of coffee • Delayed or extended transport	**Medium to high impact on cup** • Reduced acidity • Increased astringency • Increasing severity of woody off-taint

Foreign Matter	**Processing** • Can be added to coffee throughout processing • Sticks and stones not removed during harvesting • Foreign matter not removed from patios • Magnets, and de-stoners not working in dry mill	**Equipment Damage** • Damage to roasting equipment • Health issues
Parchment	**Processing** • Poorly calibrated milling equipment	**Low impact on cup** • Reduced flavour • Risk of fire in roasting
Hull/Husk	**Processing** • Poorly calibrated pulping equipment with washed coffee • Poorly calibrated hulling equipment with natural process coffee	**Low to medium impact on cup** • Large amounts can lead to a range of off taints including dirty, earthy, ferment, mouldy, phenolic • Risk of fire in roasting

Beyond detection of defects within the normal light spectrum, black (also known as UV) light analysis of green coffee appearance yields very good results in detecting a number of defects within a sample. When a sample of green coffee is placed under black light defects including stinkers, floaters, spotted beans, and pulper nippers will glow white compared to sound beans.

19.2.4. MOISTURE

The total moisture of green coffee is the combined total of free and bound moisture in coffee expressed as a percentage. ICO resolution 420 sets the parameters of 8 – 12.5% total moisture for coffee to be classified as 'speciality' quality.

The extremes of this scale are best avoided for optimum quality. Excessive moisture content can lead to mould and bacteria growth as well as a number of specific flavour taints and deterioration in storage and shipping. Very low moisture content can lead to shortened shelf life and problematic flavour development during roasting.

A number of moisture meters are available in the marketplace and commonly test moisture content indirectly via conductivity for a sample of green coffee, parchment or husk.

19.2.5. DENSITY

The bulk density of a sample is the weight to volume measurement of green coffee and is usually measured either in g/ml or kg/hal.

There is a correlation between the density of coffee and the altitude it was grown at with higher altitude coffee having a higher density. High density coffees are also roast evenly and are a sign of good seed development. Low density coffees can be a sign of defective coffee and poor development. Large beaned varieties will also have different densities to standard sized coffee varieties.

The simplest way to measure density is to weigh a cylinder of known volume with coffee beans and subtract the weight of the cylinder itself. Some total moisture meters will also read the density of a green coffee sample.

19.2.6. WATER ACTIVITY[70]

Water activity is a measure of the energy status of the water in a system and is defined as the ratio of the vapor pressure of water in a material (p) to the vapor pressure of pure water (po) at the same temperature.

At present no official standards exist but there is an increasing field of data that suggests a stable range for green coffee is 0.55 – 0.65 when total moisture is 12% and the temperature is 21°C. Beyond 0.65 sugar starts to hydrolyse and cup quality can be noticeably affected and high water activity is commonly attributed to drying the coffee too fast or milling the coffee very early after post-harvest processing.

19.2.7. RETAINING SAMPLES

An accessible library of retained lot and type standard samples is an essential part of a working laboratory. These samples provide a number of functions covering basic quality assurance through to panellist calibration.

Samples should be kept in non-taint containers and have coding or information that provides all information likely to be needed. This includes the lot information collected while processing and any contracting or pricing information required. The bulk must be large enough to allow for multiple samples to be drawn over time if needed.

Types of sample to retain are:

- A retained sample of any coffee lot sold within an 18 month period.
- Qualitative type samples of specific qualities for ongoing sample analysis.
- Quantitative type samples for ongoing sample analysis.
- Regional profile type samples.
- Standard qualities for calibration of panellists.

At a basic level good effective temperature and humidity control similar to the standard of bulk storage will preserve the quality of samples as long as possible. To improve sample lifespan, small vacuum packing machines than can keep samples at a vacuum of 90% or more are very useful pieces of allows for maintaining quality standards from season to season. The ability of being able to retain sample quality over extended periods is particularly useful for maintaining quality standards across seasons.

[70] Speciality Coffee: Managing Quality Edited by T.Oberthűr et al (2012)

20. SAMPLE ROASTING

Temperature and time evolution are the two main factors that control roasting quality and consistency and the goal of sample roasting is to consistently develop coffee samples. Once roasted this consistency allows for accurate assessment of stock lot characteristics for quality and correct classification in terms of cup score, flavour profile, and potential value. Standardising sample roasting ensures that any variation in quality of samples perceived by cuppers is a result of sample quality factors rather than roasting.

All coffee roasting has the same underlying principles and there are three main stages of coffee roasting. These are a drying stage where moisture in the bean is evaporated, a roasting phase where physical and chemical changes happen to the bean, and a cooling phase where the bean is brought back to ambient temperature.

TABLE 32. TERMINOLOGY COMMONLY USED IN THE ROASTING PROCESS

STAGE	DESCRIPTION
Charge temperature	The temperature at which green coffee is loaded into the roaster
Turning Point	The lowest temperature in a roasting cycle which is the point at which the temperature drop experienced after the initial loading of green coffee stops and temperature starts to rise
Gold	At the end of the drying phase the roast loss of the coffee will be approximately 5%. The bean has not expanded in size but will appear straw/gold coloured. This signals the start of the roasting phase proper
Cinnamon	When the bean temperature moves beyond 155°C maillard reactions take place. These non-enzymatic browning processes, in which reducing sugars react with amino acids, are what give coffee it's colour. During the early stages of these reactions the coffee will appear cinnamon coloured. Beyond this temperature sugars will start to caramelise and bean size starts to expand.
First Crack	The audible popping noise as the cell walls of coffee is broken open by the increased pressure of the gas mixture from the bean during the roasting process. These gases then escape. The bean size will have expanded to between 50 – 100% larger than the starting green coffee depending on the roast style
Roasting Phase	The transforming of sugars and proteins into browning products, physical and chemical changes in the bean until desired colour and time is reached for the beans to be released out of the roaster
Development Time	The time from the full onset of first crack to the end of the roast
Cooling	The optimum time for coffee to reach ambient temperature after roasting is 2 – 4 minutes. Any extension beyond 4 minutes leads to a reduced acidity and change in other sensory characteristics

20.1. SAMPLE ROASTING PARAMETERS

The target roast time for sample roasting depends on the roaster size, type, and manufacturer. Whether a roaster has both gas/electric burners and airflow changes the way the roaster is operated. It is important not to manipulate the roast too much because this

can create a sensory experience closer to a production roast than a reflection of the actual attributes of the coffee stock lot. To achieve consistency of roast colour for all samples the roaster operator should have:

1. Good quality high spectrum lighting with a CRI rating of 96 and kelvin rating of 5000 – 6500k.
2. A standard whole bean roast sample to refer to

Typically sample roasters will be horizontal drum roasters in a range of 100 – 300g in size. For this roaster size basic parameters are:

- Optimum roast time. Standard between 8.30 and 10 minutes
- Roast time Variation = +/- 30 seconds from laboratory standard
- Development time range = 60 – 90 seconds
- Development time variation = +/- 20 seconds
- Colour target = Agtron 65 – 70

To maintain consistency in roasting maintaining a consistent charge temperature and charge weight creates standard conditions from which the variations found in coffees begin to present themselves. Supporting this, a roast log is a commonly used method of maintaining roasting standards.

FIGURE 44: SAMPLE ROASTING STAGES

This simple log means roaster operators can identify if a roast is on target against the laboratory specification. Any roast falling outside of specification should be discarded and a further sample of the stock lot immediately re-roasted. A sample roasting log can be found in annex 5.

It can be seen above that the colour goal of Agtron 65-70 (whole bean) is light, typically at the point just when first crack finishes. An extension of the roasting process beyond this colour will mute acidity characteristics and develop undesirable roast characteristics.

Beyond this data collection it is possible to fit thermocouples to coffee roasters and link these to profiling systems on computers. This allows for further detail to be gathered and improved refinement of roast control to be carried out.

Before roasting it is important to gather information on stock lots likely to alter the roast time. Having sample information to hand before roasting means that a roaster operator can make alterations to the machine settings at the beginning of the roast. This will improve roast consistency and determine if any variation from the roasting standard is acceptable. Factors that are likely to change roast times significantly are:

- Total moisture content of green coffee samples
- Density of green coffee samples
- Species or variety variations in green coffee samples

Large beaned varieties are not common in Malawi but are grown. These require a different heat application in the beginning of the roast in order to fully develop the centre of the bean. Further care is needed during the second half of the roast to retain the characteristics of the stock lot.

The Robusta species roasts very differently to Arabica and needs a separate roast profile again. This is partly a result of a very different chemical composition but also a result of bean shape and density[71]. Typically it will need more heat throughout the roast to develop properly. The optimum roast height for sensory analysis is slightly darker than Arabica and in the range of Agtron 60 – 65. Once roasted, coffee samples should be stored in airtight bags or containers for between 8 – 24 hours before being cupped for quality attributes.

20.2. CLEANING AND MAINTENANCE

Roaster cleaning maintenance is an often overlooked job function in a cupping laboratory. Manufacturer manuals will detail the regularity and type of maintenance needed for a specific machine. However key points are:

Chaff removal	Silverskin remaining on the coffee bean surface and from the centre cut is released during roasting. This is extremely flammable and will be collected in a specially designed chaff collector on the roasting system. This should be emptied at least daily or more regularly if required
Exhausts	Coffee exhausts will build up with residues over time and this will change the airflow properties of the roaster. This can lead to an increased fire risk but also a change in the sensory characteristics developed in coffee when roasted. All exhaust pipes should be opened up and cleaned at least monthly to prevent build-up of materials and ensure smoke can be released from the roasting system safely
Heat resistant grease	Coffee roasters have many moving parts and require regular lubrication with specially designed heat resistant grease. Most sample roasters have grease nipples on moving drives where lubrication takes place and these should be checked at least weekly
Spare parts	Carrying a number of key spare parts for sample roasters reduces down time
Contact details	Hold the contact details for the local roaster distributor and maintenance company

[71] Food Chemistry by H.D Belitz, W. Grosch, and P. Schieberle (2009)

21. CUPPING

Once physical analysis and roasting of samples has been completed, the cup testing of stock lots is the final and arguably the most important analysis that takes place. Ultimately it will be the quality of the brewed coffee that will be the final determining factor in any purchase decision throughout the whole supply chain.

21.1. CUPPING GOALS

Traditionally the goal of cupping in classification systems has been to identify defects and taints present on sampled lots. While this remains true the role of cupping laboratories in any individual sample assessment has expanded to:

- Define the positive sensory attributes present
- Qualify cup scores for samples and as such determine the appropriate market segment
- Identify specific traits in samples appropriate for different global buyer preferences
- Understand quality across a range of different post-harvest processes
- Provide technical feedback to producers on the impact of field practice and processing on cup profile.

This move has been made in part with the increase in coffee consumption based on positive sensory characteristics as opposed to being free from defects. This further refinement and detail of analysis means that control of the sample preparation is crucial to successful analysis. In addition, all sensory analysis has a risk of being subjective to some degree. To maintain objectivity:

- Use a group of trained panellists to assess coffee
- Work with specific cupping methodologies
- Work in a specifically designed cupping laboratory where possible
- Use globally recognised cupping terms
- Ensure all cuppers cup regularly
- Apply statistical analysis to results
- Calibrate panellists regularly

21.2. CUPPING METHODOLOGIES

Many methodologies for cupping exist and the most standard method is to follow SCAA protocol for sample preparation. Buyers commonly use this method because it is used internationally and as a result will be familiar with sensory test parameters.

Underlying this methodology is the laboratory design and equipment used.

21.3. COMMON CUPPING FORMS

The two most commonly used cupping forms in processing countries are the SCAA and Cup of Excellence forms. Both forms are based around a 100 point scoring system (where 100 points is optimum) but each form works to a different standard and rankings in each method are not interchangeable. In addition, certain sections of the SCAA form are based around an in/out sensory analysis protocol. Specifically:

- SCAA is typically used to define if a coffee is of speciality quality or not – those coffees scoring over 80 points are rated as speciality if the green coffee quality of the sample also matches a defined standard. Protocols for assessment using the form in detail are outlined by SCAA publications.

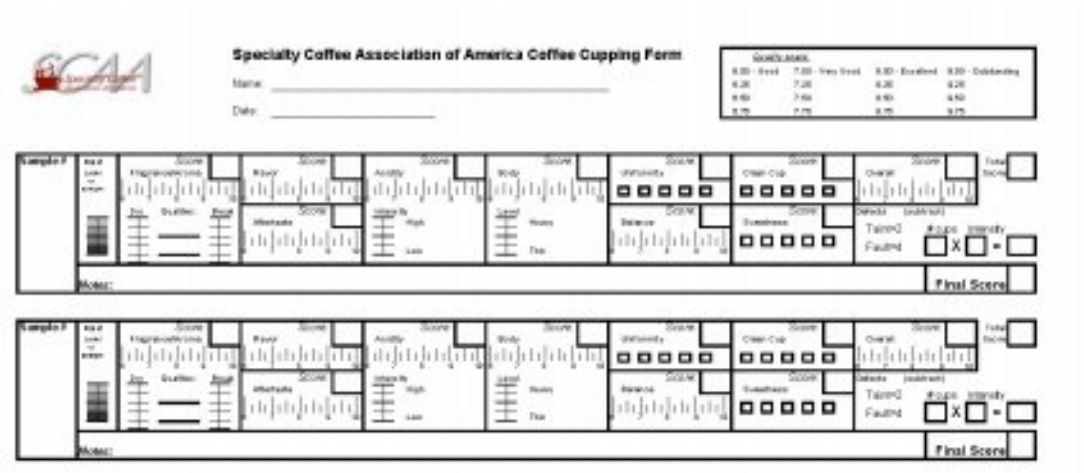

FIGURE 45: SCAA CUPPING FORM

- The Cup of Excellence form is typically used to find the best coffee from within a set of very good coffees and to identify the specific characteristics of the coffees in more detail. Protocols for assessment using the form in full are outlined by the Alliance for Coffee Excellence.

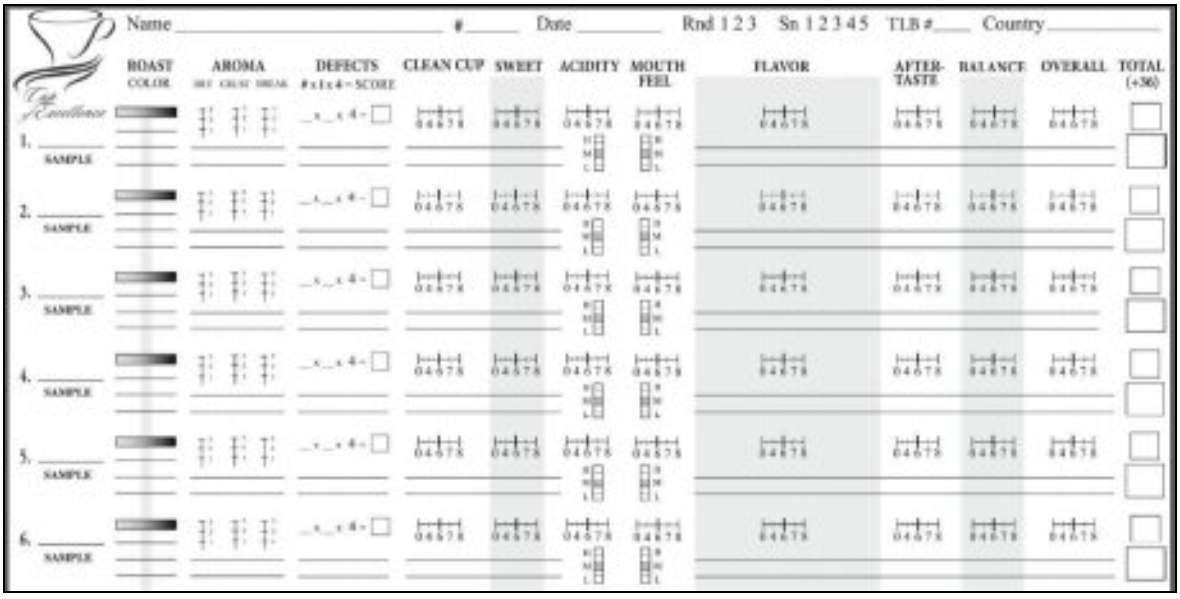

FIGURE 46: CUP OF EXCELLENCE CUPPING FORM

End buyers may reference these forms when asking for samples so having a sensory team who understand each system is crucial in making sure the right samples are selected on arrival at the cupping lab, and then are sent to the right buyer.

22. MARKETING

Markets for green coffee vary hugely in a number of ways and the level of sophistication and price sensitivity of any two coffee consuming countries are never the same. Influencing factors can include the strength of a regional economy, the maturity level of market, historical preference for certain brew methods and general regional food preference. The start of effective marketing to different global segments is defining distinctive products from a farm or co-operative through green coffee analysis and cup tasting. These will be uniquely different in the following ways:

1. Intrinsic quality
2. Post-harvest process
3. Cultivar difference
4. Taste profile preference
5. Volume availability
6. Product value
7. Third party accreditation

Core product descriptions will always match the country of origin grading system and further grading details for sampling and contracting will either match a buyers own internal specification or those of globally recognised standards. An example of this is a coffee being sold with a supporting cup score using the SCAA cupping system.

Beyond basic product definition and contracting, ensuring product consistency from season to season and the engagement of buyers is important in the ongoing success and visibility of coffee farms and co-operatives.

22.1. SAMPLING

All buyers expect to be sent samples at various stages of the contracting process. Samples must always fully represent a coffee being negotiated with end buyers and when sending samples to buyers for testing there are several standard definitions[72]:

Stocklot Samples: The actual coffee that will be shipped in a contract is concluded.

Approval Samples: Must be drawn from the actual lot being negotiated for shipment under the term SAS (subject to approval of sample).

