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# Learning about neighbour trees in cacoa growing systems

## a manual for farmer trainers

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# Learning about neighbour trees in cocoa growing systems:

# a manual for farmer trainers

*Richard Asare*

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Forest & Landscape

# *Learning about neighbour trees in cocoa growing systems*

*- a manual for farmer trainers*

*Richard Asare*

KVL A UNIVERSITY OF LIFE SCIENCES

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Learning about neighbour trees in cocoa growing systems
- a manual for farmer trainers

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Left: Cocoa farmers from Buckwane
Right: Cocoa farmers showing cocoa pods under shade tree
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# Preface

This manual was prepared by *Forest & Landscape Denmark* in collaboration with the Sustainable Tree Crops Programme (STCP), and with funding from the World Cocoa Foundation. Its publication is part of the joint project, which is entitled, »*Enhancing the knowledge base on valuable trees in cocoa in West Africa*«.

The preparation of this manual was prompted by the need for a comprehensive training manual that provides technical information on farmer preferred neighbour/shade trees, and how this can be augmented into the ongoing farmer field schools (FFS), which are being implemented by STCP.

By providing technical information on the selection and management of forest trees in cocoa farms, as well as guided decision-making exercises about timber trees in cocoa farms, this manual provides an opportunity for adult learning within STCP's broader farmer training programme.

This manual is also meant to serve as a stepping-stone to the development of a full-scale curriculum on technical information and guided decision-making exercises about timber trees in cocoa farms within the framework of the STCP. As such, it can serve as a basis for the development of a framework for tree diversification in cocoa growing landscapes in West Africa.

# Acknowledgement

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Last but not the least, I express my appreciation to the farmers who took time off and shared their knowledge and participated in the testing of the exercises that are provided in this manual. To these hard working people I say, well done! ('Ayekoo').

# Acronyms

| | |
|---|---|
| BC | Bark collar |
| CI | Conservation International |
| CRIG | Cocoa Research Institute of Ghana |
| DCT | Damaged cocoa trees |
| FFS | Farmer Field School |
| FLD | Forest & Landscape Denmark |
| LI | Legislative Instrument |
| NGO | Non Governmental Organisation |
| NPLD | Non-pioneer light demander |
| NP | Non-pioneer |
| P | Pioneer |
| SB | Shade bearer |
| SRA | Social Responsibility Agreement |
| STCP | Sustainable Tree Crops Programme |
| TUC | Timber Utilisation Contract |
| TUP | Timber Utilisation Permit |
| WCF | World Cocoa Foundation |

# Glossary

**Abandoned cocoa farm.** A cocoa farm that has been left idle for a long period of time.

**Chupon.** Vertical stem on cocoa shoot.

**Cocoa agroforest.** A complex shade grown cocoa system in which forest tree species are integrated in cocoa for their economic, social and environmental benefits.

**Cocoa agroforestry.** A dynamic, ecologically based cocoa growing management system that, through the integration of forest trees in the farmland diversifies and sustains production for increased social, economic and environmental benefits for farmers at all levels.

**Dehiscence**. The splitting of a dry fruit to discharge its content. Dehiscent fruits are those that split open at maturity, usually while still attached to the tree.

**Dioecious.** A species in which individuals are male or female.

**Dormancy.** A state in which a viable seed fails to germinate when provided with water and favourable environmental conditions for germination.

**Epigeal (or epigeous) germination.** The type of germination in which the embryonic leaves are forced above the ground by the elongation of the part between the radicle and the leaves (hypocotyl).

**Funicle.** The stalk of an ovule or seed, attaching it to the ovary placenta.

**Germplasm.** Planting material for a plant species.

**Inbreeding.** Production of offsprings after mating with closely related parents.

**Indehiscent.** Indehiscent fruits that do not split open at maturity.

**Mature cocoa farm.** A cocoa farm beyond 25 years of age.

**Mesocarp**. The middle part of the pericarp: the pulp of berries and drupes.

**Mono-specific stand.** A plantation with only one type of species grown.

**Orthodox seed**. Term used to describe seeds which can be dried down to a low moisture content of around 5% and successfully stored at low or sub-freezing temperatures for long periods.

**Pollination.** Deposition of pollen on the receptive parts of the female flower.

**Radicle.** The part of the embryonic seed that develops into the primary root.

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# 1 Why a training manual on trees in cocoa landscapes?

## 1.1 The need for technical information on trees in cocoa

»Enhancing the knowledge base on valuable trees in cocoa in West Africa« is a collaborative project between the World Cocoa Foundation (WCF), the Sustainable Tree Crops Programme (STCP), and *Forest & Landscape Denmark* (FLD).

The project started in April, 2004 with a study on farmer preferred and research recommended neighbour[1]/shade trees in cocoa growing systems in Ghana, Côte d'Ivoire, Cameroon, and Nigeria and an overview of research and development in this area. Neighbour/shade trees provide additional products (e.g. fruits, nuts, medicines, and timber) and environmental services in cocoa growing systems and form part of a tree diversification strategy by farmers.

Information gathered in the first year of the project highlighted the need for a comprehensive training manual that provides technical information on farmer preferred neighbour/shade trees, and a mechanism for integrating such knowledge into the on-going farmer field schools (FFS) being run by STCP.

The FFS approach is a concept based on discovery learning. FFS is best suited for extending knowledge-based technologies and practices. The approach does not advocate technology transfer but instead reinforces farmers' observation skills, decision-making capacity and knowledge.

While this manual does not satisfy the conditions for discovery learning, it does provide an opportunity for adult learning, and can contribute to farmer-based dissemination of information. This is because it provides technical information with guided decision-making exercises about timber trees in cocoa farms within the context of STCP's farmer training program.

## 1.2 Objectives

The objectives of this manual are therefore:

1. To provide basic technical information on forest trees species in cocoa landscapes in West Africa
2. To contribute to cocoa farmer training under the STCP initiative.

[1] Trees in cocoa agroforests other than the cocoa tree itself

## 1.3 Target group

The manual is addressed to farmer facilitators, extension workers, tree planters, NGOs, and farmer associations. It is meant to serve as a preliminary guide towards the development of a full-scale curriculum on technical information and guided decision-making exercises about forest trees in cocoa farms within the framework of the STCP. The manual also serves as a basis for the development of a framework for tree diversification in cocoa growing landscapes.

# 2 Cocoa farming system

## 2.1 Structure of cocoa farms

Cocoa farms in West Africa are structurally valuable since they provide multi-strata systems with a horizontal and vertical distribution of tree species components, which represent an important factor in sustaining the cocoa farm. In this stratified multi-cohort system, native timber trees and exotic agroforestry tree species occupy the upper canopy (overstorey) with cocoa and other fruit trees occupying the middle level, while food crops take up the lower canopy (understorey).

The pre-existing vegetation before the establishment of a cocoa farm or agroforest plays a vital role in the structure since some trees are left at the early stage of the plantation. In addition, the soil seed bank plays a key role in the regeneration of new vegetation.

This structural arrangement or the multi-strata system offers farmers the opportunity to exploit all the necessary components in the system, and their interactions, to maximise income and reduce risks. Therefore, a form of tree diversification on cocoa farms is already well established in the region.

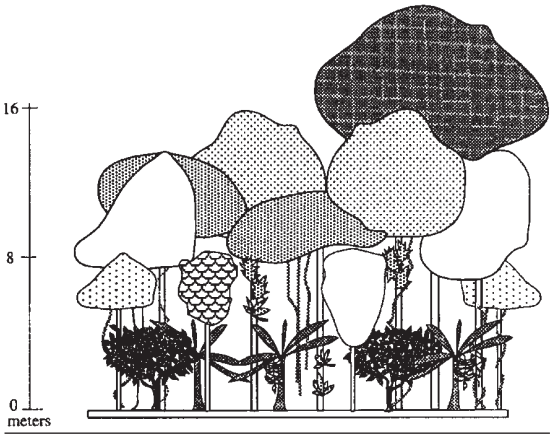



*Figure 1. Spatial arrangement of trees in cocoa. Source: adapted from Rice & Greenberg, 2000*

## 2.2 Tree diversification in cocoa

Diversification in the cocoa enterprise involves a portfolio of strategies designed to reduce exposure to product and income risks by combining a variety of activities (production, marketing, product transformation, input supply etc.) to improve productivity, farm income, and household welfare. Hence, it is assumed that diversification will allow more consistent performance under a wide range of agronomic, environmental and economic conditions.