Type Samples: Represents a quality agreed with the buyer. The quality must be matched in all aspects.

Indication Samples: Indicates what you expect to be able to ship. This will usually be followed up with an approval sample.

Shipment or Outturn: Fully representative of a lot that has been shipped.

The minimum sample size sent should be 350g of clean green coffee, which matches the sample size required under the SCAA grading protocol, but some buyers may request larger volume depending on their testing protocol. Samples should be sent:

- Logged with a reference code that links the sample sent to the laboratory retained sample and warehouse stock-lot.
- In food grade non-taint packaging that is durable for a global courier service.
- In clean green coffee form hand graded to the pre-agreed specification.

[72] The Coffee Exporters Guide (3rd Edition) by International Trade Centre (2011)

- Detailing the standard grade specification, lot size and third party accreditation details.
- With supporting lot processing data if requested by the buyer.

22.2. MICRO-LOT AVAILABILITY

Speciality buyers often look for much smaller lot sizes as little as 5 – 10 bags clean coffee. This is because many high end speciality roasters are small in size and are unable to purchase full container loads. For buyers of this type having access to a reliable shipping consolidator at an exit port helps facilitate trade.

For micro-lots, the information gathered during post-harvest processing is an essential marketing tool for the end buyer and passing this information quickly and freely will also facilitate awareness of the grower with end consumers. In addition detailed farm information and GPS data helps consuming markets have a point of reference for the coffee.

Micro-lot quality should ideally represent the top 10% of quality achieved by a processing site and have been selected during cupping analysis as being of a specific quality. An estimated cup score of the lot along with the sensory profile of the coffee can help match the right micro-lot with the right buyer and help the end buyer promote the coffee better once sold.

22.3. GLOBAL MARKETS

Markets for green coffee vary hugely in a number of ways and the level of sophistication and price sensitivity of any two coffee consuming countries are never the same. Influencing factors can include the strength of a regional economy, the maturity level of market, historical preference for certain brew methods and general regional food preference. The start of effective marketing to different global segments is understanding these preferences before defining distinctive products from a farm or co-operative through green coffee analysis and cup tasting for clients. These will be uniquely different in the following ways:

1. Intrinsic quality
2. Post-harvest process
3. Cultivar difference
4. Taste profile preference
5. Volume availability
6. Product value
7. Third party accreditation

Core product descriptions will always match the country of origin grading system and further grading details for sampling and contracting will either match a buyers own internal specification or those of globally recognised standards. An example of this is a coffee being sold with a supporting cup score using the SCAA cupping system.

Beyond basic product definition and contracting, ensuring product consistency from season to season and the engagement of buyers is important in the ongoing success and visibility of coffee farms and co-operatives.

22.4. BUYER VISITS

Buyers increasingly travel to partner farms and expect high levels of quality control in place. Those that travel regularly will have good technical knowledge of harvesting, processing and third party accreditation systems.

Buyers are likely to carry out supplier audits when visiting producing countries and many of these internal audits will be at least as detailed and rigorous as a third party accreditation

visit. Making sure that an informed technical member of the farm or co-operative is available to answer questions on all areas of the product flow from nursery through to dry mill will mean that the buyer is likely to have their questions answered

Buyers often visit during the peak of the processing season and wish to work long days from dawn right through to the end of the working day. There are a number of reasons for this including:

- Video and photography of a farm or co-operative will play a role in final marketing.
- It is an excellent time to understand how quality is managed by a producer.
- Buyers may want to process a micro-lot whilst visiting and follow the lot through to drying.
- They may carry out all their quality audits during the peak harvest.
- They may wish to cup early season samples and discuss product flavour profiles with the cupping team.

Buyers will have their own specific reasons for visiting producers and no two buyers will want the same itinerary. In preparation for these visits researching dietary needs, finding safe local hotels with access to water, heating and internet, understanding the timetable needs of the buyer, preparing swift transport, and building in some exposure to local cultural life to the timetable are all important considerations to making a successful trip.

23. CERTIFICATION

This chapter provides an overview of the certification process, the various standards available to coffee farmers and the potential positives and challenges associated with each standard.

The basic rationale behind certification for coffee growing is that consumers are willing to pay more (**a premium**) for coffee that is of **a higher quality standard** or is farmed using practices that are **more sustainable**.

The use of the term '**sustainability**' here captures three main elements:

- **Social:** improving the quality of life of farm employees and those that they support.
- **Environmental:** uses production methods that have a reduced impact on biodiversity and environmental degradation.
- **Economic:** farmers have improved market access and receive a fair price for their coffee.

The voluntary process of accreditation should be pursued if farmers stand to make a **commercial gain** from it. Therefore each individual farm/ farmer group (depending on the standard) must consider independently whether the benefits achieved from certification outweigh the costs involved with implementing the desired standards. A list of relevant individuals or organisations to contact for further information or certification is given in Annex 1. .

Certifications based on the production and processing standards employed along the supply chain are monitored and communicated to consumers through the use of **"marks"/ "seals"** which can be used on product packaging/ advertising.

Certification can sometimes be an expensive and lengthy process as producers must sometimes pay fees for the assessments as well as bearing the costs associated with compliance. Therefore many producers find it difficult to afford being accredited with more than one scheme. Knowing which certifications to prioritise because they are most applicable and will bring the most benefit is therefore of vital importance.

The table below highlights the focus areas of the most prominent standards.

TABLE 33. GENERAL CRITERIA OF COMMON CERTIFICATION PROGRAMMES FOR COFFEE[73]

CERTIFICATION SEAL	ENVIRONMENTAL CRITERIA	SOCIAL CRITERIA	ECONOMIC CRITERIA	QUALITY STANDARDS
Organic	√√	√		
Fairtrade	√	√√	√	
Rainforest Alliance	√√	√		
Bird-friendly	√√	√	√	
UTZ Certified	√	√	√	
4C	√	√	√	√

√: Weak-Moderate criteria - √√: Strong criteria

These standards are considered in more detail in the following subsections.

73 Adapted from Lentijo, G. M., and Hostetler, M., (2011). Evaluating Certified Coffee Programmes. http://edis.ifas.ufl.edu/uw351#FOOTNOTE_1

23.1. ORGANIC

"Create a verified sustainable agriculture system that produces harmony with nature, supports biodiversity and enhances soil health."

Certification Options

The International Federation of Organic Agriculture Movements (IFOAM) provides a standard (the IFOAM Standard) that is considered a good baseline for organic producers. Areas of the IFOAM standard that are relevant to coffee production include good ecosystem management, soil and water conservation, appropriate choice of crops and technologies, pest/disease management, processing and packaging/ labelling. Information about the standard's specifications, applications and the fees scheme can be accessed through their website.

The IFOAM "Family of standards" are organic standards that have been officially endorsed by the Organic Movement as part of the IFOAM Organic Guarantee System. These are mapped out in the below figure. Information on how these standards compare can be discovered through the IFOAM website.

Considering that there is a multitude of different standards offered worldwide it may be prudent for producers to choose a certification that is specific to their target market. For example, if all of the coffee grown from a farm is sold into the US then being certified under USA Organic Regulation (otherwise known as the USDA National Organic Program) would be of considerable benefit. Organic operators certified in accordance with any of the standards in the family can apply for use of the mark on their products and therefore use the mark identifiable to a specific region or the more general IFOAM mark.

Points for Consideration

OPPORTUNITIES	CHALLENGES
• Sales of organic coffee rose at around 29% annually between 2000 and 2008[74] with the total global market for organic food and drink in 2008 reaching US $50.9 billion.[75] • The sales opportunities are particularly strong in more developed countries (specifically the US, Canada, EU, Russia and Japan[76]). • Average price differential paid to producers from USDA certified produce was $0.255 per pound.[77] • Where the cooperative is sizable then producers must develop an Internal Control System (ICS) where the group demonstrates through training and internal inspection that the organic standards are met. The certification auditor checks the system rather than the individual farmers.[78]	• Organic certification only focuses on small-scale farms even though large-scale coffee estates are influential in promoting ethical supply chains. • Smallholders must be organised into a cooperative with more than 15 members. This is a barrier for isolated famers or farmers located where the governance structures/ skills are not present for farmers to form cooperatives. • Transition period to sustainable practices may be lengthy (up to 3 years) depending on what chemicals were used on the land previously. This makes it economically difficult for farmers to make the transition because the main costs come during the transition while the produce must still be sold at the conventional prices.

74 http://buyorganiccoffee.org/362/facts-about-organic-coffee/

75 The World of Organic Agriculture: Statistics & Emerging Trends 2011

76 SCAA sustainability council (2010), Sustainability Coffee Certifications: A Comparison Matrix

77 SCAA sustainability council (2010), Sustainability Coffee Certifications: A Comparison Matrix

78 http://www.grolink.se/epopa/Publications/FAO%20manual.q.pdf

	• Many small farms are organic by necessity because they cannot afford chemical inputs however they also cannot afford to pay for certification and therefore cannot achieve the price premium. • Annual re-certification is required.

23.2. FAIRTRADE LABELLING ORGANISATION (FLO)

"The FAIRTRADE Mark gives assurance to retailers and consumers that Fairtrade producers in the developing world are getting a fair deal for their work. Fairtrade certification also ensures adherence to strict social standards that foster healthy working conditions and prohibit child labour. Their environmental standards ensure that natural ecosystems are not degraded and cultivated land is used sustainably."[79]

Certification

Flo-cert is an international certification company owned by Fairtrade International but independently operational. It is responsible for the inspection of producers against FT standards on an annual basis. The standards specific to coffee can be accessed online.[80]

Points for Consideration

OPPORTUNITIES	CHALLENGES
• Benefits of marketing/awareness campaigns carried out by Fairtrade International. • If assessors decide standards are no longer being met, producers are given the support and time to enable them to rectify the problems. • Producers receive at least the Fairtrade minimum price (varies by coffee type, origin and if it is grown organically) and additionally the Fairtrade Premium. The premium is an additional amount that is utilised to improve living conditions following guidelines set out by Fairtrade standard. • Producers can apply for financial assistance to cover fees of inspection and audit from the Producer Certification Fund. May groups also receive assistance in paying certification fees from commercial partners or from NGOs/other partners.	• All actors in the chain must be certified. Therefore producers must find out if there are Fairtrade buyers willing to buy their coffee in the countries they want to target. Simply getting certified themselves does not guarantee that they will be able to sell their product on Fairtrade terms to the desired consumers. • Continuous improvement by producers is required. • Small holders must be organised into a cooperative with more than 15 members. This is a barrier for isolated farmers or farmers located where the governance structures/skills are not present for farmers to form co-operatives. • FLO Focus on small-scale farms even though large-scale coffee estates are influential in promoting ethical supply chains. • The application process will cost €500 plus the cost of the visit (the overall cost will vary depending on the number of days required). • Annual re-certification is required.

79 www.ico.org/sustaininit.asp?section=About_Coffee#sthash.CRVyHmAR.dpuf

80 See www.fairtrade.net/fileadmin/user_upload/content/2009/standards/documents/2012-04-01_EN_SPO_Coffee.pdf

23.3. RAINFOREST ALLIANCE

"By promoting sustainable land-use practices, the Rainforest Alliance helps protect the environment and ensure the well-being of workers and their communities."[81]

Certification

The Rainforest Alliance certification is granted based upon compliance with standards compiled by the Sustainable Agriculture Network. They capture human workers' rights, community relations, protection of biodiversity / wildlife, conservation of natural resources, integration of crop / waste management and prohibition of hazardous chemicals.[82] Full information on the standards can be sourced through the website.[83] Businesses that source products grown on certified farms and farms that meet the Sustainable Agriculture Network (SAN) standard may apply to use the Rainforest Alliance Certified seal. RA-Cert is the Rainforest Alliance's auditing division which provides independent and transparent verification, validation and certification services based on the standards. The percentage of certified content used in a product determines how the seal may be used on the final product.

Points for Consideration

OPPORTUNITIES	CHALLENGES
• During 2012, 375,000 metric tons of coffee, representing 4.5% of global production, was grown on Rainforest Alliance Certified farms, a 45% increase over 2011. [84] • International brands (including McDonalds, Kenco, Costa and Nespresso) stocking coffee which is Rainforest Alliance Certified has helped to boost public awareness. • Support is provided to certified producers and those in the process of achieving certification through aiding them in identifying their financial requirements, providing business advice, advising on how to use the mark to their best advantage and linking them with supporting institutions. • By implementing the Sustainable Alliance Network's (the Rainforest Alliance partners sustainable farm management system, farmers can control costs, gain efficiencies and improve crop quality.[85] • San standards are available both for producer groups and for farms.	• All businesses in the chain (buying, trading, mixing) products from certified farms must achieve SAN/Rainforest Alliance Chain of Custody certification in order to call their product certified. [86] • Annual re-certification is required.

81 http://www.rainforest-alliance.org/sites/default/files/uploads/3/RainforestAlliance-SealThatSells-2011.pdf

82 http://sanstandards.org/userfiles/SAN-S-1-1_2%20Sustainable%20Agriculture%20Standard_docx(1).pdf

83 http://sanstandards.org/sitio/sections/display/3

84 http://www.rainforest-alliance.org/newsroom/press-releases/sustainable-coffee-grows

85 http://www.ico.org/sustaininit.asp?section=About_Coffee#sthash.PNl93HO5.dpuf

86 http://www.rainforest-alliance.org/agriculture/certification

23.4. SMITHSONIAN BIRD FRIENDLY

"The Smithsonian Migratory Bird Center (SMBC) gives this certification to farmers in order to promote shade-grown organic coffee plantations that can play a key role in the conservation of our global environment and of migratory birds that find sanctuary in these forest-like plantations."[87]

Certification

The criteria applied in the field for Bird Friendly coffee are designed to provide additional accreditation for those farms whose interaction with the environment exceeds organic practices. The aim is to sensitively integrate coffee cultivation to agroforestry systems for maximum benefit to the ecosystem. Additionally, some socio-economic criteria include that healthy environment for workers is created, pollution at the processing stage is avoided, community benefits are encouraged, and, farmers are guaranteed fair and stable prices, access to markets and access to credit.

The shade criteria under the Bird Friendly standard are more stringent than those of the Rainforest Alliance standard. It requires at least 11 species of canopy trees per hectare and the main canopy must be over 40 feet in height. Furthermore, the coffee must have more than 40% foliage cover provided by three forest layers. Full shade criteria can be found on the website.[88] [89]

Points for Consideration

OPPORTUNITIES	CHALLENGES
• Potential benefits of using shade trees (e.g. better tasting coffee, recycling organic matter saves money). • Although no minimum price is set producers can use the certification to negotiate a better price for their coffee. As much as 18% more than organic coffee can be achieved in the long term. • Eco-tourism possibilities for birdwatchers, nature lovers and agricultural tourists. • Inspections can be done at the same time as the organic inspection to save time and money. • Audits are only once every 3 years because shade cover does not change very much on an annual basis and it will save money for producers. The organic inspector who visits the site in the intermediary years will need to visually assess the shade practices. • Provides a completely traceable product to the consumer – could be valuable instrument for market purposes.	• All certified Bird Friendly coffee must also be certified organic. • Producers must pay for initial periodic audits. • Affects all of the actors along the chain: Importers pay a fee of $100/yr, and roasters pay 25cents/lb to be registered. These fees are used to support bird conservation research. • Many other plants besides the coffee plants require management. • Relatively new compared to other certifications and currently only sold in certain markets (e.g. US, UK, Canada, Japan and the Netherlands). • Few certified farms in Africa.

87 http://edis.ifas.ufl.edu/uw351 using information from the SMBC website: http://nationalzoo.si.edu/SCBI/migratorybirds/coffee/default.cfm.

88 http://nationalzoo.si.edu/SCBI/MigratoryBirds/Coffee/criteria.cfm

89 http://nationalzoo.si.edu/scbi/migratorybirds/coffee/quick_reference_guide.cfm

23.5. UTZ CERTIFIED

"UTZ Certified stands for sustainable farming and better opportunities for farmers, their families and our planet. The UTZ program enables farmers to learn better farming methods, improve working conditions and take better care of their children and the environment."[90]

Certification

The certification represents the UTZ Codes of Conduct. Up until the 1st June 2014 there were three product specific standards under the certification for coffee, cocoa, tea however these have now been amalgamated under one Core Code. The standards offer a good baseline across environmental, social and economic criteria. A full list of requirements are detailed on the website[91] including information about the changes that have been made to the new standard. [92,93] An approved certification body undertakes the auditing and the central UTZ team give the final stamp of approval and authorise the company/ group to trade as UTZ certified.

Points for Consideration

OPPORTUNITIES	CHALLENGES
• Producers do not have to pay for taking part in the programme besides auditing costs. • Application to both mainstream and speciality coffees. • High take-up in the ethical coffee market – almost 50% of all certified sustainable coffee in UTZ certified. [94] • Profile of the certification is rising as brands such as Mars, Ahold, Ikead, D.D Master Blenders 1753, Migros, Tchibo and Nestle get involved. • Offers the possibility to track and trace the coffee from the shelf in the store to the farmer. • Farmers have a better crop using more efficient means due to training in improved farming practices. • Producers trained to think more commercially. • UTZ helps to improve accessibility to capital and credit opportunities for producers. • With the certification comes an international network of support including buyers, development organisations, trained agronomists and UTZ field standards. • Additional benefits may be provided to workers (e.g. farmers and their families are provided with healthcare, education, better living conditions, good working standards) meant that employees likely to be more productive and moticated and business may find it easier to recruit individuals. • Different kinds of certifications are available for different types of producers (e.g. groups, invdividuals, multi-sites, mulit-groups).	• Certification must be renewed annually through assessment and therefore fees for audit must be paid annually. • Continual improvement is expected from producers: Core criteria must be fulfilled from the outset and more detailed requirements are added over following years. • To make auditing a less complex process, UTZ ask that groups of small producers must first have a functioning Internal Management System (IMS) before applying for certification. • The constant quality control involved and internal management system/ reporting systems mean that farmers may have an increased administration burden. • Potential for high administrative burden. • For the final product to possess the UTZ certified seal then all the "downstream" actors must follow the chain of custody standards.