Tree diversification in cocoa farms, however, involves the strategic integration in time (at various stages in the establishment and management of cocoa farms) and space (the three-dimensional arrangement of trees on the

ground and into the canopy) of suitable and valuable non-cocoa tree species and other plants. Species may include indigenous forest species, fruit trees, common agroforestry species, food crops, shrubs etc.

As mentioned earlier, the integration of valuable trees in cocoa plantations is a practice that is widespread in smallholder cocoa farms in West Africa. Despite the fact that farmers may plant some of these trees species, especially fruit trees, a large proportion of the remaining trees, particularly indigenous timber trees, are remnants from cleared forests. There is therefore no pattern in the arrangement of the various species in time and space, therefore limiting efficiency of the system.

## 2.3 Importance of tree diversification

Tree diversification in cocoa, when planned well, provides greater productivity by fully exploiting nutrients, water, and light resources within a stratified mixture of food crops, tree crops, and shade trees. In a diversified system, mixtures of species with different growth requirements and production potentials should be encouraged so as to reduce inter-specific competition and increase yields as compared to mono-specific stands.

For example, mixed stands which combine faster growing over-storey tree species, which may improve nutrient availability in the soil or increase soil moisture, with slower growing shade tolerant species can improve survival and growth rates, and provide additional environmental, economic, and subsistence benefits. Mixed stands can also contribute to higher landscape-level diversity.

One of the methods of achieving tree diversification on farm is to promote a wider distribution of species that are already present somewhere in the landscape or from outside the landscape. These species may either be planted in mixtures or planted in sets of mono-specific plots in the cocoa system.

## 2.4 Forms of tree diversification

Tree diversification in cocoa production commonly occurs in three different forms, which vary in both time and space. The three main forms can also overlap at various stages and levels of the life span of the cocoa system. These include:

- Establishing cocoa with food crops
- Integrating fruit trees in cocoa
- Integrating timber and nitrogen fixing tree species in cocoa
- A mixture of two or all of the above.

### 2.4.1 Cocoa with food crops

In the initial stages of cocoa establishment (from year 1 to 3), the appropriate combination of food crops like plantain, cassava, maize, etc. may provide cocoa seedlings with the much needed temporary shade and reduce competition from weeds since food crops grow faster than trees. It also provides farmers with income and food for the household until the main cash crop is ready for harvest.

Food crops may also be incorporated in mature cocoa fields during enrichment planting. Gaps created as a result of dead trees may be filled with new cocoa seedlings while food crops provide shade for the seedlings.

It is important to note that to obtain optimum output per unit area, cocoa seedlings should be planted in lines according to recommended planting distances (e.g. 3 x 3m). Food crops should then be planted in between the cocoa seedlings in an arrangement such that the shade effect is prominent while reducing initial competition.

### 2.4.2 Fruit trees with cocoa

Fruit trees refers to any fruit bearing tree other than cocoa that can be integrated in the cocoa plantation. These may include, but are not limited to *Mangifera indica* (mango), *Citrus sinenses* (oranges), *Persea americana* (avocado), *Irvingia gabonensis* (bush mango), *Dacryodes edulis* (safou), *Garcinia kola*, *Ricinodendron heudelotti*, *Cola nitida*, *Elaies guineensis* (oil palm) etc.

Fruit trees may be incorporated in cocoa right from year 1 or as a replacement for food crops after year 3 when cocoa (hybrid variety) has started fruiting and food crops have been harvested. It is recommended that fruit trees like *Cola nitida* and *Citrus sinensis* are planted at a spacing of 24 x 24m, totalling 17 fruit trees/ha each, in association with cocoa planted at 3 x 3m (giving a total of 1111 trees/ha) to give good results.

### 2.4.3 Timber and nitrogen fixing tree species in cocoa

Timber trees have been recorded as the major source of permanent shade in cocoa. All across West Africa, timber tree species like *Milicia excelsa*, *Ceiba pentandra*, *Terminalia ivorensis*, *T. superba*, *Alstonia boonei*, *Khaya ivorensis*, *Triplochiton scleroxylon* etc, have been used by farmers as shade for cocoa. In addition species like *Gliricidia sepium*, *Albizia* and *Acacia* spp. with their nitrogen fixing ability have been planted for both temporary and permanent shade. Mature timber trees may be left during initial establishment of cocoa or planted after the cocoa is established.

Together, timber and nitrogen fixing tree species ameliorate the soil and provide good microclimate for cocoa growth. Timber trees planted at a distance of 12 x 12m initially (this may be thinned to a spacing of 24 x 24m after sometime), in association with cocoa planted 3 x 3m will ensure good growth conditions for cocoa.

### 2.4.4 Planting pattern of cocoa and non-cocoa tree species in cocoa farms

In a research[2] trial conducted and still under monitoring in Ghana, timber tree species are planted in a triangular spacing of 12 x 12m, with cocoa planted under two different scenarios. These planting arrangements could be adopted by farmers and improved upon over the years as the timber trees grow in size.

Scenario 1, which is captured by figure 2, is set on-farm with typical planting arrangement practised by farmers in which cocoa is planted in an irregular pattern not conforming to the 3 x 3m spacing. However, timber tree species like *Albizia adianthifolia, Entandrophragma angolense, E. utile, Khaya anthotheca, Newbouldia laevis, Pericopsis elata, Tetrapleura tetraptera* are planted in a triangular spacing of 12 x 12m.

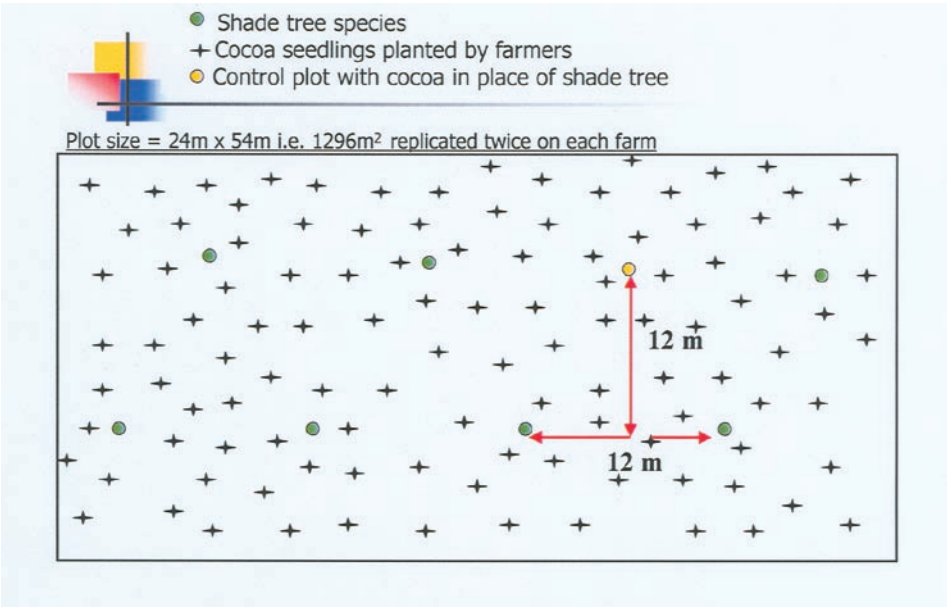



*Figure 2. Irregular arrangement of cocoa with timber trees*

Scenario 2 is represented by figure 3 and is set under research station conditions and it depicts a regularly arranged pattern conforming to the 3 x 3m spacing of cocoa and 12 x 12m triangular spacing of the timber species, which include *Entandrophragma angolense, E. utile*, *Newbouldia laevis, Tetrapleura tetraptera,* and *Terminalia ivorensis*.