90 https://www.utzcertified.org/en/aboututzcertified/whatisutzcertified

91 http://www.utzcertified-trainingcenter.com/home/images/stories/library_files/EN+UTZ+Certification+Protocol+v3.0.pdf

92 http://utzcertified-trainingcenter.com/home/images/stories/library_files/EN%20UTZ%20Changes%20Document%202014.pdf

93 http://www.utzcertified-trainingcenter.com/home/images/stories/library_files/EN+UTZ+Code+of+Conduct+Coffee.pdf

94 https://www.utzcertified.org/en/aboututzcertified/whatisutzcertified

23.6. 4 C COMMON CODE

The 4C Association is a global platform for stakeholders in the coffee sector to come together and collectively work to improve the economic, social and environmental conditions of those working in the industry. The Code of Conduct has four main pillars: rules of participation for trade and industry, support mechanisms for farmers, a verification system and participatory governance structure.

Certification

The Code encompasses 10 Unacceptable Practices and a 4C Code Matrix presenting 28 principles for guidance on good sustainability practices. A traffic-light system acts as the indicator for how effectively the organisation aligns itself with the 28 principles. To achieve certification the producer (or "unit") must have reached an "average yellow" level on the traffic light system as well as having excluded the 10 Unacceptable Practices. "Average yellow" means that within each dimension (economic, social, environmental) there may be some "red" practices so long as there is equal number of "green" to balance them out. The full details of these criteria can be found online.[95]

The certification system starts with a self-assessment and mapping exercise of all the business partners/ organisational structure. Then an independent verification is completed by a third party.

Collective consultations are used for making revisions to the code. Consultation is currently underway for a new version which will be effective as of mid-2015.

Points for Consideration

OPPORTUNITIES	CHALLENGES
• A 4C License is valid for three years. • Open to coffee producers at all levels. • Seen as an improvement tool. To aid this, producers can get increasingly efficient by being trained in better agricultural practices, access to new technologies/materials, applying integrated pest management systems, record keeping and enhancing management capacity. • Freely available online information. • Seen as a first step/baseline in reaching other certifications. • Benchmarking partnership held with Rainforest Alliance for a 4C license without any additional cost or verification procedures. Be part of the international community to share new thinking/ ideas and co-produce the standards. • Continuous improvement approach.	• All actors in chain face a fee for membership (which increases along the chain). • Must pay for verification on services (cost will depend on different factors e.g. the daily rate of the verifier, travelling expenses). The average cost per external verification is thought to be approximately €2,800. • During the 3 year interim period between audits the producers must conduct self-assessments on a yearly basis and send their results to the 4C Secretariat. • If they are expanding to include more farmers, 4C Units may need to be visited annually • 4C verifiers may conduct additional unannounced random verification visits. • No on-product seal or labelling as promotion is mainly used business-to-business. • No minimum price but free to negotiate price based on high quality and sustainable production methods.

95 http://www.4c-coffeeassociation.org/uploads/media/4CDoc_001a_Code_of_Conduct_v1.4_en.pdf http://www.4c-coffeeassociation.org/uploads/media/4C_Code-of-Conduct_IllustratedGuide_en.pdf

24. CARBON FINANCING

24.1. CLIMATE CHANGE AND CARBON SEQUESTRATION

The changing global climate is a concern to everyone as it threatens our established agricultural production systems, our water resources and our energy supplies, and it may force us to change the way that we live. Just as people have caused climate change, so we can implement activities to reduce its impact or even reverse its effects. One approach to achieve this is through changing forest management. Half of a tree's dry weight is carbon and therefore the global carbon balance is greatly impacted by the presence or absence of forests. In this context forestry activities may be implemented in two distinct ways in order to enhance global forest carbon stocks:

Forest conservation: where existing forest areas are protected from future deforestation or forest degradation. This is also referred to as reduced emissions from deforestation and degradation (REDD).

Planting trees for reforestation: As trees grow they remove atmospheric carbon dioxide and store it as carbon in all the growing parts of the tree i.e. the stem, bark, branches, leaves and roots. The carbon will remain stored in the tree biomass until the tree is cut down and for even longer if parts of the harvested tree are used for long lived wood products such as in houses and furniture. This is known as carbon sequestration or carbon removals.

Tree planting for reforestation is the activity that is applicable to coffee farmers in Malawi that wish to access carbon finance and this will therefore be the focus of this chapter.

24.2. CARBON MARKETS

A fuller understanding of the threat posed by climate change encouraged the first attempts to make 'polluters' pay for their greenhouse gas emissions in the 1990s. The concept is that polluters pay someone else for carbon emission reductions (i.e. units of carbon offset from a forestry project measured in tonnes of carbon dioxide) which they then use to report against their emissions. This was perceived to be a win-win solution as polluters can offset their emissions (which makes them look good) whilst providing the finance required for forestry activities in other locations (to either sequester carbon or prevent future emissions and deliver other socio-economic and biodiversity co-benefits).

Forestry projects that are developed with the objective of selling carbon offsets must pass a number of tests to be considered 'eligible' and the volume of carbon offsets generated must be measured using approved methods. There is however still no single global standard that may be applied to projects but broadly speaking two distinct markets have evolved:

Compliance: For example, under the Kyoto Protocol developed nations are given emission reduction targets. The Clean Development Mechanism (CDM) under the Kyoto Protocol allows projects in developing countries to generate carbon credits from afforestation/ reforestation (AR) which can be used by developed countries to meet their emission targets. CDM projects are supposed to contribute to sustainable development, however it has had limited success for AR because developing and implementing projects is administratively complex and costly. Other compliance (or cap and trade) schemes such as the European Union Emission Trading Scheme (EU ETS) or the Californian pre-compliance market either do not allow for forestry credits or for credits generated in other countries. The current state of compliance markets for forestry offsets is unlikely to provide any significant opportunities for small to medium sized coffee producers in Malawi.

Voluntary: Buyers in the voluntary market are typically companies that wish to purchase offsets as part of their corporate social responsibility (CSR). Many of these companies lean

toward forestry offsets because they offer social and environmental benefits beyond carbon sequestration. The voluntary market currently makes up more than 95% of forestry carbon credits transacted[96] but within the voluntary market there are various offset certification options. The most widely used certification body is the Verified Carbon Standard (representing 57% of all transacted forestry offsets in 2012) because there is a strong market preference for VCS certified offsets and dual project validation by the Climate, Community, Biodiversity Alliance (CCBA). Other certification options of relevance to coffee growers in Malawi include Plan Vivo (which is designed specifically for smallholding farmers in developing countries) and the Gold Standard (first forestry methodology approved in 2013).

The voluntary market is likely to be the best current market option for coffee growers in Malawi. The voluntary market for forestry offsets has been growing slowly since 2010 with an average price of $7.8 per offset paid in 2012.[97] The market is highly stratified with premium prices paid for offsets from projects that demonstrably produce significant socio-economic and environmental benefits.

24.3. DEVELOPING A CARBON PROJECT

TABLE 34: KEY BENEFITS AND RISKS ASSOCIATED WITH A CARBON PROJECT

BENEFITS	RISKS
• Diversified land use • Carbon credits / finance • Reduced use of chemical fertiliser • Improved coffee yields and quality • Increased soil and plant protection • Long term supply of timber products from on farm trees • Diversified income base from sale of timber products • NTFPs such as beekeeping and fodder	• Reduced coffee yield • Increased farmer workload • Cost of implementation • Long term requirement to invest in MRV • Carbon markets are quite volatile • Impermanence of carbon stocks • Potential conflict between participating farmers

One of the first considerations for small holders will be how to aggregate or 'bundle' together with other small holders in order to achieve a viable scale. It will not be possible for individual small holders to develop, implement and register their own projects so they will have to form a 'group scheme' with other coffee farmers that are looking to implement similar activities. In this way many of the costs of carbon evaluation and project set up can be spread across multiple sites. A single baseline would be established to cover all project locations, and generic carbon uptake models developed to avoid the need of performing complicated and costly calculations for each individual site. Such an approach does require close working with the relevant communities and other stakeholders for the development of tree planting systems. Participating farmers are then restricted to using these pre-defined tree planting systems which specify which tree species may be used, how they should be planted and managed. A group scheme also necessitates an on-going administrative presence to co-ordinate monitoring and reporting at the project level, to act as a single point of sale for carbon offsets and to redistribute payment for carbon offsets generated back to the farmers.

[96] Molly Peters-Stanley, Gloria Gonzalez and Daphne Yin (2013). Covering New Ground: State of the Forest Carbon Markets 2013 Report published by Forest Trends' Ecosystem Marketplace.
[97] Ibid

It may be possible for medium scale coffee producers to develop their own projects (which may allow them more autonomy) but it is likely to be more profitable to participate in carbon offset trading as part of a group scheme.

All farmers entering into a carbon sales agreement must be able to demonstrate clear right of land tenure and ownership of all future potential carbon sequestration rights for the duration of the project.

The commitment period for farmers entering into a carbon offset sales agreement is typically between 20 – 100 years i.e. it is very long term. During this period there will be restrictions on the way that trees are managed (i.e. they should be maintained in accordance with the pre-agreed technical specification). During this period access should be permitted to the project area when required for monitoring and third party verification.

24.4. ELIGIBLE ACTIVITIES

Carbon sequestration in coffee plantations may be achieved through one of the following:

Planting shade trees with coffee: Where shade trees are grown together with coffee plants farmers may be paid for the carbon sequestration benefits of that system because of the carbon sink created and the nutrient recycling through natural mulching and reduced need for chemical inputs. Full details on planting with shade trees can be found in section 8.5.

Boundary tree planting: The boundary planting system may provide coffee farmers with another opportunity to create carbon sinks, access carbon markets whilst also demarcating their property boundaries and providing other livelihood benefits such as fuelwood, poles and lumber or NTFPs such as fodder or beekeeping. Boundary trees will typically be planted in single or double rows with 2 m to 5 m between trees, subject to land availability and shading requirements.

24.5. POTENTIAL GAINS

Forestry carbon projects require the application of rigorous methodologies to measure and monitor their carbon benefits because there are a large number of unknown variables that will impact the rate at which tree planting activities on coffee farms in Malawi may generate certified carbon offsets. These variables include planting and farming practices (including species of tree chosen, spacing, fertiliser usage, management regime, effect on mulching), the chosen certification body and level of risk associated with the project.

An accurate estimation of the projects potential to generate offsets will be obtained by carrying out a feasibility study and by compiling the Project Design Document (PDD) which will address all of the variables listed above. However, typically, planting shade trees will generate between 2 – 6 tCO_2 / ha / yr.

Actual certificates of emission reduction (offsets) are only issued to a project after third party verification. Certificates of emission reduction may be issued in two different ways:

- Ex-post certificates are issued after monitoring and verification typically on a five year cycle.
- Ex-ante certificates are issued ‘up-front’ once a project has been validated and the activities (tree planting) have been completed.

Relevant Project Examples

A. Carbon projects that involve coffee growers

Example 1. The Scolel Te Plan Vivo project in Mexico was registered in the mid 1990's. One of the eligible activities to the small scale farmers that participate in this project is to plant shade trees with coffee. The shade tree planted are *Cedrela odorata* and *Swientenia macrophylla* planted at 10m X 10m (100 tree per hectare) with a 25 year rotation for timber. Carbon sequestration potential is 143 tCO_2 above the initial soil and vegetation carbon baseline.

Example 2. The Emiti Nibwo Bulora Plan Vivo project in Tanzania has developed a dispersed inter-planting technical specification to be used by small scale coffee producers in Kagera District. The system involves planting 200 trees per hectare (using a planting spacing of 10m X 5m) with *Markhamia lutea, Maesopsis eminii, Albizia lebbeck, Albizia coriara, Acacia nilotica, Acacia polyacantha, Acrocarpus Fraxinifolius* and *Cedrela odorata.* Carbon sequestration potential is 61 tCO_2 above the initial soil and vegetation carbon baseline and allowing for a 20% risk buffer.

B. Carbon projects in Malawi (which do not involve coffee growers)

Example 3. The Trees of Hope Project in Neno and Dowa District (Malawi) has been developed by the Clinton Development Initiative and was registered with the Plan Vivo Foundation in 2011. This project is already working with 1,148 smallholders and 142 community groups planting mixed woodlots, mango orchards, citrus orchards, boundary planting and dispersed interplanting. This project does not involve coffee farmers.

Example 4. VCS validated project: Fuelling A Greener Future for Farmers In Malawi Through The Use Of *Jatropha Curcas*

Example 5. VCS project in preparation (in combination with CCBA): Kulera Landscape REDD+ Project for Co- Managed Protected Areas, Malawi.

25. RENEWABLE ENERGY

It is important for Malawian coffee farmers to take advantage of the opportunities available to minimise energy costs which will improve profitability and insulate the business from severe energy price fluctuations. In this section we will cover the various projects available for coffee farmers, and the potential problems.

Malawi has seen a relatively substantial deployment of small scale solar photovoltaic electricity production. Hydro-electricity has a long history in Malawi and provides the majority of grid electricity from a number of large installations on the Shire River, alongside smaller installations where smaller and steeper rivers have been exploited. Farm waste streams can be turned into viable energy sources via anaerobic digestion ("biogas"). Biogas installations are currently clustered around Mzuzu due to the local university's expertise.

25.1. POTENTIAL PROJECTS

25.1.1. ENERGY AWARENESS

All organisations with a substantial energy use should be engaging with their staff to encourage energy saving behaviours (e.g. switching equipment/lighting off when not in use, ensuring maintenance schedules are adhered to, and following recommended operation of boilers/equipment) and achieve up to 5% energy savings with little capital outlay. This will have greatest impact where there is a large workforce.

25.1.2. IRRIGATION: RATIONALISING ROUTES AND SOLAR PUMPING

Coffee production involves a substantial amount of water for irrigation and cherry/bean processing. In most cases this will equate to a substantial requirement for water pumping and an equivalently high energy use. Coffee farms should rationalise the routes of their irrigation, to avoid any unnecessary height gain, as pumping water uphill requires substantial amounts of energy. Energy consumption can also be reduced through reducing water volumes, for example by converting to precision/drip irrigation methods. Once energy requirements have been reduced through rationalisation it becomes viable to use solar PV electricity generation to power the irrigation pumps. Farms with smaller pumps already may find it easier to bring power demand down to a level which can be provided by solar pumps, but savings could be greater for organisations rationalising their irrigation routes.

25.1.3. BIOMASS BRIQUETTES

If there is a substantial heat demand on site (for example for kitchens for the workforce, or drying processes for other agricultural products) waste vegetable matter from agricultural processes should be gathered, dried and compressed into briquettes for use within cookers/boilers to reduce the demand for current fuels. Where the current fuel is wood this will help to reduce deforestation.

If there is not the demand onsite for this fuel source, the material could be sold as a fuel source for domestic use to help reduce the pressure on wood fuel in the area. The sale of this fuel could be undertaken by the farm, or by a separate spin-off company.

25.1.4. LIGHTING EFFICIENCIES AND CONTROL

Many organisations have T8 or T12 fluorescent lighting which could be replaced by more efficient T5 equivalents which can result in savings of around 30% compared to T8, or 50% compared to T12. The installation cost of replacing fittings and lamps can be quite substantial and will be most cost effective when the fitting required replacement anyway. Savings will be greatest where long operational hours are required.

Another way to reduce lighting energy consumption and cost would be to install occupancy controls to ensure that lighting switches off when rooms are not occupied. Where a large number of lights can be controlled by one sensor this can prove highly cost effective.

25.1.5. MOTORS AND DRIVES

The organisation should assess all old motors for efficiency (i.e. determine whether the actual RPM is the same as that stated). Re-wound motors can lose a significant amount of their power output, while maintaining the same power input, resulting in reduced efficiency. Energy savings will be greatest where old high-power motors are replaced.

In addition, drives should be assessed to determine if any V-belt drives could be replaced with flat-belt drives. Flat-belt drives have lower resistance, and as such can result in a 5% energy saving – however V-belt drives may be required if torque levels are high.

25.1.6. WIND

If a location is thought to have an average wind speed of greater than 5m/s this should be confirmed by installing a met mast for at least 12 months (purchased or hired). This data can then be used to calculate the energy generation potential and support funding applications. The investment required would make this impractical for most smallholders.

25.1.7. HYDRO[98]

The cost of installing hydro-electric generation can vary significantly as it is influenced by the amount of civil engineering required. The investment required would make this impractical for most smallholders.

25.1.8. MICRO-SOLAR FOR STAFF ACCOMMODATION

Coffee farms with staff accommodation could invest in micro solar photovoltaic panels to provide electricity. This could have a substantial impact on quality of life if the accommodation currently has no electricity. However, if grid connected, this is an expensive solution to the problem of power-cuts, and a battery charging system may be preferable.

25.1.9. EFFICIENT DOMESTIC / COMMUNAL STOVES

The organisation could assist their staff in reducing domestic energy consumption by providing energy efficient cook stoves. These can be produced by a small local SME (either part of or separate from the farm) providing local employment and income opportunities.

25.1.10. ANAEROBIC DIGESTION

Some coffee farms grow or process a variety of crops, producing a significant amount of waste vegetable matter in addition to coffee waste, and may provide latrines for their work force. Combining human and vegetable waste in a digester will produce methane-based gas which can be used as a fuel source[99] either as fuel for heating (or cooking), or to fuel a gas-fired generator producing electricity. Electricity generator engines are only around 33% efficient – this should be taken into account when deciding whether to utilise the gas for electricity production or directly for heat.