[2]Anglaaere (2005)

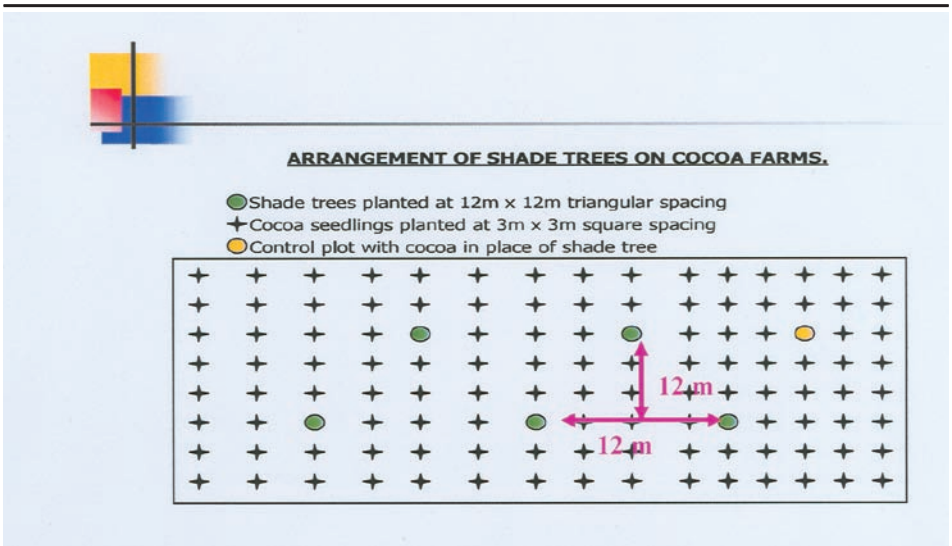



*Figure 3: regular arrangement of cocoa with timber trees*

## 2.5 Rehabilitation of mature cocoa farm

For the purposes of this manual, rehabilitation of cocoa refers to any method or scheme designed to breathe new life into an unhealthy stand of cocoa, which is potentially productive but has been hindered by unfavourable factors[3]. These factors may include:

- Pests and diseases attack
- Poor planting materials
- Neglect
- Decline in soil fertility and
- Lack of appropriate vegetation cover.

In effect, rehabilitation of cocoa implies the removal of these obstacles[4] in order to realise the full potential of the cocoa farm. In a broader context, rehabilitation can also refer to the planting of shade and soil fertility improving trees to improve the environment and/or the replanting of cocoa if the farm was converted to another use, like oil palm, or was damaged from bush fires. In this case rehabilitation will mean recycling the land, as it will involve efforts to restore soil fertility and appropriate vegetation cover for cocoa cultivation.

In order to rehabilitate a cocoa plantation there are three methods to choose from. These are:

- Under-planting of cocoa
- Complete replanting/re-establishment of cocoa and
- Rejuvenation of the cocoa tree.

3 Ahenkorah *et al.* 1979.

4 This document will focus on the last two factors since the others have already been dealt with in the FFS ICPM manual (see David, 2005)

### 2.5.1 Under-planting of cocoa

Under-planting is carried out when the cocoa tree stock is old (e.g., over 30 years) or when the tree stock is suffering from disease and pests attack. With under-planting, the old cocoa tree stand is thinned or diseased/dying trees are removed and new cocoa seedlings are planted underneath the canopy of the older trees. In certain cases, if death or disease has created significant gaps in the cocoa farm, then these open areas can be enriched with new cocoa seedlings. In this case, when the gaps are large and there is little shade, it may be necessary to plant food crops or other trees with the cocoa seedlings in order to provide the necessary initial and/or permanent shade. These additional trees do not only provide shade for newly planted cocoa seedlings but also conserve and improve soil conditions.

Under-planting allows the farmer to maintain certain level of income from the old cocoa tree stock while planting young cocoa seedlings under the old tree stock. However the risk of possible infection of the new trees with diseases and pests like black pod and swollen shoot disease is quite high.

### 2.5.2 Complete replanting of cocoa

Complete replanting (re-establishment), on the other hand, demands that all disease infected or unproductive trees are removed and the site is entirely replanted with new cocoa germplasm. This method is appropriate when the cocoa tree stand is infested with diseases and pest. Prior to planting, the area may be left fallow for a couple of years before re-establishing the cocoa. In the process, farmers may improve the fallow by adopting tree-based strategies, like preserving and/or planting timber and nitrogen fixing trees, to intentionally improve soil conditions and increase organic matter.

Where disease is prevalent, complete replanting disrupts the cycle of disease transmission by preventing old trees from re-infesting the new ones. However, this option requires that farmers identify other income generating activities in the interim to substitute for the fall in income as a result of the eradication of the old cocoa stand.

### 2.5.3 Rejuvenation of cocoa

This refers to any mechanical technique to bring an unhealthy cocoa tree back to life. These methods can be used to improve the health and yield of unproductive trees. It involves the selective removal of chupons, removal of mistletoe and moss, grafting, and pruning, and ensures the rapid recovery of a previously unproductive stand. However, rejuvenating a diseased or pest ridden cocoa plantation does little to remove the infection or infestation since the old tree stock is maintained.

## 2.6 Forest trees for rehabilitating or establishing cocoa farms

By improved fallows[5] farmers may choose to substitute the natural plant succession with planted trees of one or a few species. Improved fallows improve soil fertility and soil properties in a relatively short period of time, allowing farmers to then re-establish a new cocoa farm on the land quickly and efficiently. This function is particularly important on highly degraded sites following long-term cultivation where invasive weeds take hold and out-compete forest species. *Chromolaena odorata* is an excellent example of such an invasive species.

The first phase of an improved fallow is to remove the grasses, shrubs, and old cocoa trees, though farmers may choose to preserve selected forest seedlings or mature trees.

Following the site clearing, the stand is initiated (either through cuttings or broadcast seeding) by planting »classic« agroforestry species like *Gliricidia sepium*, *Albizia* spp. and *Acacia* spp. These fast growing species are highly to moderately shade intolerant, and can fix nitrogen, thereby improving the site quality and rapidly increasing the amount of available growing space.

The most common species used are fast growing timber and nitrogen fixing trees. For example, fast growing timber trees such as *Terminalia superba*, and *T. ivorensis* may be planted in a mixture with the above mentioned agroforestry species. Improved fallows are typically planted for 1-3 years to improve the soil fertility and then the agroforestry trees are either completely removed or thinned to allow for cocoa cultivation.

## 2.7 Forest tree establishment in cocoa fields

### 2.7.1 Classification of forest trees

A forest tree species' ability to regenerate and grow depends on its autoecology (way of life), the species' preference for a specific environmental niche, and the nature of the openings in the canopy that allow light to penetrate. Given the wide range of characteristics, tropical forest tree species are often classified into the following groups:

- Pioneer species (P) - these are tree species that germinate and grow in open spaces and play a vital role in bush fallow systems in forest areas where their ability to regenerate depends on the fertility of the farm environment. They also create favourable conditions for germination of primary forest species that need shade to germinate and grow
- Non-pioneer species (NP) – these are species that either germinate or grow in shade conditions rather than in open conditions
- Non-pioneer light demander (NPLD)– these are species that germinate in shade conditions but need gaps in the canopy to develop further

5 Improved fallows are part of a relay floristic process that prepares the site for the successive cohort of trees

- Shade bearer (SB)– these are species that require shade conditions to germinate and develop further.

### 2.7.2 Criteria for forest tree selection in cocoa

The criteria for species selection in cocoa production systems depend upon two concepts. One is figuring out which trees to maintain or plant during rehabilitation of mature or abandoned old cocoa farms and the other involves the establishment of new cocoa farms in newly cleared forestland, fallow or degraded forest environment.

Tree species preserved or planted in cocoa fields are selected depending on the site of the plantation or field, and the purpose for which they will be used. Species selected must therefore meet requirements within the following three categories:

- The purpose for preserving or planting
- The wanted or expected product/environmental service
- The site for preserving or planting.

Traditionally, forest timber trees are selected for a variety of desirable traits such as:

- High degree of resistance to particular diseases and pests
- Rapid growth
- Good stem form
- Good natural pruning
- Wood of high density.

However, in selecting forest trees in cocoa fields, farmers should place emphasis on the ability of a chosen tree to promote complimentarity or neutral interactions, as opposed to increasing competition or antagonism in cocoa.

Therefore, desirable traits to look for when selecting forest trees for cocoa plantations may include:

- Crown size and architecture
- Leaf size and shedding rhythm
- Root structure and composition
- The ability of the particular tree to serve as alternative host to disease and pests which can affect the cocoa underneath it.

In addition to the above considerations certain forest trees may be selected in cocoa farms depending on social considerations like demands for traditional medicines or household utensils.

*Figure 4. Selecting desirable trees as shade for cocoa. Adapted from: Mularwarman et al, 2003*

Invariably, farmers and researchers often disagree on what constitutes desirable traits for selecting forest tree to integrate into cocoa cultivation systems. The main point of contention has centred on the trade-offs between a forest tree's potential as an alternative hosts for cocoa pests and diseases, and the tree's purported social-economic benefits to farmers, which tend to differ from place to place and from farmer to farmer.

For instance in countries like Ghana and Côte d'Ivoire, research recommendations have come out with a long list of trees species that are claimed to be incompatible and for that matter should be eliminated from cocoa farms since they serve as alternative hosts for pests and diseases. Most common on the list are *Ceiba pentandra, Triplochiton scleroxylon,* and *Cola nitida*. In a conflict of interest, these species happen to be among the farmers' most preferred species due to their economic and traditional values.