The digester size should be roughly 120-fold the daily input quantity at average expected digester temperatures over 25°C, or 180-fold the daily input quantity for temperatures

[98] Table sourced from "Introduction to run-of-river micro hydropower and small hydropower", Renewables First (2011)

[99] Human waste is not a requirement for biogas production but it can help to speed up gas production

between 20 and 25°C.[100] The following calculation is sufficient for a **rough indication of costs**[101]:

- the cost of 6.5 sacks of cement x m3 digester volume plus
- the cost of 5 days' work for a mason x m3 digester volume plus
- the costs of 100 m gas pipes (1/2"), plus
- the costs of two ball valves (1/2"), plus
- the cost of gas appliances which are feasible for this size.

25.2. POTENTIAL CHALLENGES

25.2.1. QUALITY

The private sector market for solar PV is growing but is currently not sufficiently regulated, resulting in poor quality equipment sold at massive mark-ups. It would be prudent to import good quality solar PV equipment from USA/Europe/Japan, rather than purchasing from the open market in Malawi, where many products are from poor quality manufacturers and will not be supported by guarantees. An organisation must be registered with the Malawi Energy Regulatory Authority (MERA) to import any renewable technology. The equipment should be authorised by the Malawi Bureau of Standards (MBS). If the organisation wished to import their own equipment they should register with the MBS, or contact an organisation which is already registered with the MBS.

25.2.2. DELIVERY AND IMPORT TARIFFS

Importing registered renewable energy technology equipment is import duty free; however some parts (e.g. cabling, frames, nuts and bolts, etc.) would not be classed as a renewable energy technology, and thus would be liable for duty/import payments. VAT would be payable on renewable energy generating equipment.

25.2.3. FEED IN TARIFFS

Malawi Energy Regulatory Authority is responsible for drafting and publishing the RE Feed in Tariff scheme. They have advised GEP that the FIT document was submitted to Ministry of Justice, and they are still waiting for this process to be finalised. They are aiming for approval of the document by September 2014 but the change of government may alter this timescale. For details of the latest updates either contact MERA or Imani.

25.2.4. GRID INFRASTRUCTURE

The Malawian electricity grid is in poor condition and demand often exceeds supply. The price of grid electricity is limited, and as a consequence the Energy Supply Company of Malawi (ESCOM) sells electricity at a loss and is dis-incentivised to extend the grid. Thus, sites which are currently off-grid struggle to arrange for grid extensions to their property. There is limited support available for organisations wishing to export electricity to the grid (e.g. line upgrades or transformers) other than the Rural Electrification Programme. Electricity exporters must register as an Energy Producer with the Department of Energy.

25.2.5. MICRO-SOLAR TRAINING

Micro-solar at a domestic scale has been distributed by many NGOs, with varying results. In the most successful long-term projects the recipient has purchased the kit or the energy, perhaps using a micro-loan scheme, incentivising maintenance. New technologies should be accompanied by training/education in appropriate use of the equipment (i.e. solar panel

[100] http://www.gate-international.org/documents/publications/webdocs/pdfs/biogasdigestvol3.pdf
[101] http://www.gate-international.org/documents/publications/webdocs/pdfs/biogasdigestvol3.pdf

positioning, switching lights off, keeping medicine fridge doors shut), and maintenance arrangements made (including how/where to get replacement parts e.g. light bulbs/cables).

25.2.6. LACK OF WIND OR WIND DATA

Wind speed data in Malawi is limited, but what data there is indicates that average speeds are below the standard limit for economic viability of 5 m/s. This wind speed is considered the lower limit for 'average' projects, but where installation/transport costs are higher (as may be the case in Malawi) even a wind speed of 5 m/s may be too low to make a project economically attractive.

Further studies are on-going, namely the Malawi Renewable Energy Acceleration Programme (MREAP), and the results of these studies should be monitored closely to gain a better idea of the commercial viability of wind turbines in an agricultural setting in Malawi.

More viable projects for wind have focussed on domestic/small community scale operations where 'home-made' wind turbines are constructed by the local population with the help of NGOs, using locally available materials such as bicycle parts and wood. These have proved to be financially viable due to the much lower installation costs in comparison with turbines available on the market. Some successful projects are located in the Thyolo area, which would otherwise not be considered commercially viable for wind, based on anecdotal evidence and available wind speed data.

25.2.7. VARIABLE FUEL PRICES

Fuel price fluctuations have a knock on effect on any product which has a significant reliance on oil or gas. This would apply to products which need to be transported internationally, such as components for many RE and EE technologies. International transport also runs the risk of potentially time consuming border crossings.

26. GLOSSARY [102]

WORD OR TERM	DESCRIPTION
Additionality	The project must pass an additionality test to demonstrate that revenue generated from selling carbon credits is required to make the project viable i.e. that the tree planting will not just happen anyway with or without the money received from the sale of carbon credits.
Afforestation/reforestation (AR)	New tree planting activities which may range from dispersed interplanting systems including planting shade trees with coffee on smallholders land to large scale forest plantations.
b.	Bait
Baseline	The baseline is an assessment of past land use in the project location which is used to predict future land use and associated carbon stocks. Carbon credits generated must be additional to the baseline carbon level.
Buffer	Many certification standards (e.g. VCS) stipulate that the project undertake a risk assessment to determine what proportion of the carbon credits generated should be set aside in a risk buffer in case the project fails at some point in the future.
Buying Conversions	Below are useful buying calculations when converting coffee to different units of volume and currency: · c/lb to $/MT = x 22.046 · c/lb to $/KG = x 2.204 · $46 to c/lb = No calculation needed. '$' become 'c'
Caffeine	A bitter alkaloid compound present in the coffee bean that has a dose dependent action on the human body.
Carbon credit	A carbon credit is a tradable permit representing the right to emit one tonne of carbon dioxide. Similar terms used are offsets and certificates of emission reduction.
Carbon sequestration	Carbon sequestration is the removal of atmospheric carbon dioxide through photosynthesis which is stored as carbon in the trees biomass. Also referred to as carbon removals.
CBD	Coffee Berry Disease
Centre Cut	Cleft or groove on the flat side of the bean.
Certification	Assurance that specific rules/ regulations provided under a given set of standards are being met by a particular producer/ producer group.
Certified Stocks	A recorded volume of coffee bags that have been inspected by a designated official and determined to be of a quality that meets the Futures Exchange standards. Certified stocks are kept in designated warehouses
Clean Coffee	A well graded coffee, free of defects.
Coffee Cherry	The flesh fruit of the coffee tree.
CLR	Coffee Leaf Rust
Cultivar	A variety of plant produced by selective breeding.
d.	Dust
Decaffeinated Coffee	Coffee from which the caffeine content has been removed.
e.c.	Emulsifiable concentrate
Fermentation Tank	A specially designed tank, usually made of concrete, and often varying in shape and size with a sloped bottom. They are built for the natural fermentation and

[102] Those in *italics* are taken directly from Part VI of J. N. Wintgens, (2009). "Coffee: Growing, Processing, Sustainable Production" [2nd Ed.]

	degradation of mucilage from coffee
f.w.	Flowable
Fermented	Enzymes on the green coffee sugars causes coffee to adopt a very unpleasant odour and chemical taste.
Futures Market	Participants buy and sell a price for a standard quality of coffee. The futures transaction centres around trading a futures contract based on a physical coffee at a price determined in an open auction – the futures market.
Grading Screen	Coffee is graded by size using rotating or shaking screens. Screen sizes are expressed as numbers (e.g. Screen 16) or as letters (AA). Screen sizes are either measured in 64ths of one inch e.g. screen 18 (18/64 inch) or by mm against a comparable ISO scale (7.10mm). Slotted screens with oblong slits (usually 4.5mm or 5mm) are used to remove pea-berries.
Gran.	Granules
Hedging	Hedging is a trading operation that enables some management of the risks posed by unforeseen price movements. The price risk is offset through opposing but matching transactions in both physicals and futures.
Humectant	A substance that absorbs and retains moisture. With reference to coffee, humectants are used to prevent the air in the storage space reaching dew point (100% RH).
Incoterms	A series of three letter commercial terms published by the International Chamber of Commerce (ICC) for use in global commercial transactions.
Leakage	Leakage is the displacement of GHG emissions from the project area to another location outside of the project which must be accounted for when calculating the net carbon project impact e.g. if a farmer has to clear a forest area because he has planted coffee in a field previously used for food production, the overall carbon balance may be negative.
Mechanical Drier	Static or moving mechanical driers that force heated air through coffee to remove moisture until it reaches 12% total moisture
Methodology	A methodology is a prescribed method used to measure the baseline, and how to monitor the project carbon benefits.
m.o.	Miscible oil
Mucilage	A slimy jelly like and slightly sticky layer that adheres to the parchment. It is 0.5 – 2.0mm thick and composed of pectins and sugars.
Mulching	The practice of spreading fresh or decayed plant material on the surface of the soil with a view to decreasing weed growth, reducing evaporation losses from the soil surface and ultimately increasing soil organic matter levels.
Natural Processing	The whole coffee cherries are dried by sunlight or mechanical driers on patios or racks.
Non-Visual Defect	Off tastes present in coffee only detectable by cup testing.
Option	A commodity option gives the holder the right, but not the obligation, to purchase or sell a given amount of that good at a specified price and after a certain period of time.
Ochratoxin A (OTA)	A mycotoxin produced by species of fungi which is a known carcinogen. Roasting reportedly destroys between 30 - 90+ % percent of OTA present in green coffee and the residual OTA is readily extractable in aqueous solution.
Patio	Drying grounds for parchment coffee and cherries, usually made of concrete or asphalt and built on a slight incline to help drain rainwater.
Project (design) document	The Project Design Document is a standard reporting template for forest carbon projects. The PDD helps to present the information in standardised manner and facilitates third party evaluation (validation).
Pulped Natural Process	The cherries are pulped and then the beans in parchment are dried in the mucilage.

Quaker	Blighted and under developed beans. This shows up as a roast defect as it gives a peanutty taste.
r.f.u.	Baits ready for use
Raised (African) Bed	Flat wire or plastic mesh trays assembled on table legs which are used to dry parchment coffee.
Rioy or Phenolic	A taste with medicinal odour and of notes, slightly iodised phenolic or carbolic. Rio flavour is typically associated with certain Brazilian coffee (but is also encountered elsewhere). In some countries Rio flavour is considered equivalent to phenolic but there is an important difference: true phenolic beans can occur sporadically in a parcel but Rio is usually encountered more generally.
s.l.	Soluble liquid
s.p.	Soluble powder
Silverskin	The dried seed coat of the coffee bean that is usually silver or copper coloured. (Note: It becomes chaff when coffee is roasted).
Skin Drying	The first stage of drying parchment coffee where the internal moisture will be reduced from 55-60% to 20-25%. This may take from 6-12 hours.
Species	A group of interbreeding individuals having some common characteristics not normally able to interbreed with other such groups.e.g. Arabica or Canephora
Stumping	Cutting a tree back, leaving only the stump.
Support & Resistance	Support is an area on the chart under the market where buying interest is sufficiently strong to overcome selling pressure. As a result prices increase. Resistance is the opposite of support and represents an area over the market where selling pressure overcomes buying pressure and a price declines.
Total Moisture	The combined total of free and bound moisture in coffee expressed as a percentage
TRFCA	Tea Research Foundation of Central Africa
Variety	A plant grouping within a species which can be: · defined by particular characteristics resulting from a given genotype or combination of genotypes · has at least one characteristic which distinguishes it from other plant groupings e.g. Bourbon or Typica
Visual Defect	Anything about a bean that means that it is different from a normal bean in the lot. It can be produced in the field or during the harvest, processing, transport or storage.
w.s.c.	Setter soluble concentrate
w.p.	Wettable powder
Washed Process	The removal of the pulp by a pulper and subsequent removal of the mucilage either mechanically, by the use of chemical products, or by fermentation.
Water Activity (aw)	Water activity is a measure of the energy status of the water in a system. It is defined as the ratio of the water vapour pressure in a material (p) to the vapour pressure of pure water (po) at a consistent temperature i.e. aw = p/po = ERH (%) / 100
Woody	Common, coarse flavour peculiar to old crop coffee. Coffee stored at low altitudes in high temperatures/ humidity tends to become woody more quickly.

27. ANNEX 1. FURTHER INFORMATION

27.1. DOCUMENTS FOR FURTHER READING

SUSTAINABLE AND ETHICAL GROWING PRACTICES
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Contact Hervé Bouagnimbeck, Organic for Africa! Coordinator, Address: Charles-de-Gaulle-Str. 5, 53113 Bonn, Germany, Tel: +49-228-9265023, E-mail: h.bouagnimbeck@ifoam.org, www.ifoam.org
Mzuzu Coffee Association, Square Nyasulu, square.nyasulu@yahoo.com, P.O. BOX 20133, LUWINGA, MZUZU, MALAWI
Stanley Chidaya, Malawi Organic Growers Association (MOGA), (and Founding member of IFOAM SOUTHERN AFRICAN NETWORK), Postal address: PO BOX 20288, Lilongwe, Malawi, Tel: +265-01-752818, Email: mogaorganics@hotmail.com
FAIRTRADE
Flo-Cert: An application form can be received by emailing africa-applications@flo-cert.net or a form can be completed at www.flo-cert.net/fairtrade-services/fairtrade-certification/apply-for-fairtrade-certification
Mzuzu Coffee Association, Square Nyasulu, square.nyasulu@yahoo.com, P.O. BOX 20133, LUWINGA, MZUZU, MALAWI
SMBC
In the first instance contact Rob Rice at the centre via their website (http://nationalzoo.si.edu/contact). The website lists a variety of suitable auditing agencies (see nationalzoo.si.edu/scbi/migratorybirds/coffee/certification_agencies.cfm). As none of these are located in Africa options would need to be discussed with SMBC.
UTZ
Only those approved as Certification Bodies (CBs) are authorised to conduct the audits of producers and Chain of Custody actors. If any advice is required on relevant CBs to use then the UTZ office should be contacted via certification@utzcertified.org
AfriCert Ltd., Mrs Susan Mugure, Plaza 2000, 1st Floor, East Wing, P.O. Box 74696, Nairobi, 00200, Kenya. Tel: +254 (20) 8081330 or +254 715041339, info@africert.co.ke, smugure@africert.co.ke, www.africert.co.ke
Control Union Ethiopia, PO Box 7642 AA, Addis Ababa, Ethiopia, MR Lakew Belaineh, lbelaineh@controlunion.com or cueastafrica@controlunion.com Tel: +251 0116298330
SGS Australia, Mr John Buchanan, 480 Princess Highway, Noble Park, VIC 3174, Melbourne, Australia, John.buchanan@sgs.com Tel: +610397903477, Malawi office: SGS Malawi Ltd.
Certification Body, No. 23 Chilembwe Rd., Blantyre, Malawi, Tel: +265 1 622060
Mzuzu Coffee Association
4C COMMON CODE
CERES GmbH, Mr Albrecht Benzing, Vorderhaslach Nr. 1, 91230 Happurg, Germany. Tel: +49

9158928290, benzing@ceres-cert.com, www.ceres-cert.com.
AfriCert Ltd., Mrs Susan Mugure, Plaza 2000, 1st Floor, East Wing, P.O. Box 74696, Nairobi, 00200, Kenya. Tel: +254 (20) 8081330 or +254 715041339, info@africert.co.ke, smugure@africert.co.ke, www.africert.co.ke
Ugocert, PO Box 33743, Kampala, Uganda. www.ugocert.org, ceo@ugocert.org
GENERAL ADVICE AND ENQUIRIES ABOUT CERTIFICATION
Filtone Sandando, International Projects Manager, Eastern African Fine Coffees Association. Been involved with projects building capacity for certification in coffee in Malawi and the region. Tel: +256 (0)412 269 140/1/7, filtone.sandando@eafca.org.