Table 1 presents researchers' list of desirable and undesirable trees in Ghana. This does not exactly match those that are preferred by farmers.

*Table 1: Desirable and undesirable forest shade trees in cocoa based on research recommendations*

| **Desirable species** | **Local name** | **Undesirable species** | **Local name** |
|---|---|---|---|
| *Albizia coriaria* | Awiamfo semina | *Adansonia digitata* | Odadee |
| *Alstonia boonei* | Nyamedua | *Blighia sapida* | Ankyewobiri/Akye |
| *Entandrophragma angolense* | Edinam | *Canthium glabriflorum* | Gyapam |
| *Funtumia elastica* | Funtum | *Carapa procera* | Kwakuo bese |
| *Milicia excelsa* | Odum | *Ceiba pentandra* | Onyina |
| *Pycnanthus angolensis* | Otie | *Cola chlamydantha* | Kra bese |
| *Terminalia ivorensis* | Emire | *Cola gigantia* | Watapuo |
| *Terminalia superba* | Ofram | *Lecaniodiscus cupanoides* | Dwindwera |
| | | *Musanga cecropoides* | Odwuma |
| | | *Myrianthus arboreus* | Nyankuma |

*Source: Manu and Tetteh (1987)*

Despite the range of differences in views on desirable traits, there are some common traits, which are shared by farmers and researchers alike, and can therefore serve as appropriate and adoptable selection criteria.

### 2.7.3 Common traits of desired forest trees in cocoa cultivation

*Crown size and architecture*

Tree crown size should be moderate with small branches. The crown should not be too thick or wide in order to avoid excess humidity within the farm. The crown should also be open so that it allows sufficient sunlight to reach the crops and/or cocoa growing beneath it.

*Root structure and composition*

Selection should focus on trees with few or no buttresses, as well as trees that have deep roots that will not compete with other crops for available moisture and nutrients.

*Leaf shedding rhythm*

The tree should be one that maintains most of its foliage in the dry season (this is the time desiccation is high in cocoa) in order to provide shade for cocoa. It should also have a high decomposition rate so as to maintain soil organic matter and nutrients within the soil.

*Alternative host for diseases and pests*

It is important to avoid tree species that serve as alternative hosts for diseases and pests that tend to affect cocoa. Most of these species are trees that are part of the *Sterculeaceae* family (of which cocoa is a species) or the *Bombacaceae* family, which share common diseases and pests with cocoa.

## 2.8 Regeneration of forest trees in cocoa

In an agroforest landscapes, trees can regenerate through either natural regeneration or artificial regeneration. In West Africa cocoa farmers predominantly rely upon natural regeneration for the propagation and establishment of forest trees in their cocoa fields. However some farmers also plant shade (*Gliricidia sepium)* or fruit trees (e.g. *Persea american, Citrus sinensis, irvingia gabonensis* etc.) or transplant seedlings from the forest onto their farm.

### 2.8.1 Natural regeneration

Natural regeneration relies on nature to provide the seeds to start a new stand of trees. Natural regeneration is a dynamic process by which different species of trees succeed one another in a forest, or by which they re-colonise land when the vegetation has been partially or totally destroyed. Natural regeneration (while slower than an improved fallow) typically produces a

diversity of indigenous trees that are adapted to local conditions and part of the natural forest succession.

There are three main sources of naturally regenerated trees:

- Seed already present in the soil (seed bank)
- Seed dispersed onto the ground by wind or animal
- Sprouts that grow from parts (above or below ground) of trees that have been cut (coppicing).

In order to ensure that the majority of seed germinate, which are present in the soil or fall to the ground, the soil around desirable trees needs to be turn around and all debris cleared from the surface. The major obstacles to natural regeneration on farm are:

- The absence of remnant vegetation from which native seeds will spread, especially large shade trees
- Weeds (weeding during cropping season)
- Bush fire
- Attack from rodents and insects.

Periodic weeding eliminates recently germinated tree seedlings in cocoa farms. Bush fires or burning at the beginning of the cropping season also destroys newly geminated seed or seedlings. For natural regeneration to occur:

- Provide a shallow, fine surface and ensure the seeds are covered with soil (this can be provided after controlled burning)
- Supply an adequate soil moisture for germination and initial seedling establishment
- Look for a viable seed source either in the ground or from a recent seed fall from parent tree
- Ensure low competition from other plants through selective weeding.

If the proper conditions are set for natural regeneration, one can anticipate new, vigorous growth with little cost. Natural regeneration is most appropriate when cocoa is being established in a newly cleared forest environment, including secondary forest and old fallows. This allows an already established stand of important indigenous species to provide a natural habitat for continuous forest based agriculture.

In this situation farmers need to thin the stand to a number that will spatially accommodate the recommended number of cocoa trees per hectare. Depending on the diversity of tree species occurring, farmers have the choice of maintaining different species, which are useful for different agronomic, social, and environmental purposes.

In general, the dynamics of natural forest regeneration reflect a changing pattern of species dominance in which pioneers or non-pioneer light

demanders that establish underneath the canopy dominate the site. For instance, small pioneers like *Musanga* spp. and *Macaranga* spp. are often replaced by larger and longer lived *Terminalia* spp. or *Milicia excelsa.*

Non-pioneer light demanders like *Entandrophragma* spp., which might be considered late secondary or climax species under different definitions, are able to germinate under the pioneer canopy and when openings occur they develop and eventually occupy the overstorey as the pioneer canopy breaks down. If propagules are available, then shade-bearing species can germinate, establish and develop under low light levels in the understorey.

In cocoa agroforests, the natural regeneration, and successional processes for that matter, are drastically disturbed due to continuous weeding. In a shaded system, cocoa dominates the understorey making it difficult for non-pioneer light demanders or shade bearers to establish or germinate. The diversity of non-cocoa trees in many old cocoa farms is the result of relic trees that were actively retained or selected by farmers. Under most cocoa establishment conditions, preferred trees in the cocoa farming system all belong to pioneer or non-pioneer light demander species and the majority are dispersed by wind.

### 2.8.2 Artificial regeneration

This includes direct seeding and planting. Direct seeding is the sowing of seed directly on the growth site either by hand or machine. Planting involves growing of seedlings and/or cuttings. By sowing seeds and planting seedlings farmers choose the species, genetic quality, and spacing. Although this process requires a capital investment, the result is a more productive stand in a shorter period.

One of the major advantages of artificial regeneration may be an increased density of the trees, which will result in less weeding and potentially better formed trees as the trees develops. A simple recipe for broadcast sowing is to till the soil and broadcast. Direct seeding may result in trees, which have faster initial growth, and better form than trees that are planted as seedlings. One possible disadvantage is that thinning may be required earlier in these direct seeded fields.

Artificial regeneration is mostly used after clear cutting. Seedlings can also be raised in a nursery and then transplanted at a relatively low cost.
A tree seed nursery is a place where seeds germinate and are transplanted when mature. Collected seed can be planted on a nursery bed. Artificial regeneration can appropriately be used for both farm rehabilitation and new establishment.

## 2.9 Exercises to identify and select desirable trees in cocoa farming systems

*Introduction*

Farmers have various reasons for selecting species in association with cocoa on farm. However, there is no developed framework for this decision-making process.

Therefore, there is the need for a decision-making framework, which will assist farmers in identifying and using forest trees that are compatible with cocoa and have economic value.

The proposed framework should be based on an approach that is dependent on farmers' concept of a compatible and good shade tree. This point is pivotal since the issue of desirable and/or undesirable shade trees in association with cocoa is different in different environments and it is dependent on individual farmers' own concept of a »good shade tree«.

The framework therefore has to be flexible so that farmers can make decisions based on specific conditions pertaining to their particular environmental conditions coupled with the economic opportunities linked with such forest tree species.

For example, one tree species that exists in area A might not exist in area B and two farmers may have different priorities/needs with respect to a particular tree at different geographic locations.

In order to achieve this, the proposed framework should provide room for a conceptualisation that is based upon capturing farmers' description and/or reasoning behind their perceptions of »good/bad« trees in association with cocoa. For example, consideration should be given to farmers' thoughts on shade, moisture, shedding of branches that might damage cocoa trees, and alternative hosts for diseases and pests. These perceptions could then be scientifically validated with research information and advice.

*Framework to identify and select forest trees for shade in cocoa*

In developing a framework for forest tree species selection for adult learning, a rating system in the form of a matrix could be used. This will enable farmers to decide on a desirable and/or undesirable tree with respect to cocoa.