27.4. CONTACTS RELATING TO CARBON FINANCE

EXAMPLES OF PROJECTS
Scolel Te Plan Vivo project - www.planvivo.org/projects/registeredprojects/scolel-te-mexico/
Emiti Nibwo Bulora Plan Vivo project - www.planvivo.org/projects/registeredprojects/emiti-nibwo-burola-tanzania/
Trees of Hope Project - www.planvivo.org/projects/registeredprojects/trees-of-hope-malawi/
Fuelling A Greener Future For Farmers In Malawi – vcsprojectdatabase2.apx.com/myModule/Interactive.asp?Tab=Projects&a=1&t=1
Kulera Landscape REDD+ Project - www.climate-standards.org/?s=malawi
APPROVED CVS BODIES FOR VALIDATION AND VERIFICATION OF LAND USE AND FORESTRY PROJECTS
For a full list of global verified bodies see http://www.v-c-s.org/verification-validation/find-vvb
Bureau Veritas Certification Holding SAS, 495 Summit Road, Summit Park, Morningside, Sandton, JOHANNESBURG Tel. : + 27 (0) 11 217 6300 www.bureauveritas.com/wps/wcm/connect/bv_com/group
Carbon Check (Pty) Ltd 374 Rivonia Boulevard, Ground Floor, Block A, Rivonia, Johannesburg, Republic of South Africa, 2128, info@carboncheck.co.za, www.carboncheck.co.za/contact.html
Eco-Cert - Wynberg Mews, 1 Brodie Road, Wynberg Cape Town, SOUTH AFRICA Tel. +27 21 797 1837, office.southafrica@ecocert.com, www.southafrica.ecocert.com
Lloyds Register Quality Assurance Ltd. - Suite 700, 7th Floor, Victoria Maine, 71 Margaret Mncadi Avenue, Durban Tel: +27 31 305 4441, enquiries@lrqa.co.za, www.lrqa.co.za
SCS Global Services - P.O. Box CT 8469, Cantonments, Accra, Ghana. Richard Bonsi, Ph.D. office: 0233-54180-7849, RBonsi@scsglobalservices.com, www.scsglobalservices.com/africa
OTHER HELPFUL LINKS
Verified Carbon Standard - www.v-c-s.org
Climate Community Biodiversity Alliance (CCBA) - www.climate-standards.org
Plan Vivo- www.planvivo.org

The Gold Standard - www.goldstandard.org

27.5. CONTACTS FOR ENERGY EFFICIENCY (EE) AND RENEWABLE ENERGY (RE) OPPORTUNITIES

BIOGAS
Rhollent Kumwenda – Biogas expert at Mzuzu University - rhollent.kumwenda@yahoo.com
Sithembile TemboNyirenda – Community Energy Development Programme - sithembile.tembonyirenda@gmail.com
Martina Kunert – Renew'n'able Malawi - cd@renewnablemalawi.org
FLAT BELT DRIVES
BMG – one supplier of belt drives in South Africa - http://www.bmgworld.net/pages/home.asp
Lighting efficiencies
Power Speed Electrical – one supplier of T5 lamps and other lighting products in Zimbabwe - http://www.powerspeed.co.zw/
Philips Lighting – a well-respected global lighting brand with good quality control - http://www.philips.co.za
Osram Lighting – a well-respected global lighting brand with good quality control - http://www.osram.co.za
SOLAR PUMP
Kim Jacobson – Blue Zone, Blantyre - kim@bluezone4u.com - http://www.bluezone4u.com/
SOLAR HOT WATER
Andrew Nkoloma Global Solar – one of many suppliers of domestic scale solar hot water systems in Malawi - andrew.nkoloma@gmail.com
Williamson's tea in Kenya has installed solar heat exchangers - http://www.williamsontea.com/our-tea-farms/our-environment/#3
BRIQUETTES
Peter Ivanoff – Austro – one supplier of briquette machines in South Africa - http://austro.co.za/
Peter Underhill – Nukor group – one supplier of briquette machines in South Africa - http://www.nukor.co.za/
Jay Khodiyar Machine Tools – one supplier of briquette machines in India - http://www.jkbriquettingplant.com/
MICRO/ DOMESTIC SOLAR
Andrew Nkoloma Global Solar – one of many suppliers of domestic scale solar PV systems in Malawi - andrew.nkoloma@gmail.com
Martina Kunert – Renew'n'able Malawi - cd@renewnablemalawi.org

Sithembile TemboNyirenda – Community Energy Development Programme - sithembile.tembonyirenda@gmail.com
Sunny Money – an NGO funded by Solar Aid - http://www.sunnymoney.org/
WIND
Power predictor – one Met Mast company - http://www2.powerpredictor.com/
John Gallachar – Gaia wind turbines – a Scottish wind turbine company - http://www.gaia-wind.com/
Ralph Torr – Sgurr Energy – a wind farm development consultancy working with the Scottish Government funded project in Malawi - http://www.sgurrenergy.com/
Sithembile TemboNyirenda – Community Energy Development Programme - sithembile.tembonyirenda@gmail.com
Martina Kunert – Renew'n'able Malawi - cd@renewnablemalawi.org
FUNDING
The funding situation changes regularly and it is recommended that the following contacts are used to provide an up to date picture of the national funding situation.
Malawian and international banks are also thought to be options for loan funding.
Kerry Johnstone at the UK's Department for International Development can provide a good overview of private sector support.
FEED IN TARIFF
Malawi Energy Regulatory Authority is responsible for constructing and publishing details of the Renewable Energy Feed in Tariff scheme.
SITE VISITS
Imani should be contacted in order to find African agricultural estates which are already practicing some of the actions mentioned in this report. Site visits to other estates to view their technologies and practices can be the best way to gain a good understanding of how that technology/practice might be transferred to your estate.
METEOROLOGICAL DATA
Malawian Meteorological Services - a department of the Ministry of Environment and Climate Change Management – offers data for the development of hydro, wind and solar projects. Data requests must be made to the department (this can be undertaken via their website - http://www.metmalawi.com/index.php).

28. ANNEX 2: BUDGET GUIDELINE

SUGGESTED BUDGETING PROGRAMME

SUGGESTED ACCOUNT NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SYMBOLS KEY
Picking Wages													
Picking Equipment													
Infilling													
Weeding													
Conservation													
Waterways/ Contours													
Pruning													
Irrigation													
Pests and Diseases													
Fertilizing													
Mulching													
Roads and Boundaries													
Tools													
Field Transport													
Insurance													
Depreciation													
Salaries													
Travelling													
Nursery													
Borer													
Antestia													

FARMER'S FIELD COSTS

YEAR	COSTS (CURRENCY)	YIELDS (T/ HA)
0		
1		
2		
3		
4-5		

PERCENTAGE BREAKDOWN OF FIELD COSTS (4-YEAR-OLD-COFFEE)

	%	AMOUNT (CURRENCY)/ HA
Roads and Boundaries		
Tools		
Infilling		
Weeding		
Conservation (Mulching)		
Pests and Diseases		

(Labour)		
Chemicals		
Fertilizer		
Irrigation		
Picking Equipment		
Picking		
Processing		
General Transport		
R & M (building)		
R & M (machinery)		
Depreciation		
Insurance		
Bank Interest		
Travel Expenses		

29. ANNEX 3: A GUIDELINE ON HOW TO SET UP A SEED PLOT

29.1. COFFEE MOTHER PLANT AND SEED SELECTION

In Coffee one of the most important criteria to ensure true to type seedlings, which bear the characteristics of the variety is the identification of mother plants for seed collection. Generally Coffee around the world is propagated through seed. In Arabica Coffee a high degree of uniformity can be achieved because of its self-compatible nature. Various methods of vegetative propagation have been perfected but are not commonly used by the farmer due to the high level of skill required.

The protocol mentioned below for mother plant identification and seed selection is a ready reference for use by the TCL estate managers for preparation of seed for the nursery. Estate managers are advised to use the resources books at the R&D Laboratory for further clarifications.

29.2. IDENTIFICATION OF PLANTS FOR SEED FOR MOTHER PLANT IN SEED PLOT

1. Identify the variety from which seed needs to be collected.
2. Identify the fields with the variety, which has given more than 1500 kgs of Green Bean per hectare on a 3 year average.
3. Identify fields that are 6 – 9 years old.
4. First marking and identification to be done on the most robust plants which have good leaf retention, no leaf rust, stem borer, leaf miner or any other disease.
5. Use tags which mention the date of marking and plant code or number. Coding to done as follows. 21100440. This is interpreted as, 21 being the date, 10 the month, 04 being the year and 40 being the plant number.
6. The record is maintained in the Mother Plant selection record.
7. The tagged plants are monitored during the course of the season on the following points.
    - Internodal length.
    - Extension growth.
    - Resistance to pest and disease
    - Thickness of the stem.
    - Ripe fruit harvested.
    - Green Coffee and grades
    - Cup quality.
8. At the end of the first season those plants that have show signs of diseases especially Leaf Rust and Koleroga are deleted from the list of selected plants and tags removed.
9. During the second year the same parameters are observed and recorded. Those that exhibit signs of disease are removed and those that give more of off grades in Green Coffee when compared to the characteristics of the variety are removed.
10. Those plants that have been identified in the second year are selected for Seed collection.

29.3. SEED COLLECTION AND PREPARATION

1. Induce blossom in these selected plants by irrigation.
2. Cover these plants with a white polythene cover on the day of blossom opening to prevent cross pollination.
3. Monitor the fruit set and all other parameters as mentioned in item 7 above to 10. If any plant exhibits any rogue characteristics these are removed.
4. At the time of harvest the red ripe fruits which are not over ripened are picked and hand pulped.
5. The wet parchment is then put in a container of clean water and the floaters and lights removed.
6. Mix this wet parchment with finely sieved wood ash and then spread evenly at a thickness of not more than 5 cms and allowed to dry in the shade.
7. This ash coated parchment is stirred at least 3 times a day and the excess ash is removed after about 5 days.
8. This wet parchment is then had sorted to remove any elephant beans, triangular of damaged beans.
9. This seed is then treated with Mancozeb 50 WP at 1g/kg.
10. The seed can be put out as the seed does not exhibit dormancy.
11. The seed is then sown in beds and is expected to germinate within 45 days.
12. Follow the prescribed nursery practices.
13. Once the Seedling has reached a height of 22 cms it is ready to be put out into the Seed Plot.

29.4. SEED PLOT

1. The Seed Plot which will now carry the new seedlings is laid out as per the Attachment 1.
2. The Plot is monitored for all the parameters as mentioned item 7 – 10 of A.
3. As the plants mature and bear fruit follow parameters as mentioned in item 1 – 13 of B.
4. The selected seeds are from these mother plants will form the base for future nursery operations.

29.5. PROTOCOL FOR EVALUATION OF COFFEE MOTHER PLANTS FOR SEED COLLECTION

Number of varieties introduced:

Number of plants per variety: As per the requirement of estate

Coffee Seedlings are to be planted in two separate plots: A trial plot and a multiplication plot

Experimental design for the trial: Randomized Complete Block Design (RCBD)

Number of replications: 3

Number of Seedlings to be planted per replication per variety: 20

Total number Seedlings per variety to be planted in the 3 replications: 20 x 3= 60

Size of an experimental unit (=plot size per variety per replication): one row of 20 m long

Spacing between rows = 4 m

Spacing between plants within a row: 1 m

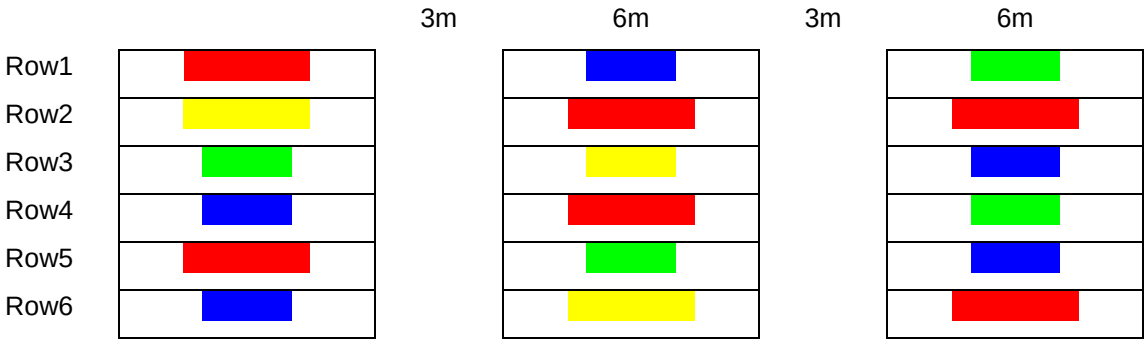
Fertilizer application: Use the same types, doses and method being used by the company

Apply same quantity on each experimental unit. Record the quantity applied

Irrigation: As per standard estate practices

Distance between blocks or replications (separation path): 3 m

Draw the field layout in the field book and label each row with the variety number.



30. ANNEX 4: RECORDING SHEET TEMPLATES[103]

Farm Activity Record

Date	Plot / Field	Activity	Method	No. of Workers	Material Cost	Labour Cost	Outcome / Comments

The table above is an example and can be utilised to record any activities such as:

- Land Preparation
- Planting
- Weeding
- Mulching
- Fertilising
- Crop Protection
- Pruning
- Harvesting

Farm Sales / Income Record

Date	Item Sold / Service Rendered	Quantity	Unit Price	Income	Buyer / Employer	Comments

The table above is an example and can be utilised to record all income generating activities such as:

- Sales of Coffee
- Sales of Other Crops
- Sales of Animals
- Sales of Handicrafts
- Working as Hired Labour
- Other Services

[103] Ibero (Uganda) Limited, (2005). "Manual for Sustainable Coffee Production".

31. ANNEX 5: SAMPLE ROASTING LOG

Sample Roasting Log

coffee nexus

Date: _____ Room Temperature: _____ Room Humidity: _____ Roaster Model: _____

Roaster Initials: | Batch Size (g) : | Target Colour:

Target Profile

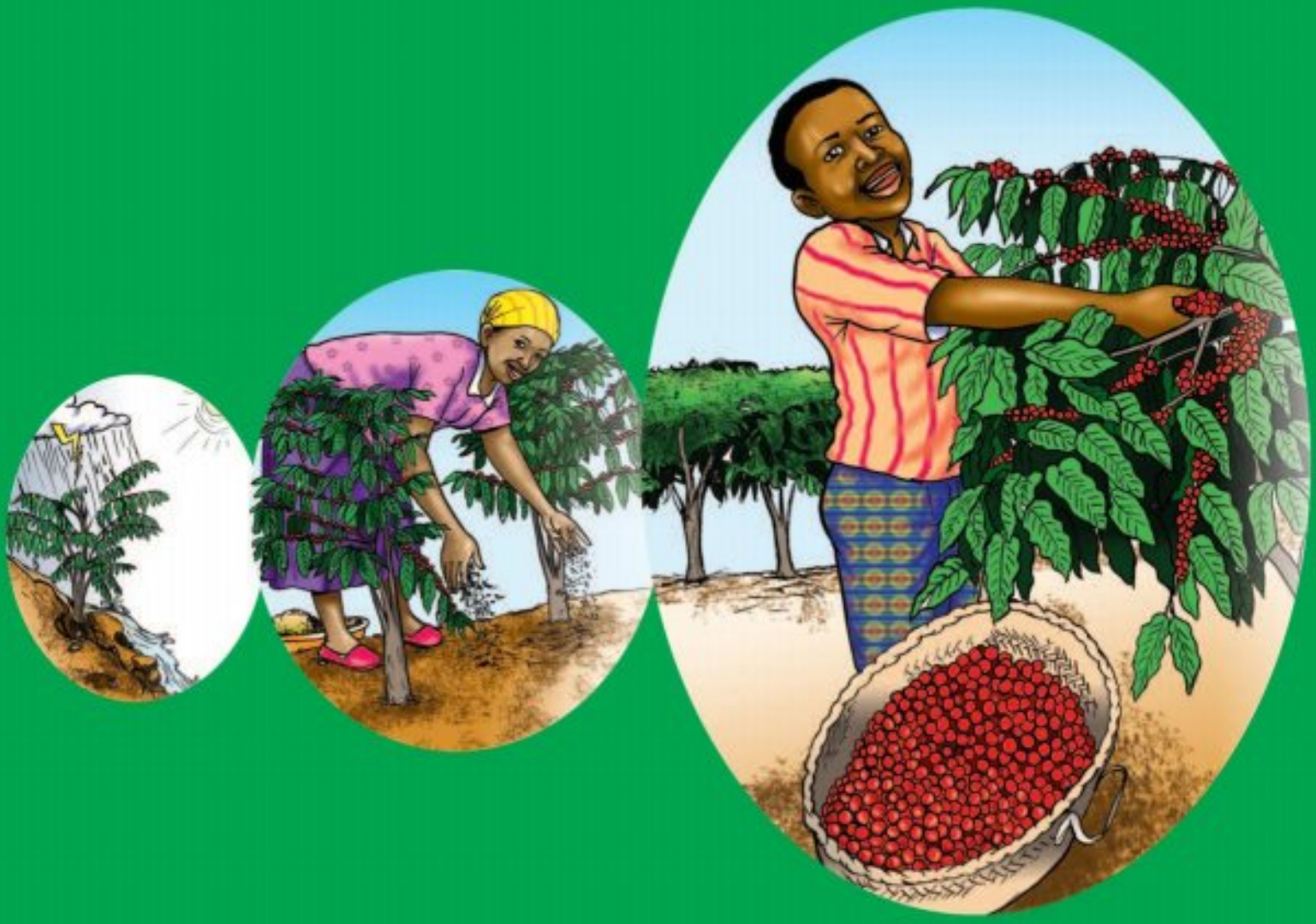
Time	00:00	01:00	02:00	03:00	04:00	05:00	06:00	07:00	08:00	09:00	10:00
Temperature	140.0	141.0	143.0	145.0	152.0	159.0	166.0	173.0	179.0	184.0	Cool

Coffee					Charge °C	Gold		1st Crack		Roast End		Development Time (1st Crack to end)	Colour	Comments
Origin	Farm	Variety	% H_2O	Density		°C	Time	°C	Time	°C	Time			

Author: JT
Version: 1.2

32. ANNEX 6: GOOD COFFEE MANAGEMENT

Good Coffee Management

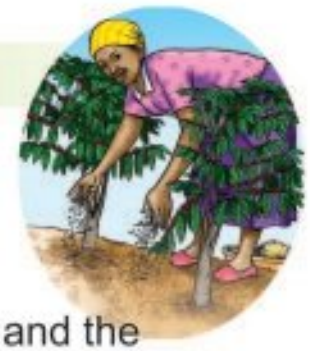


LORNA YOUNG FOUNDATION

FUNDED BY COMIC RELIEF

Bioclimate

Contents



Acknowledgements

The artwork was done by Nairobi based artist Elijah Njenga and the layout was devised by Willie McGhee with input from Rob Harley, both of Bioclimate Research and Development.

This booklet was produced as part of Comic Relief funded Smallholder Training Program on Climate change Project[1]. Thanks to Comic Relief for their support

We are grateful to the following people for their input;

In Kenya - The staff and members of the Gikanda and Rumukia Coffee Cooperatives in particular Charles Mukiuki who provides inspirational leadership to Gikanda; to Horace Njagi, Francis Mbogo and staff at the Nyeri Technical Training Institute; to Peter Kimata, Joseph Macharia, Jane Nyambura, Kamau Kuria, Beatrice Okeyo, Amos Wekesa, Bo Lager and Bridget Carrington.

Thanks to the following farmers from Rumukia and Gikanda Cooperatives for providing thoughts and suggested amendments to the draft training materials:-

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Antony Galhahi
Charles Njure
John Maina
Peter Kingori

Gikanda cooperative Society
Charles Wanjohi Gakuu
John Mgure Maina
James Maina Gachungu
Jane Nyaguthii Kirigo
Peterson Githinji
Teresa Wanjiru Maina
Charity Wangui Kariuki
Gachera Njogu

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In the UK; Ian Agnew and Cristina Talens of the Lorna Young Foundation and special thanks to Rose Clarkson for inspiring us to use pictures as a training aid.

1 Part of a larger project, the Lorna Young Foundation Africa Peer Smallholder Support Network

Introduction

This booklet is intended to assist small holder coffee farmers in East Africa to manage coffee crops in the face of unpredictable change in weather and shifting seasonality. It can be used by agricultural extension agents and by literate farmers. The booklet contains pictures and simple text, and has been trialled in Kenya by small holders and agricultural extension agents.

Three themes are covered; protecting coffee trees, soil improvement and water management. There are seven short chapters containing pictures of small holder farmers doing good farm practice within each of the themes. The sequence of the pictures depict actions involved in a task and they are accompanied by simple explanatory text.

The examples of good farm practice were chosen through a series of participatory activities in two coffee cooperatives near Nyeri in Kenya, and a site visit to Misraq Hararghe in eastern Ethiopia.

English was chosen as the training manual language after consultation with Kenyan farmers.

Shade trees provide protection for coffee and crops

Without shade trees heavy rains and storms can damage your coffee trees and berries and wash away your soil.

You should choose a shade tree that suits your land and your needs. Shade trees, such as mkungu, provide soil nutrients and animal fodder. Other trees, such as macadamia produce crops of nuts which can earn you cash.

Make sure you plant your tree at the beginning or during the rainy season.

Dig a hole and carefully plant your tree.

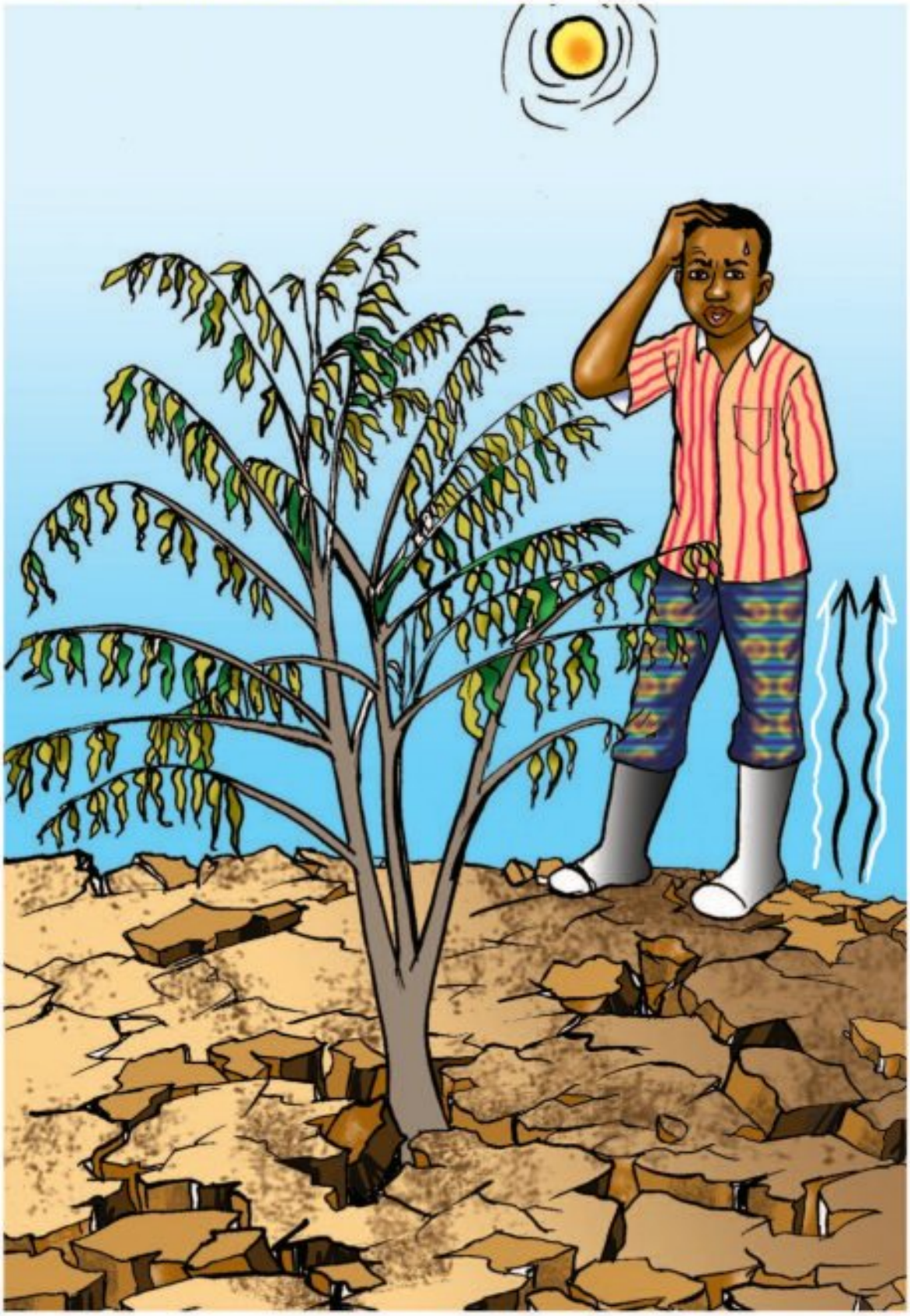
Water your tree when you plant, and during the dry seasons.

Weed round your trees and look after them well. If you look after them they will look after your coffee trees.

Protect your tree
from hungry animals

Your shade tree is now protecting your coffee trees and producing fruits and leaves that you can harvest to sell, or feed to your animals or use for cooking.

Mulching to keep your soil moist and add nutrients



Putting mulch round your trees keeps your soil moist, protects against drought, is good for your soil and stops weeds growing.

Mulching

You can use green material for mulch; grass, straw, leaves and crop residues.

Do not use leaves that do not decay easily, eg. Mango and Avocado, or, leaves that are toxic eg. Eucalyptus (Blue gum).

You should mulch at the beginning of the dry season. Collect as much green material as you can and make a mulch pile.

If you want to make compost with your mulch material you need to cover it and check it once a week to make sure it is composting properly.

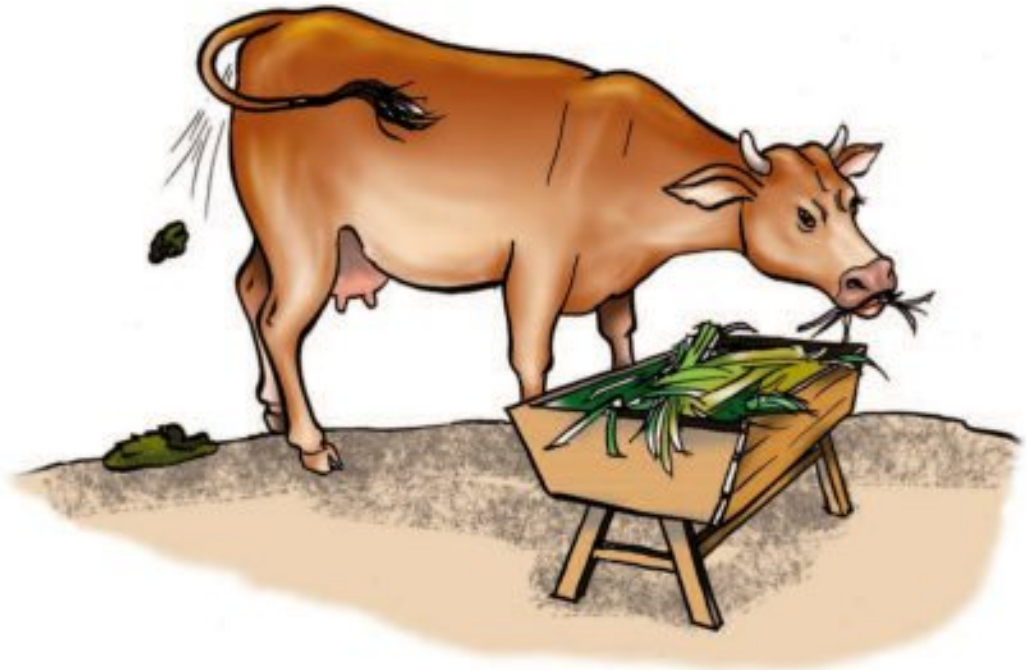
Spread your mulch or compost around the drip line of your coffee trees or crops.

The reward for good farming practices

Manure / Compost from domestic animals

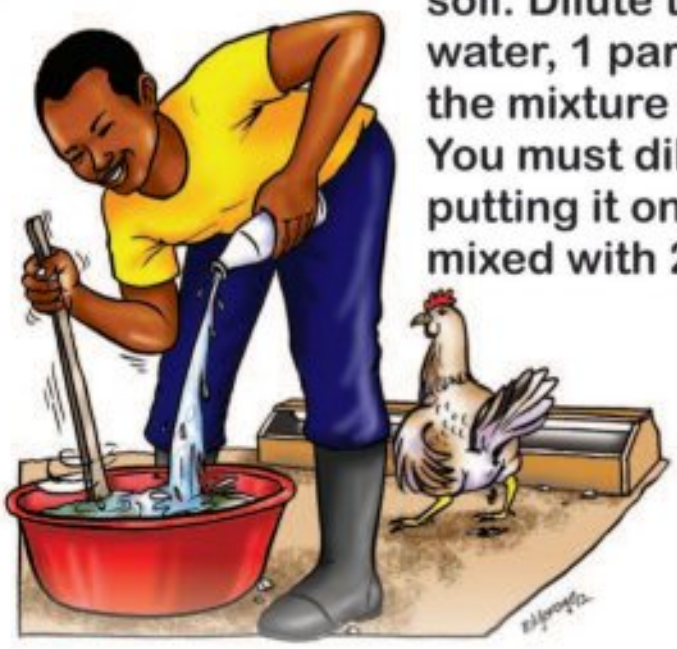
Manure and compost can help make your soil productive and give it better structure.

Manure comes from your domestic animals and is good for your soil and crops. Leave it to mature before spreading it.



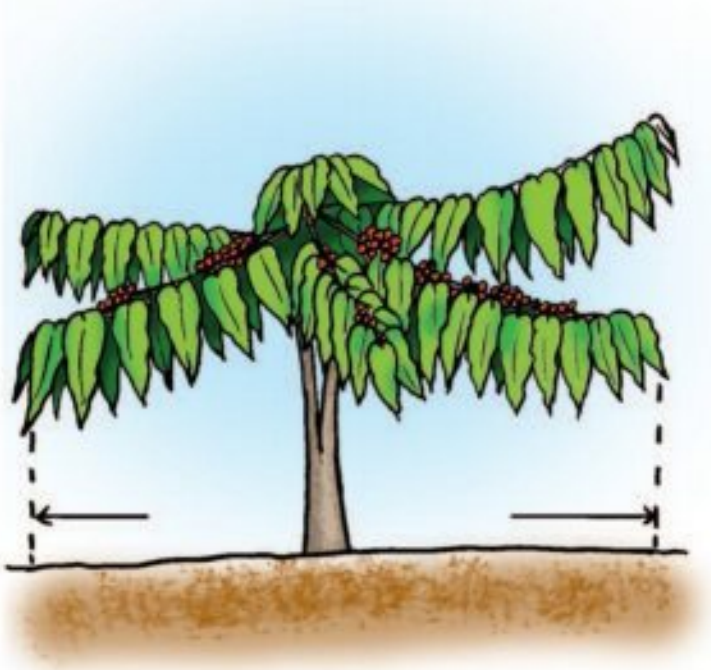
You should collect manure when it is produced by your animals and you should store it for at least one month before using it.

You can mix the manure with green material to make compost. You must be careful to mix the manure and the green material well and turn the compost every week. Compost with manure heats quickly up so it is important to check it regularly. Do not use chicken manure to make compost.

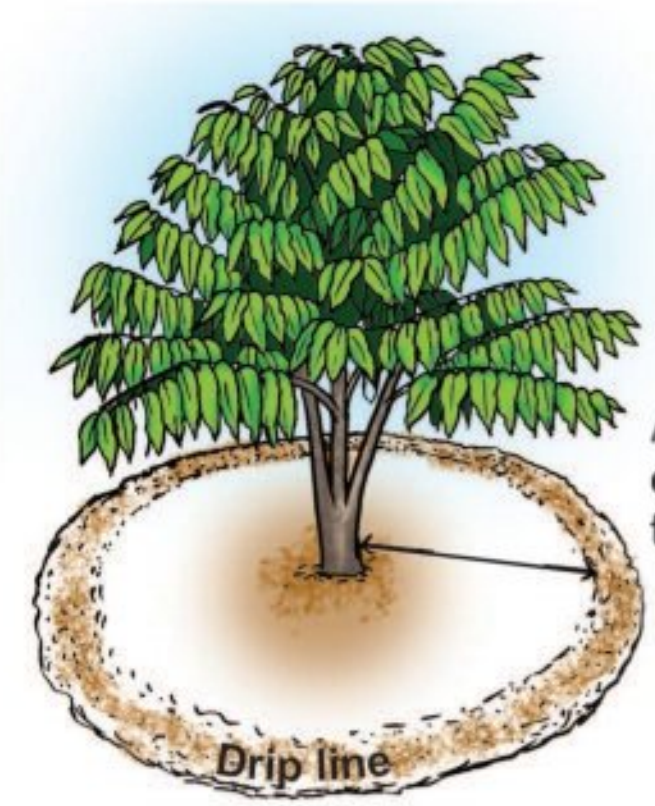


Chicken manure is very concentrated and needs treatment before putting it on your soil. Dilute the manure with water. 1 part water, 1 part chicken manure. Then leave the mixture to mature for at least four weeks. You must dilute this mixture again before putting it on your field. 1 part manure liquid mixed with 20 parts of water.

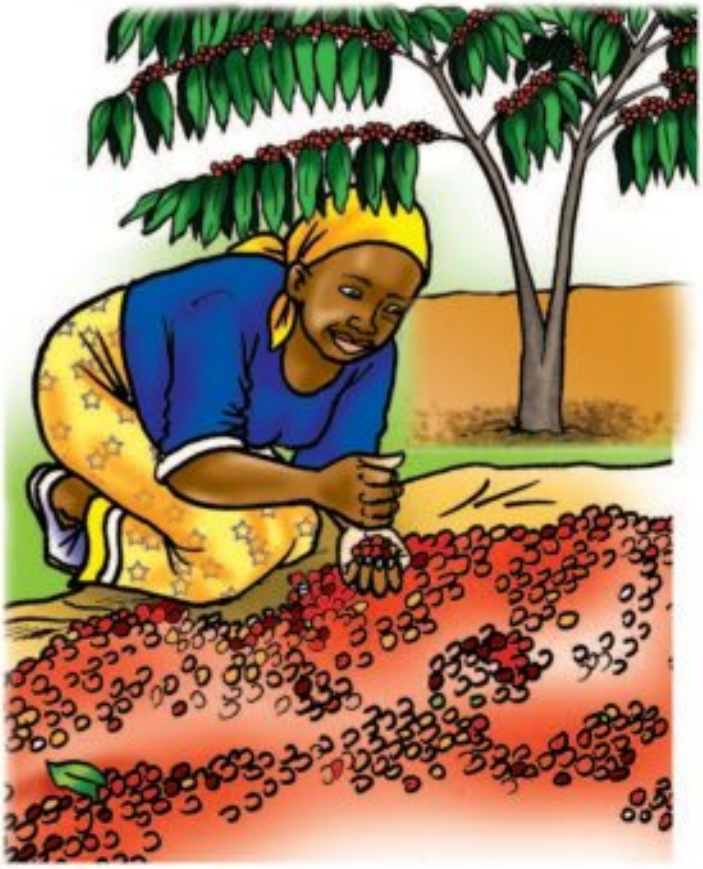
Spread the manure or compost around the drip line of coffee trees.



The drip line of a coffee tree.