In this framework, farmers' reasoning for selecting a desirable tree is treated as attributes or indicators, which are then rated against forest tree species according to farmers' judgement.

Attributes can be similar from place to place but ratings may differ since these depend on individual farmers' judgement through experience.

In constructing the matrix the duty of a facilitator is important, as always,

in order to help farmers list as many attributes as possible. This ensures that good trees meet all requirements, while bad trees stand out.

When the matrix is well developed it allows farmers to dwell on a whole range of characteristics to help pass judgement on a particular tree. Ratings of the various attributes should depend on consensus, so that experience is shared from various opinions.

**Exercise to identify and select desirable forest trees in cocoa**

*Learning objectives*

1. To facilitate and validate the detailed description and clarification of what farmers perceive a »desirable« neighbour/shade tree in association with cocoa and what they believe to be the beneficial characteristics
2. To stimulate discussion about specific economic and environmental benefits farmers obtain from neighbour/shade tree species.

*Materials*

- Cocoa farm with shade trees

*Procedure*

Creating a basic matrix

- Gather the participants (best with about 6-10 persons) together at one side of the chosen farm
- Ask participants to identify non-cocoa trees on the side of the farm where they are, and note their spatial arrangements and their desirable characteristics
- Invite farmer participants to mention qualities from experience, that relate to a good and compatible tree with cocoa. Arrange the qualities under different headings and present them in the first column of a table under »Attributes«
- Ask participants to mention 5-10 desirable tree species, other than cocoa, identified on the farm and represent these species in the first row of the same table under »Tree species«. The named species should be agreed upon by all participants so that consensus can be reached with regards to attributes
- Let farmers rate every tree species from 1-10, with 1 being the lest desired and 10 the highest with respect to the attributes mentioned in the first column.

*Table 2: matrix for selecting desirable trees*

| Attributes | Tree species | | | | |
|---|---|---|---|---|---|
| | Species 1 | Species 2 | Species 3 | Species 4 | Species 5 |
| Shade quality | | | | | |
| Moisture | | | | | |
| Soil fertility | | | | | |
| Weed suppression | | | | | |
| Mechanical damage | | | | | |
| Wind break | | | | | |
| Allows good aeration | | | | | |
| Good timber value | | | | | |
| Good NTFP value | | | | | |

*Rating is done from 1-10*

*Follow-up discussions*

- Make sure to facilitate the rating process in the matrix. Continuously ask the participants to ask themselves questions such as do the trees they have represented in the matrix really exist on the farm and if so how close are they arranged and how many per hectare? Are the cocoa trees pruned or unpruned? Are the neighbour/shade trees far apart, close together, tall or short?
- Ask participants to make ratings in the matrix to reflect conditions observed with inputs from knowledge and experience from their individual cocoa farms
- It is important that the matrix becomes a framework through which the farmers can discuss and reflect on the specific situation on their own farms. Therefore, it is equally important that the framework comes to reflect the nature and experience of their individual cocoa farms. This includes making clear to outsiders/resource persons what their reasons are behind the ratings that they have assigned to the »Attribute«s.

*Detailed application of the matrix*

Once the first basic general matrix is built, you can start the more detailed use of the framework.

- Initiate a discussion on what is happening on individual farmers' fields as far as the mentioned tree species are concerned
- Each time a farmer presents ideas on what is good about a listed neighbour/shade tree invite him/her to determine a better rating and ask the approval of other participants until a consensus is reached
- In this way, you can establish a framework on what benefits the farmers are obtaining as a result of the trees. You may chose to start with one farmer, inviting him or her to describe in detail what measures he/she is putting in place to promote positive interaction between tree species

- Once farmers have covered all their key benefits, you can go on to a discussion about some new options which could be tried out alongside what the farmers are already doing.

*Things to avoid*

The facilitator should avoid the tendency to introduce species, which are not represented in the matrix. The ratings should be used to demonstrate the importance of the species in cocoa.

*Some ideas for questions*

- Which are the desired tree species you have identified in combination with cocoa on this farm? Put them in the matrix
- What are the benefits of these species with regards to cocoa with reflection to the actual conditions on your farm
- Using numbers from 1-10, how would you rate the benefits referred to here as attributes?
- Are you satisfied with the ratings?
- What do you think can be done to promote positive interactions between cocoa and associated tree species? Explain the measures you have taken yourself in your field to ensure this?
- What do your fellow farmers think about these measures? Has anybody tried out the same measures or are there different ways to ensure positive interactions between cocoa and neighbour/shade trees?

Formulate other questions according to circumstances, major problems, kinds of technologies, and recommendations that are available from resource persons (researchers) and so on.

**Exercise to identify undesirable forest tree species in cocoa**

*Learning objective*

1. To facilitate and validate the detailed identification, description and clarification of which neighbour/shade tree farmers perceive to be »undesirable« in cocoa fields, and the specific problems associated with them
2. To stimulate discussion about specific economic and environmental implications with regards to problems posed by certain neighbour/shade tree species.

*Materials*

- Cocoa farm with shade trees.

*Procedure*

Creating a basic matrix

- Gather the participants (best with about 6-10 persons) together at one side of the chosen farms
- Ask participants to identify non-cocoa trees on that side of the farm and note their spatial arrangements and characteristics
- Invite the farmer participants to mention problems that they have experienced with regards to undesirable and incompatible trees in association with cocoa. Arrange the undesirable qualities into different headings and present them in the first column of a table under »Attributes«
- Ask participants to mention 5-10 undesirable tree species identified on the cocoa farm, and represent these species in the first row of the same table under »Tree species«. The named species should be agreed upon across board so that consensus can be reached with regards to attributes
- Let farmers rate every species from 1-10, with 1 being the poorest and 10 the most desirable with respect to each attribute.

*Table 3: matrix for identifying undesirable trees*

| **Attributes** | **Tree Species** | | | | |
|---|---|---|---|---|---|
| | **Species 1** | **Species 2** | **Species 3** | **Species 4** | **Species 5** |
| Too much shade | | | | | |
| Moisture stress | | | | | |
| Nutrient stress | | | | | |
| Low rate of decay | | | | | |
| Mechanical damage | | | | | |
| Root competition | | | | | |
| Harbours pests | | | | | |
| Harbours diseases | | | | | |
| Good NTFP value | | | | | |
| Good timber value | | | | | |

*Ratting is done from 1-10*

*Things to consider*

- Make sure to facilitate the rating process in the matrix. Continuously ask the participants to ask themselves questions such as do they agree that trees they have represented in the matrix are undesirable?
- Ask participants to make their ratings in the matrix to reflect observed conditions on the school farm, as well as their own knowledge and experience from their individual cocoa farms
- Make sure the matrix becomes a framework through which the farmers can discuss and reflect on the specific situation on their own farms
- Make sure that the framework comes to reflect the nature of their individual cocoa farms. This includes making clear to outsiders/resource persons, which practices are creating problems, despite the farmer's attempts to find solutions.

**Detailed application of the matrix**

Once the first basic general matrix is built, you can start the more detailed use of the framework.

- Initiate a discussion about what is happening on individual farmers' fields. Each time a farmer presents ideas on what is undesirable about a listed neighbour/shade tree invite him/her to determine a better rating and ask the approval of other participants until a consensus is reached
- In this way, determine the general problems affecting the performance of the cocoa, and what each farmer is doing about these problems. You may chose to start with one farmer, inviting him or her to describe in detail what measures he/she is putting in place to promote positive interactions between tree species or to reduce competition or other key problems
- Ask other farmers to comment on these efforts. Do they experience the same problem? Are they trying out the same solution? If not, what are they doing? Make sure each individual shows what they are talking about by using the rating system in the matrix
- Once the farmers have covered all the key areas of concern, have explained their attempts to find solutions and have agreed that these measures are satisfactory or unsatisfactory, you can go on to a discussion about some new options which could be tried out in addition to what the farmers are already doing.

*Things to avoid*

The facilitator should avoid the tendency to introduce species, which are not represented in the matrix. The ratings should be used to demonstrate the importance of the species in cocoa.

*Some ideas for questions*

- Which of the observed tree species are integrated with cocoa in the part of the farm you inspected?
- Indicate the trees with undesirable characteristics in the first row of the matrix
- In terms of your own farm, what are the problems associated with these species and cocoa?
- In your own way rate the attributes
- Are you satisfied with the ratings?
- Which tree species are you dissatisfied with on your own field? What are their attributes? What do you think is the cause of these particular problems?
- What do you think can be done to solve these particular problems associated with these tree species? What measures have you yourself taken in your field to solve the problems?
- What do your fellow farmers think about the problem with this particular

tree species? Do you all have the same problem? Have you tried out the same solution?