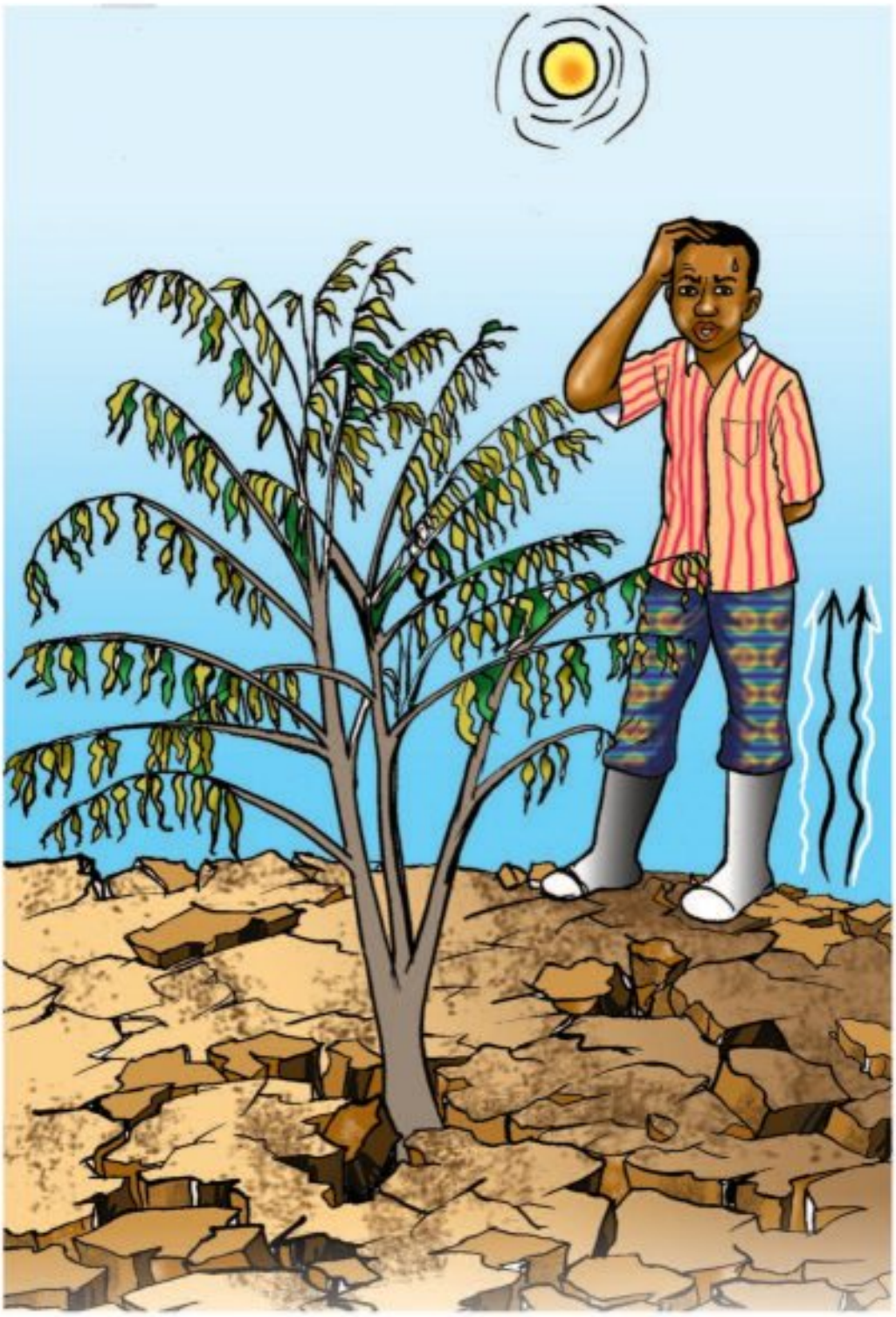


After spreading your compost or manure around the coffee tree gently dig it into the soil.

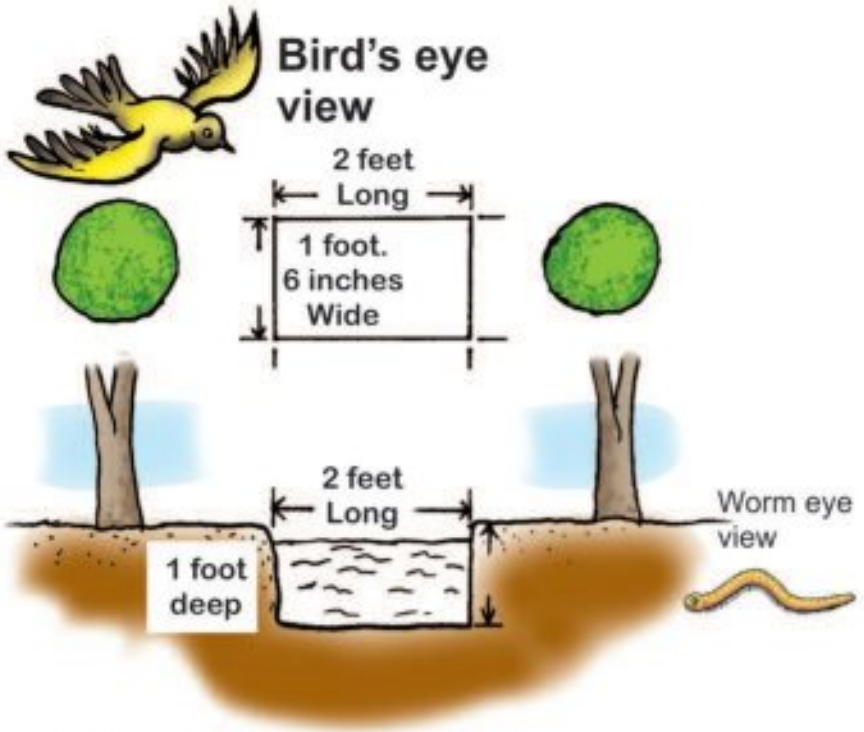


The reward for good farming practices

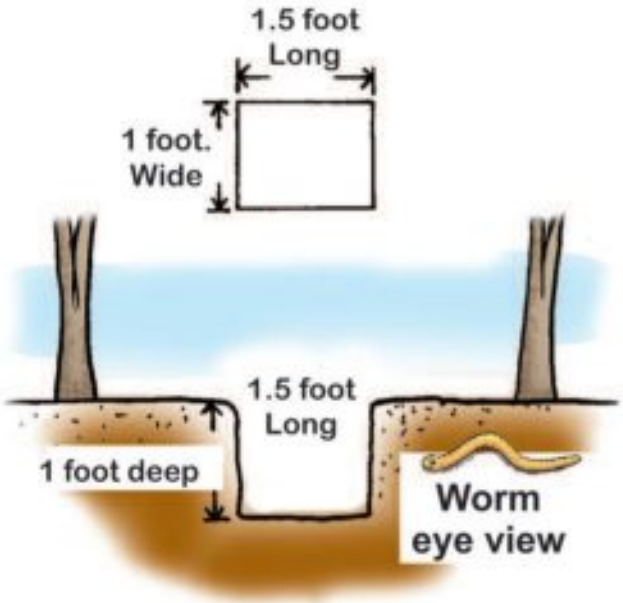
Digging holes to maintain soil moisture



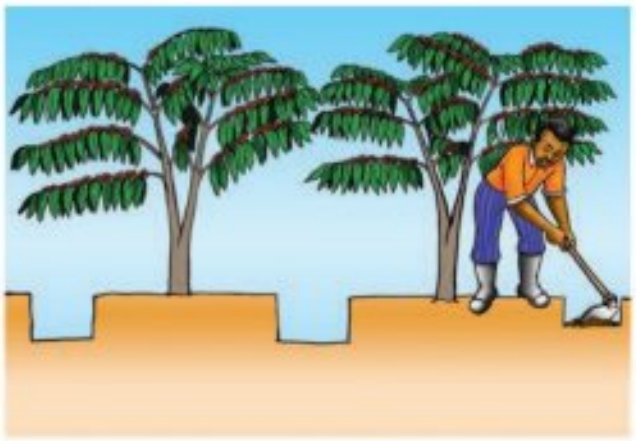
Digging holes can help to keep the soil moist around your coffee trees.



Big holes for coffee trees planted at 9 feet spacing(SL 34)



Small holes for coffee trees planted at 6 feet spacing (Ruiru 11 and Batian)



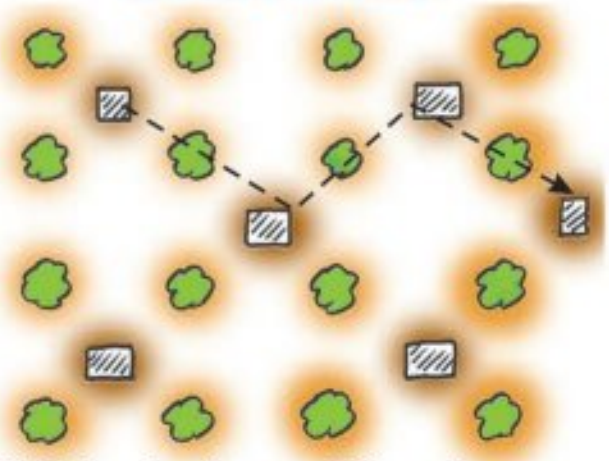
One large hole can hold 1 drum (200 litres) of water

Digging holes

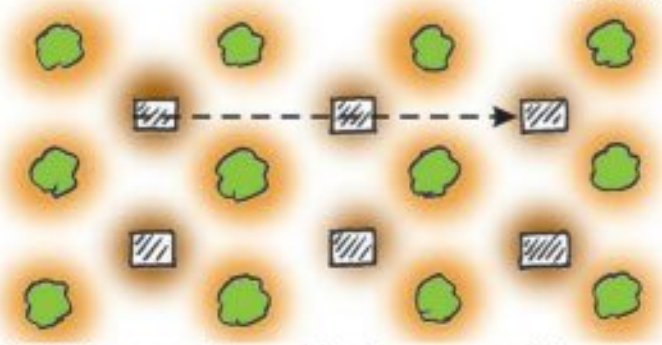
Dig holes at the start of the rainy season. The holes will hold water and keep the soil moist for longer during the dry season.

A birds eye view of coffee bushes and holes

1.Holes in lines with coffee trees - for SL 34 (1300 trees/ha)



2.Holes in diagonal lines for Ruiru 11 and Batian (2500 trees/ha)

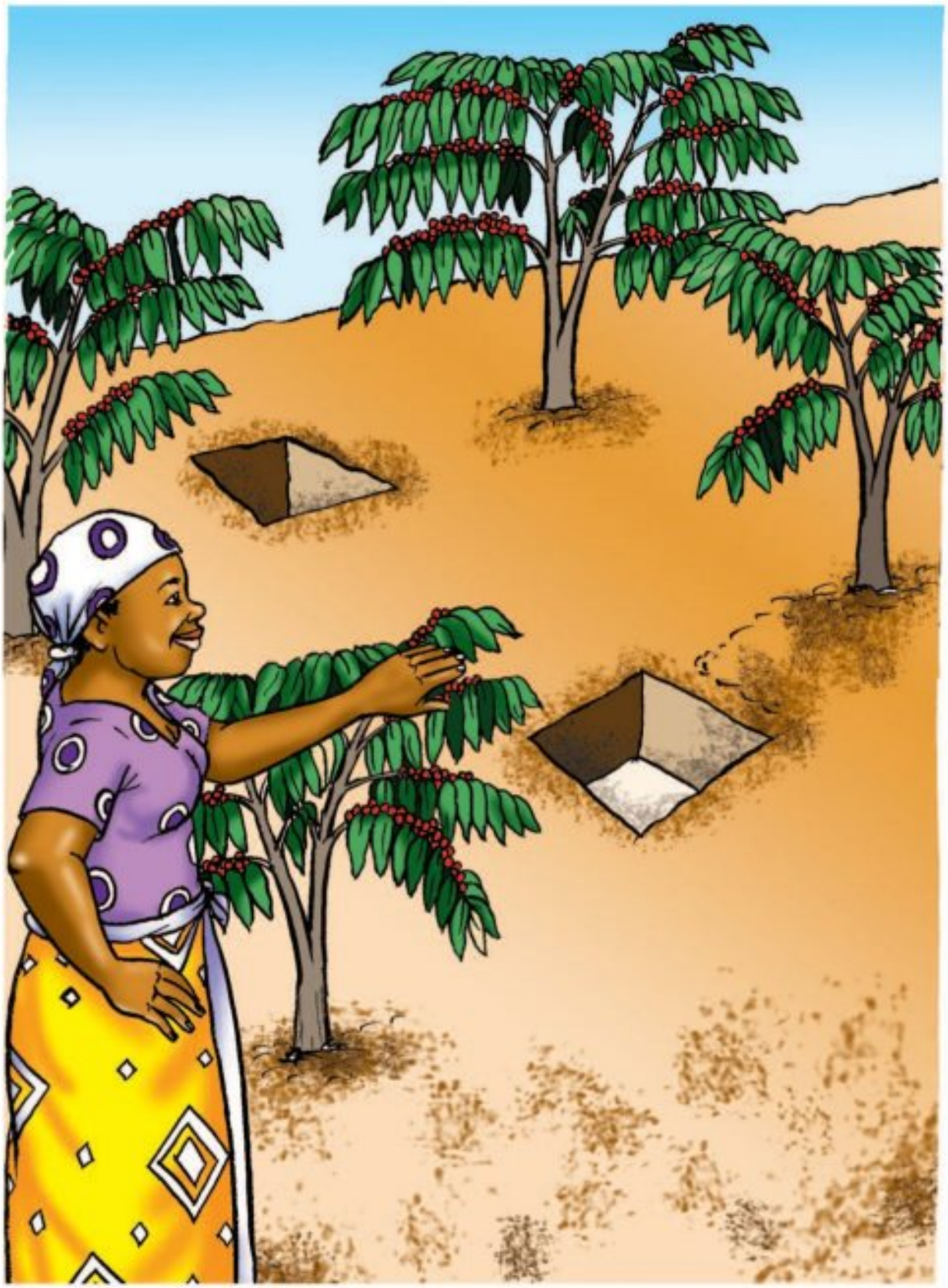


3.Holes centered between coffee trees

Key

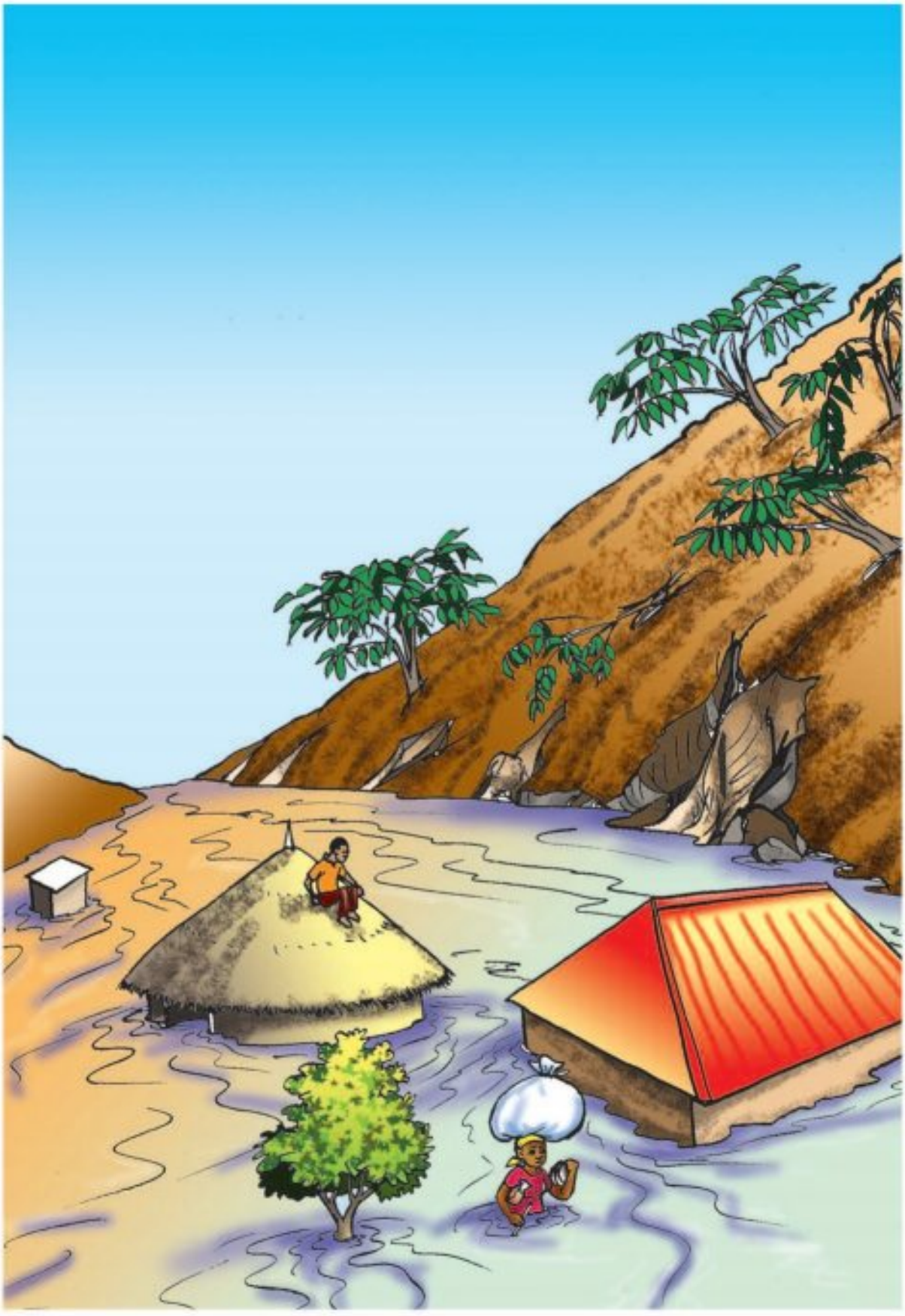
- Coffee tree
- Hole

If you are digging holes in line with coffee trees use a peg to mark the hole at an equal distance between two coffee trees. You do this with 9 foot spaced coffee trees (SL 34)



Your hard work will be rewarded with healthier coffee trees.

Drainage ditches to stop flooding



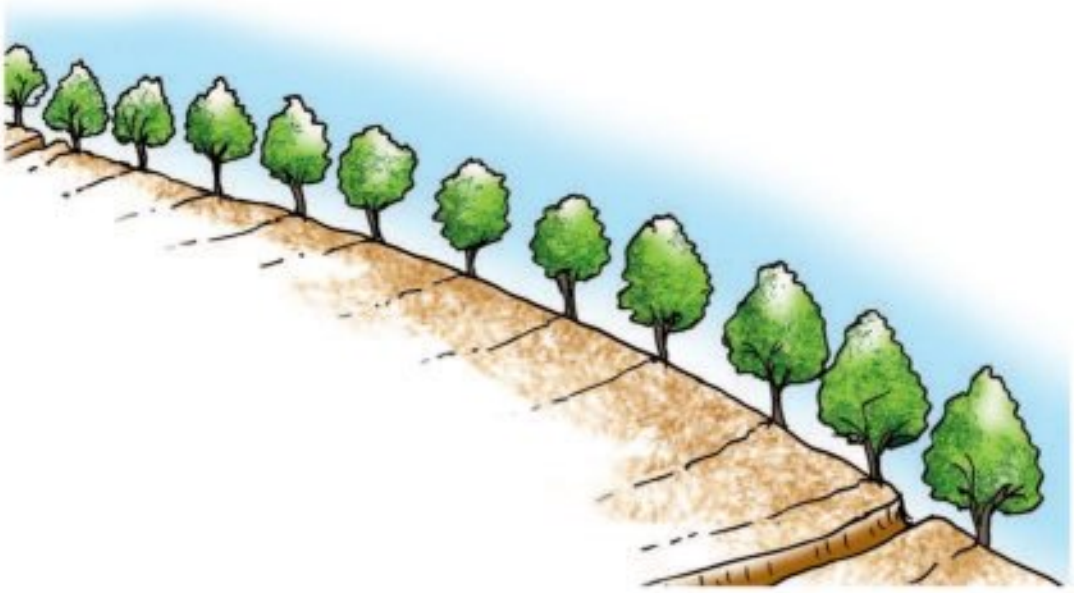
Heavy rains and bad farming practices can cause flooding and loss of livelihoods.

Drainage ditches

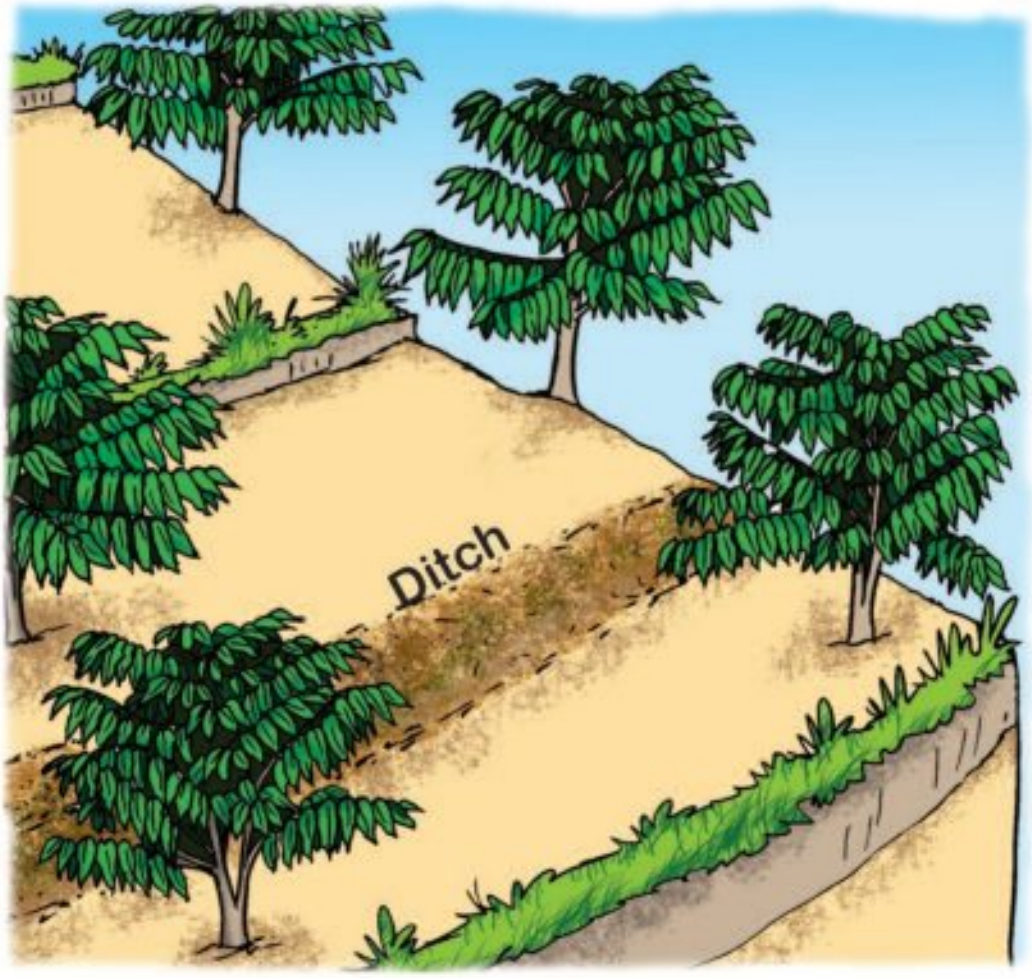
Ditches are optional if you already do benches and dig holes.

Dig ditches before the rainy season. Mark your drainage ditch along the contour to take flood water away from your coffee and crops.

Dig your drainage ditch and make sure the ditch runs along the contour.



Drainage ditches can be dug after every 10 lines of coffee trees

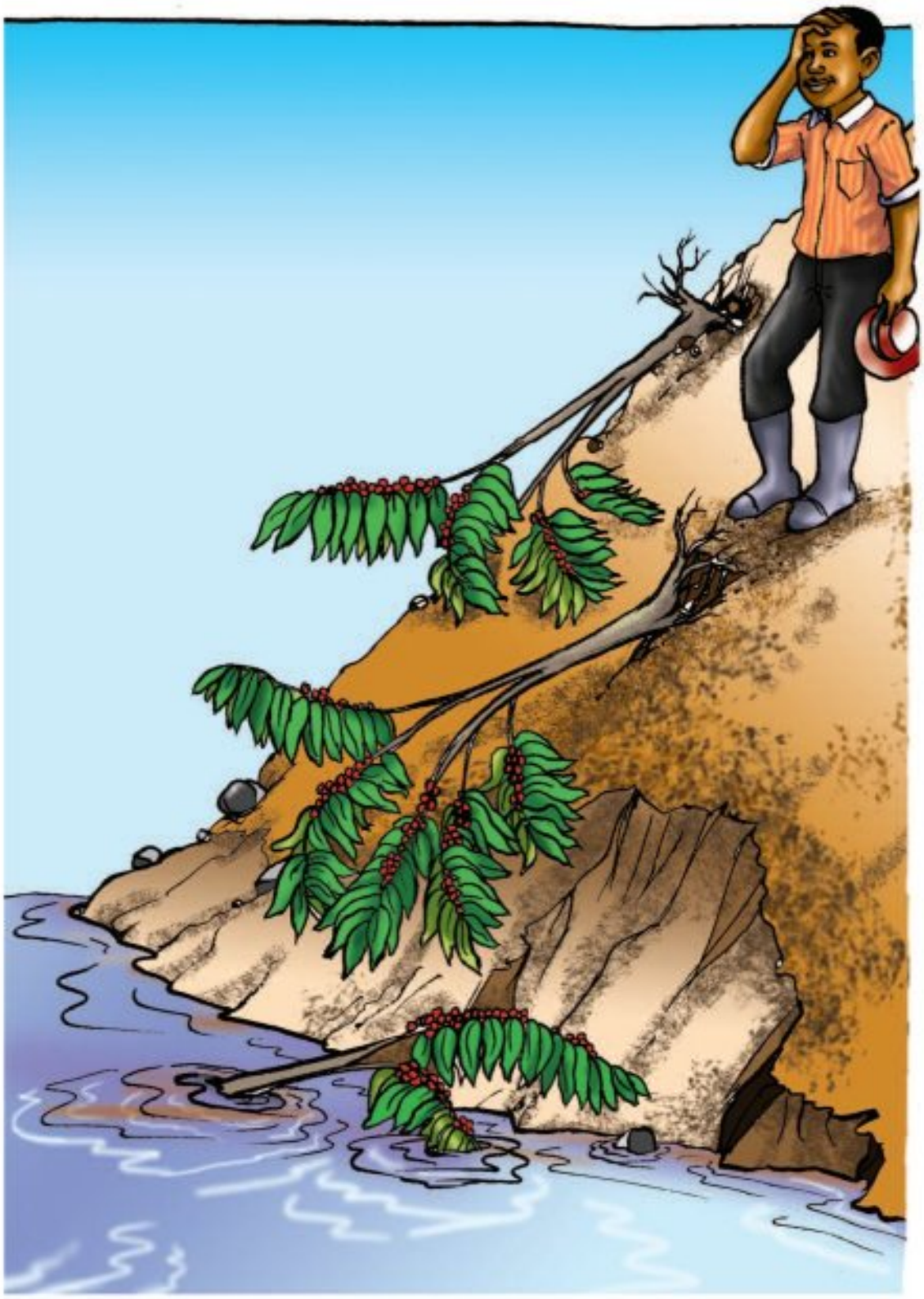


Dig your ditches between your rows of coffee bushes.

Keep your drainage ditches free from vegetation and soil. Check them before the rainy seasons and clean before the April and October rains.

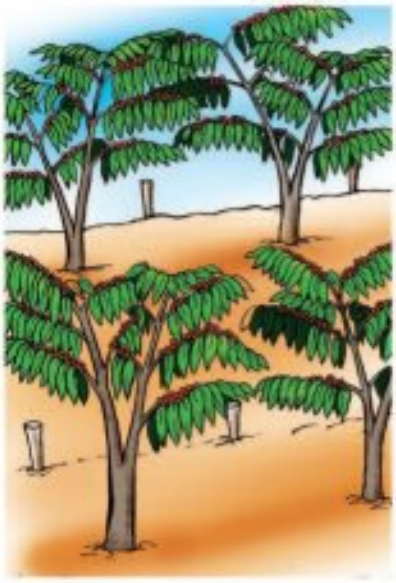
Be happy with your hard work, it may stop flooding.

Live terracing (benches) for soil retention



You need to provide protection for your coffee trees and crops.

Prepare your terraces (benches) at the start of the rainy season. Use sticks and string to mark out the line of the terrace along the contour.



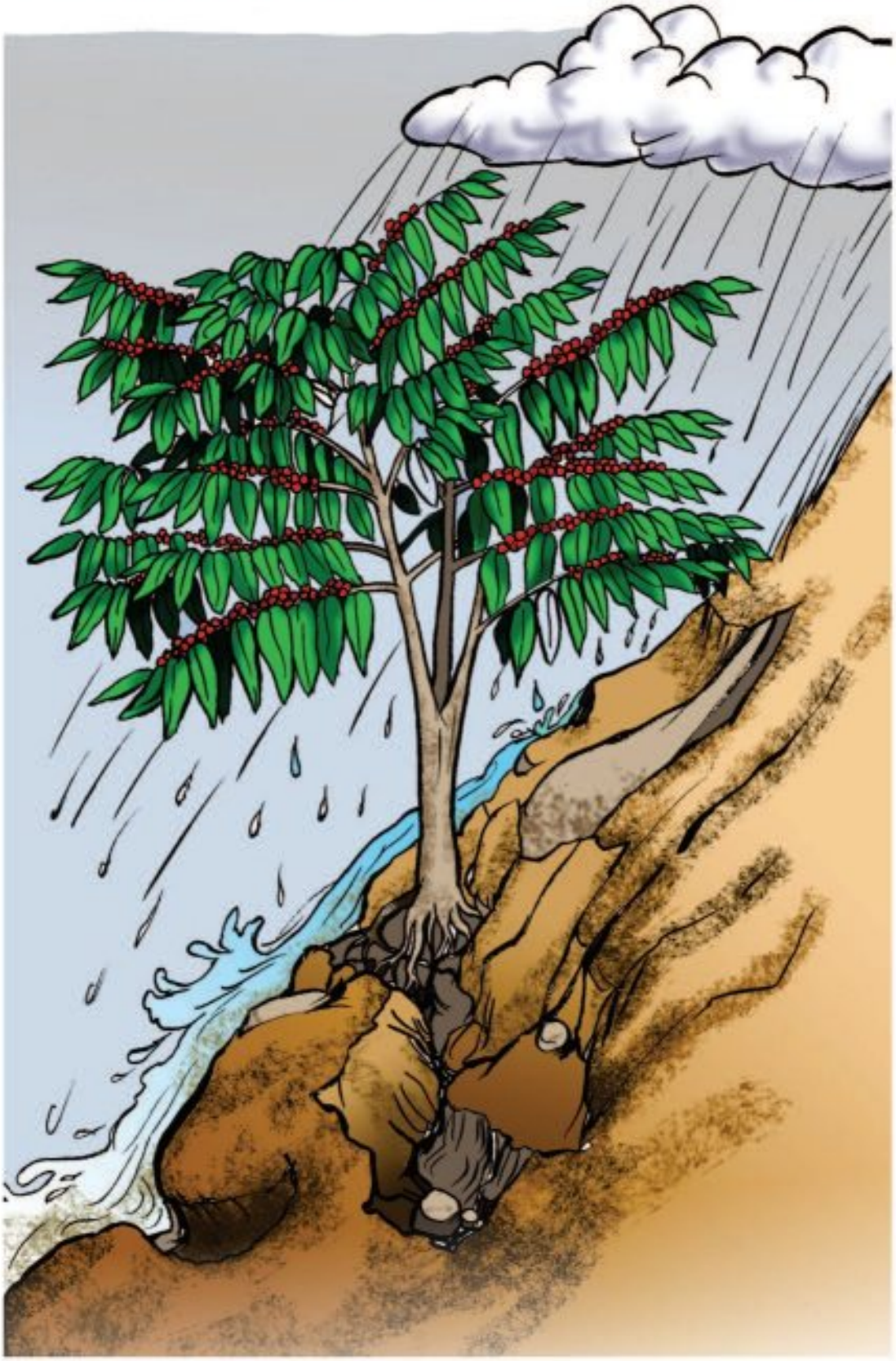
Dig your bench along the contour of the slope and plant your grass in the rainy season.

Plant your grass along the bench, do not use grass that takes all the nutrients like Napier grass

Grass should be one foot deep and when it grows you can cut it for fodder or mulch.

A job well done, your soil is more stable and less likely to be washed away.

Building stone terraces to avoid soil erosion

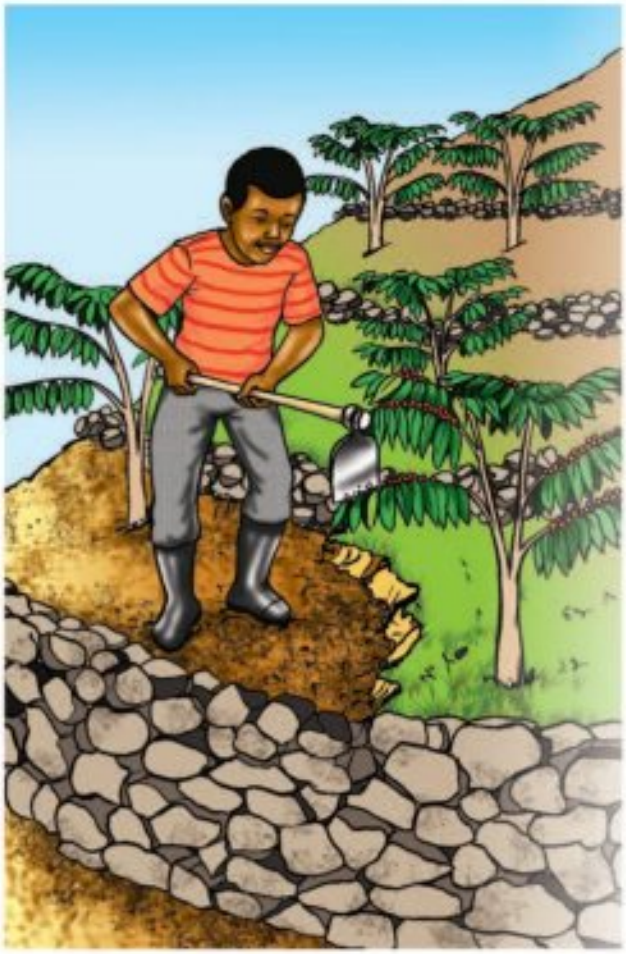


Heavy rain on hill slopes can cause flooding and erosion.

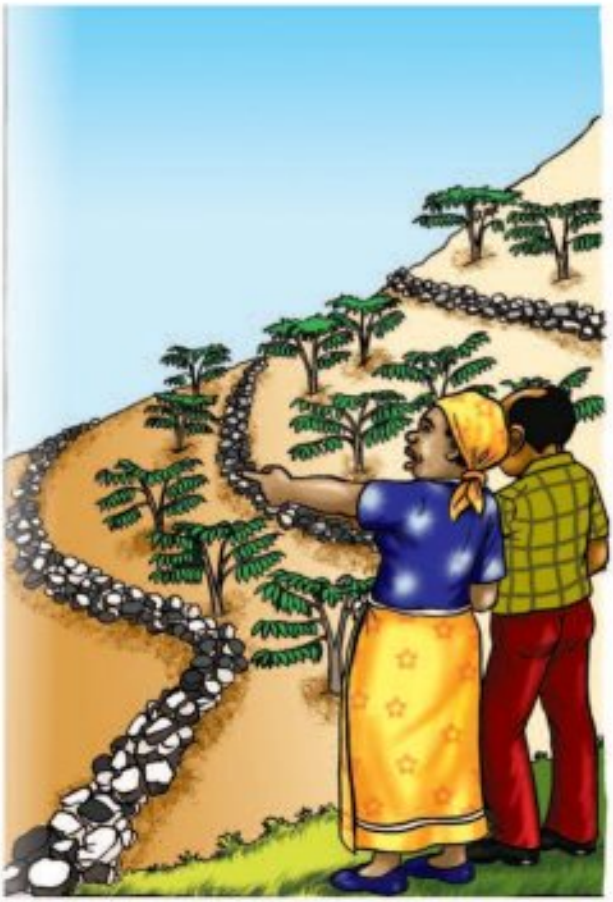
Prepare your terraces (benches) at the start of the rainy season. Use sticks and string to mark out the line of the terrace.

Dig out the foundation of your terrace along the contour.

Collect stones to build your terrace along the contour.



After you have built the stone terrace, cultivate your coffee or crops along the contour.



Your hard work protects you and your crops from flooding.

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