Formulate other questions according to circumstances, major problems, the kinds of technologies and recommendations that are available from resource persons (researchers) and so on.

**Exercise to identify and select temporary shade trees in cocoa**

*Learning objective*

1. To identify and validate a detailed description and clarification of what farmers perceive »good« temporary shade trees for cocoa;
2. To stimulate discussion about specific economic and environmental benefits farmers obtain from such shade tree species;

*Materials*

- Newly established cocoa farm, approximately three to six years of age.

*Procedure*

Creating a basic matrix

- Gather the participants (best with about 6-10 persons) together at one side of the chosen farm
- Ask participants to identify non-cocoa trees on the farm used as temporary shade, their spatial arrangements, and note their characteristics
- Invite the farmer participants to mention qualities that, from their experience, relate to good temporary shade trees for cocoa. Arrange the qualities into different headings and present them in the first column of a table under »Attributes«
- Ask participants to mention 5-10 tree species identified as being used for temporary shade and represent these species in the first row of the same table under »Tree species«. The named species should be agreed upon across board so that consensus can be reached with regards to attributes
- Let farmers rate every tree species from 1-10, with 1 being the poorest and 10 best with respect to the various attributes.

*Table 4: matrix to identify desirable temporary shade trees*

| Attributes | Tree species | | | | |
|---|---|---|---|---|---|
| | Species 1 | Species 2 | Species 3 | Species 4 | Species 5 |
| Shade quality | | | | | |
| Fast growth rate | | | | | |
| Coppicing ability | | | | | |
| Moisture | | | | | |
| Soil fertility | | | | | |
| Weed suppression | | | | | |
| Wind break | | | | | |
| Future timber value | | | | | |
| Future NTFP value | | | | | |

*Rating is done from 1-10*

*Things to consider*

- Facilitate the rating process in the matrix by continuously asking farmers questions such as is the tree too tall or short and if so how close are they arranged and how many per hectare? Has the shade tree a high coppicing ability?
- Ask participants to make ratings in the matrix that represent the reality in their own cocoa fields.

*Detailed application of the matrix*

Once the first basic general matrix is built, you can start the more detailed use of the framework.

- Initiate a discussion on what is happening on individual farmers' fields as far as the mentioned tree species are concerned
- Each time a farmer presents ideas about what is good about a listed shade tree invite him/her to determine a better rating and ask the approval of other participants until a consensus is reached
- In this way, establish a framework on what benefits farmers are obtaining as a result of the trees. You may chose to start with one farmer, inviting him or her to describe in detail what measures he/she is putting in place to promote positive interaction between tree species
- Once farmers have covered all the key benefits, you can go on to a discussion about some new options which could be tried out in addition to what the farmers are already doing.

*Things to avoid*

The facilitator should avoid the tendency to introduce species, which are not represented in the matrix. The ratings should be used to demonstrate the importance of the species in cocoa.

*Some ideas for questions*

- What different tree species have you identified as being used for temporary shade for cocoa on the farm?
- Put the identified trees in the matrix
- What are the benefits of these species with regards to cocoa as it reflects the actual conditions on your farm?
- In your own way rate the benefits
- Are you satisfied with the ratings?
- What do you think can be done to promote positive interactions between cocoa and associated tree species? What are the measures you have taken yourself in your field to ensure this?
- What do your fellow farmers think about these measures? Has anybody tried out the same measures or are there different ways to promote positive interactions?

# 3 Propagation of tree seed

## 3.1 Tree seed selection

Seed collection is a very basic practice for tree growing. It is important to collect seeds for planting from the »right« trees because within a species there can be wide variation. Therefore it is important to select from the best-looking mother trees.

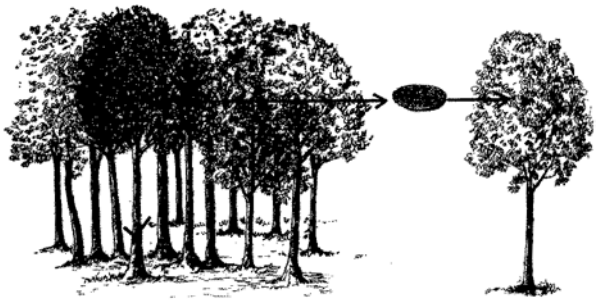


*Figure 5. Tree selection for seed collection. Source: Mularwarman et al., 2003*

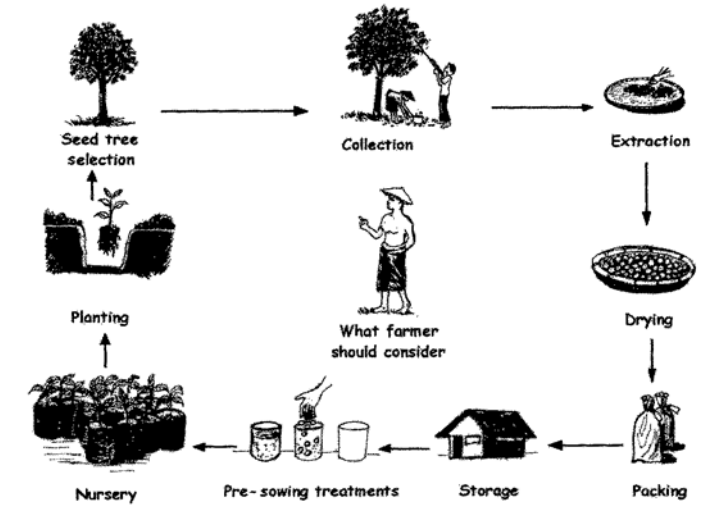



*Figure 6. Seed collection activities. Source: Mularwarman et al., 2003*

### 3.1.1 Variation within species

Variation within species can result from many causes, including age, different growth conditions, effects of wind or fire, competition or suppression by large trees, and true inheritance difference. Only inheritance differences will affect offspring.

To identify true inheritance differences one must compare trees at the same age growing under similar environmental conditions. Inheritance difference is always part of the tree as we see it, but can be difficult to identify visually if we do not have neighbouring trees to compare with, or if the trees are growing in very different sites.

### 3.1.2 Site source matching

Trees of the same species can adapt differently to different environments. Some species can grow under a wide range of environmental conditions, while others have more specific requirements. It is important to collect seed from trees that grow under approximately the same conditions as where you want to grow them.

Trees growing closer to lakes and other water bodies are tolerant to water levels. Trees growing in sand, rocky and hilly areas are often drought tolerant. These characters are sometimes inherited.

### 3.1.3 Site selection

This means selecting seed from groups of trees that grow on similar sites as your planting site.

### 3.1.4 Inbreeding

When closely related individuals mate and have offspring, the offspring is usually poor. Many plants can self-pollinate but the quality of the seed produced is usually poor in the sense that the plants grown from them perform poorly.

Inbreeding occurs when the trees' flowers are pollinated with pollen from the same tree or its close relatives, and this often gives poor offspring. The strongest inbreeding is with self-fertilisation but inbreeding can also occur when siblings cross-pollinate.

Inbreeding can also occur when individual flowering or fruiting occurs out of phase with other trees. They mate by themselves because there is no one else to cross with.

Inbreeding is very common in trees grown on farmland. This is because the trees grow far away from other trees of the same species and have little chance to cross-pollinate.

Even though an isolated tree may appear nice and healthy, it is not always a good seed source (especially if it is the only one) since there are no other trees surrounding it and the seeds produced may be a result of inbreeding.

To avoid inbreeding:

- Never collect seed from a single isolated tree on a farmland
- Avoid trees which flower at a different season from the other trees of its kind
- Choose plantations where the origin of the trees is known.

### 3.1.5 Diversity

Despite precautions taken during seed collection from selected stands and mother trees, failure can still occur during tree establishment.

This failure may be due to inheritance defects and can be prevented by making sure that seeds are collected from several different parents. In order to ensure this, the following may be applied:

- Find a good stand of trees with many nice trees
- Collect seed from several trees in the stand so you get a good variation and adaptability
- Avoid collecting seed from neighbouring trees since trees that grow closely together in a forest stand may be closely related even though they may look nice – seed often share the same father.

In tree plantations neighbouring trees are not usually related because seed and plants were mixed during establishment. The distance of mother trees is not crucial in plantations.

Rules for selecting mother trees

Always collect from:

- Trees that grow on similar sites to where you want to plant your trees
- Good looking mother trees
- Trees which grow in stands, best in large stands like plantations
- Trees that fruit during the main fruiting season
- Several different trees in the stand. Collect from at least 10 individuals for small collections, and from 25 individuals for large collections
- Widely dispersed trees in the stand, with at least 50m to next seed tree
- Collect from several different woodlots if stands are small.

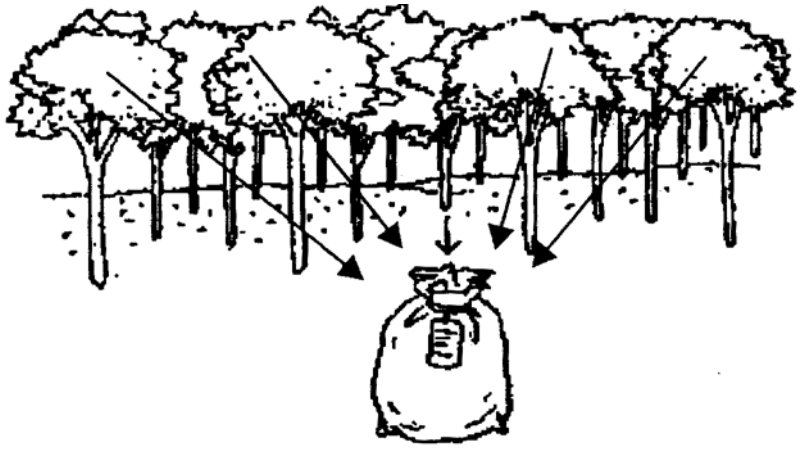


*Figure 7. Seed collection from multiple trees. Source: IFSP 2004*

Avoid collection from:

- Trees that grow on sites which are different from where you want to plant your trees
- Poor looking mother trees with deformities or diseases
- Single isolated trees
- Trees that fruit out of season, or very early or very late compared to other trees
- Only few trees in a stand
- Neighbouring trees, especially in the natural forests
- Plantations or planted trees where the origin of the mother trees are unknown.

## 3.2 Seed collection (maturity)

Seeds germinate best and keep best in storage if they are fully mature and free from insect pests and diseases when they were collected. The best quality seed are usually those that have just fallen or are just about to fall.

How to judge if seed are mature

- Look at the appearance of the fruits
- Open and look at the seed.

Dry fruits change colour from green to brown or grey. Fruits that have reached maturity will show signs of opening. Dry fruits, which do not open on the tree, break up easily in storage when they are nearly mature.

Fleshy fruits, which are usually dispersed by animals, change to bright and conspicuous colours. Large seeds can be examined directly, e.g. by cutting through the seed.

Some species have a short fruiting season, others have fruits almost throughout the year. Seed quality is best at peak fruiting season. If a collected seed lot contain a lot of immature seed they should be discarded.

### 3.2.1 Seed collection method

#### Natural seed fall

Large seeds or fruits, which fall to the ground when mature, can be collected on the forest floor from mats laid beneath the trees. This technique is useful with certain forest species but is unsuitable for trees with fine seeds dispersed by wind.

*Figure 8. Seed collection from the ground (seed fall). Source: Mularwarman et al., 2003*

### Seed from low branches

Fruits on low branches can be hand picked into a container or stripped onto mats laid beneath the tree. With acacias, when the pods are brown and split along the margins, beat the branches with a stick or shake to dislodge seeds and pods onto sheeting.

*Figure 9. Seed collection from lower branches. Source: Mularwarman et al., 2003*

### Seed from higher branches

If branches are out of reach, a variety of long handled tools (saws and pruners) can be used. A bow and arrow can also be used. Fasten the line to the arrow and shoot the line across the end of a branch. Then haul the cord or rope over and use it to break off the end part of the branch.

Long-handled tools for seed collecting can be made by fastening a curved pruning-saw blade to a wooden or aluminium pole. Secateurs and a rake can also be used when collecting.

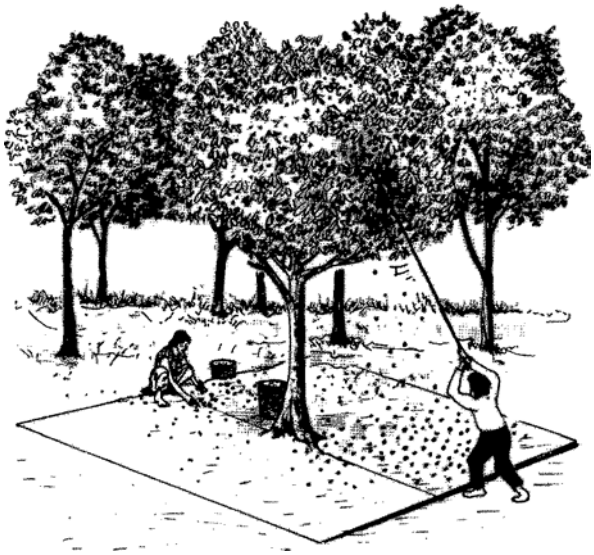


*Figure 10. Collecting seeds from higher branches. Source: Mularwarman et al., 2003*

### Climbing

Climbing taller trees may be possible but agility and special attention to safety are required. Common aids include climbing irons, safety belt and portable or sectional ladders.

*Figure 11. Collecting seeds by climbing ladder. Source: Mularwarman et al., 2003*

### Felled trees

Trees should not be felled simply for harvesting seeds. However, if a tree is being cut down for other reasons, any seeds present can be salvaged from it. In areas where timber is being harvested, this will provide an easy and cheap way to collect large quantities of seed. Obtain permission beforehand and select good parent trees. The quantity of seeds can be worth the effort.

## 3.2.2 Seed collection (diseases and pests)

Insects attack fruits and seed when they are on the trees. While some of the seeds are also attacked when they fall to the ground, others start to germi-

nate or rot. Only seed that are healthy should be collected since infestation can spread from affected seeds to healthy seeds.

Seed health can sometimes or often be determined on the outside of the fruit or seed coat. Seeds that are infested often have holes on the surface. Seeds that have soft coats or are clearly rotten should be discarded.

Seed that have started to germinate will usually dry out and die when stored. Unless they are to be planted immediately, germinating seeds need to be discarded.

### 3.2.3 Seed after collection (temporary storage)

Seeds should be treated as living organisms until they are planted. At time of collection seeds are often moist and have a high temperature, therefore lack of ventilation during storage may cause damage or decay. This is particularly important to remember during temporary storage.

Collected fruits and seeds are usually put in baskets until they can be processed. Seed should not be put in plastic bags since the temperatures in those bags could reach high levels in a short time, especially in the sun.

Temporary storage in baskets and in the shade is best for most species. If fruits and seeds are temporarily stored in the field, they should be:

- In the shade
- With adequate ventilation.

### 3.2.4 Seed after collection (extraction, cleaning, and drying)

Seeds are extracted from fruits. If seeds are to be stored for some time, they should be cleaned and dried.

EXTRACTION ⟶ CLEANING ⟶ DRYING ⟶ STORAGE

This process is collectively called PROCESSING. Processing should be done as soon as possible after seed collection.

Extraction of seed from fruits depends on fruit type and species. Many dry fruits will open just after drying and the seed will fall out by themselves. If the seeds are small and easily lost, fruits are often collected prior to full maturity.

Fruits may be dried in the sun to allow it to split open. Some dry fruits do not open directly and must be broken up by hand. Fleshy fruits can be cleaned in water by rubbing.

Some types of seeds are not extracted, e.g. if they remain tight inside the fruit. The whole fruit is usually sown after breaking off the wings. If the seed contains a lot of debris like leaves, branches and fruit pods, it is inconvenient to handle.

Large size debris can be removed by hand. Deformed or damaged seed of some species could also be removed by hand. Small size debris could be removed by winnowing.

### 3.2.5 Seed label

Seed that is collected from the same place at the same time is called a »seed lot«. A seed lot has to be given a label, with the following information:

- Seed lot number (for additional information)
- Name of the species
- Location where the seeds were collected
- Type of stand where it was collected, e.g., plantation, woodlot
- Date of collection
- Date of processing.

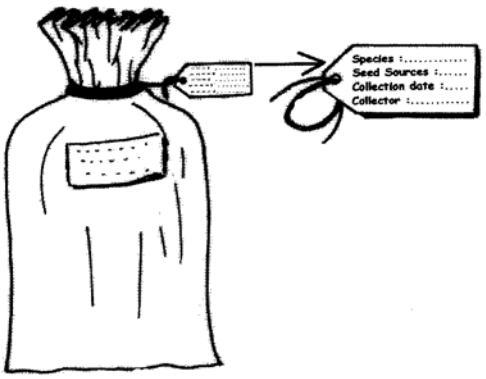



*Figure 12. Seed labelling. Source: Mularwarman et al., 2003*

### 3.2.6 Seed storage (long term)

Seeds that are stored in the open may regain moisture, and are easily attacked by insects, or respire so that they rapidly lose viability. Dry seed should be stored in closed containers such as plastic or metal containers. The best thing is to store seed in clay jars (cooler) in a cool place in the house.

Seeds in storage should always be labelled in order to preserve its origin and other vital information. It is recommended to put one label inside and attach one to the outside of the container.

## 3.3 Conditions for sowing the seed

The ultimate purpose of a seed is to germinate and develop into a new plant. Germination depends on internal and external factors.

Internal factors:

- Health
- No dormancy or broken dormancy
- Seed vigour.

External factors include:

- Adequate water
- Good temperature
- Oxygen (air)
- Light (for some species)
- Substrate (soil)
- Seeds must also be kept free of pests and diseases.

Viable and healthy seed can germinate if they have no dormancy. Dormancy can impede or restrict germination even of healthy seed. Dormancy can be caused by hard seed coat, which restricts seed from taking water. If seeds are dormant, they need to be pre-treated before they can germinate.

Dormancy caused by hard seed coats can be broken by scarification (this allows seed to take up water), e.g. by filing the seed coat before sowing. When the hard seed coat is broken, the seed can then take up water.

Dormancy may also occur when there are inhibitors in the fruit and seed coats. Inhibitors often prevail in fleshy fruits. If the fruit flesh is removed and the seed thoroughly washed with water, they can usually germinate.

### 3.3.1 Germination

Germination is promoted by providing suitable seed bed and nursery environment. Some seeds only germinate in light, others can germinate in the dark. The first process of germination is the uptake of water. Once the seed has imbibed water it also needs air for respiration. If the seed gets too little air, it will rot. Too much watering hampers respiration.

Seeds must have the right temperature for germination to occur. Conditions, which are too hot or cold, may restrict germination and even kill the seed. If the temperature is not optimum, germination may take place slowly with the risk that fungi can infect the seed.

If the seed or the soil is infected by fungi, the fungi may kill the seed before germination. Fungi attack the seed during germination or at early development.

### 3.3.2 Sowing depth

The optimum planting depth varies with species. As a rule of thumb, seeds should be sown at a depth that is approximately 3-4 times their diameter. However, large seeds (>1.5-2cm diameter) need a sowing depth of only twice their diameter.

Under moist conditions many seeds germinate readily on the surface. Under nursery conditions, it is normally preferred to cover the seeds with a layer of soil since freely exposed seeds are readily damaged by heat or desiccation and small seeds may be washed away by showers or watering.

When seeds are sown too deep it delays their emergence and when they are sown very deep, emergence may fail entirely.

### 3.3.3 Moisture (water)

Water requirement differs from species to species, and according to different weather conditions. Too little water results in reduced growth or wilting. Too much water creates respiration problems and sometimes promotes fungal diseases.

Newly germinated seeds are sensitive and need to be watered frequently. As seedlings grow their water requirement increases and watering should be increased accordingly.

As seedlings grow they attain a certain level of tolerance against desiccation. Hence, the frequency of watering could be reduced, for example from several times a day to only once or twice a day.

Towards the end of the nursery period, watering should be reduced as part of the »hardening« up of the seedlings in order to adapt them to the field conditions.

## 3.4 Nursery bed establishment

There are 2 types of nursery beds:

1. Temporary nursery bed
2. Permanent nursery bed.

A temporary bed is appropriate for nursing a small quantity of seedlings, suitable for a household. A permanent bed is more appropriate for nursing a large quantity of seedlings, for commercial use. Therefore, the intended purpose of the seedlings will determine the type of nursery bed to employ.

### 3.4.1 How to establish a tree nursery

The following could be used as guidelines when establishing a tree seed nursery:

**1. Location**

- Look for a place close to a water source
- There must be sunlight

- There should be a good drainage system
- The land must be fertile or you can apply fertiliser or prepare compost
- It must be easily accessible to the nursery operator.

**2. Management**

- The nursery must be fenced to prevent strangers or animals from entering
- It also needs to be shaded.

### 3.4.2 How to construct the nursery bed

The physical structure of the soil in which seeds germinate is crucial both for germination and early seedling establishment. A good seedbed should provide a balance between moisture and aeration.

A loose but fine structured soil assures good contact between the seed and soil, and allows water to be supplied continuously, while providing adequate aeration for respiration by the roots.

1. Dig, loosen and turnout the soil about half a meter wide. This will loosen the clods in the soil and also allow watering of the bed without stepping on it. The soil surface should have a texture that will not form a crust since this will restrict air circulation and also block emerging seedling. Small seeds should have a finer and more compact soil than larger seeds
2. Raise the bed to a height of about 10cm to 20cm and a length of about 2m in other to allow water to permeate through the bed
3. The distance between each bed should be 60 cm, if more than 1 bed
4. The nursery bed must be levelled
5. Start the bed with gravel before adding the soil, this will allow water to permeate through the soil and make picking of the trees very easy
6. Provide shade for the beds
7. Provide furrows in between the beds to drain excess water.

Soil that is too loose or compact may negatively affect seed germination and subsequently seedling establishment. Most species germinate well in a medium of loam texture – soil particles that are not too sandy and not too fine.

A mixture of sand (river sand) and peat (material with high organic matter) can be mixed with available soil to provide the desired soil medium for the seedbed. Sand improves the drainage and aeration (air circulation), while peat improves water retention capacity.

It is important to weed, and remove all old plant debris and work the soil thoroughly to root depth. This is easiest when the soil is slightly damp but not wet. Once the seedbed is ready avoid any physical compaction such as that caused by walking on the soil.
In large scale nurseries, soils from previous year's seedbeds may be con-

taminated by pathogens and so should be sterilised before use. This may be done by heating or fumigating and this requires that the soil be removed and put back after it is sterilised.

### 3.4.3 Sowing the seed

1. If seed is too hard, pretreat them by leaving them in water for a day before sowing
2. Sow the seed in the nursery bed or in polythene bags
3. Before planting the seeds, the nursery beds or polythene bags must be watered and placed in a cool place
4. Leave a space of 10cm to 15cm in between seeds
5. The seed must not be sown deep in the soil. The depth of the hole must be twice that of the seed
6. Water the nursery bed or polythene bags and place them at a cool place
7. Use the soil in one polythene bag to plant one tree
8. Shade the bed with palm branches, water it and when the branches rot they will add up to the soil to make it fertile
9. Seed can also be broadcast on the raised bed
10. Water the nursery bed or polythene bags at least twice a day.

### 3.3.4 How seedlings are planted in a polythene bag

1. Mix the soil with sand and compost
2. Make a hole in the polythene bag and fill it with the mixture, press it to stand firm
3. Let the polythene bag be straight so that arrangement of seedlings can be easily done
4. In arranging the polythene bags on the ground there should be paths for watering and pruning.

### 3.4.5 Light and shade provision

Seedbeds and polythene bags must be shaded during germination and early seedling stages. Shade or shelters protect seeds and young plants from:

1. Direct sunlight
2. Large temperature fluctuations
3. Desiccation
4. Heavy rains.

The shade or shelter should be raised about 30-60cm above the seedbed and approximately 2m above polythene bags to allow for a convenient working height.

The density of the shade or shelter must be adjusted according to species. For light demanding species, shade that is too dense may result in thin, weak

seedlings (etiolation). Too little shade may provide inadequate protection against the above factors.

Shade is gradually removed as seedlings grow, except in the case of shade loving species like *Khaya* spp., which normally grow under a shade canopy of pioneer or other trees in the field.

### 3.4.6 Hardening

Just before seedlings are planted in the field, watering is reduced and the addition of fertiliser is stopped under nursery conditions to harden the seedlings to enable them withstand field conditions.

Shade or shelters can be removed to expose seedlings to full sun light, although shade may be left for certain species that are to be planted under shade trees, e.g., shade tolerant species.

1. Water seedlings at least once a day on the bed and the polythene bags so that the soil does not become too dry
2. If the seedlings grow to about 50cm in height, you can plant them at the desired location.

### 3.4.7 Fertiliser application

The need to apply fertiliser and the specific type depend on:

- The nutrient content of the soil
- Size of seedlings
- Length of time they will spend in the nursery.

Where fertile forest soil is used in germination beds or as potting soil, fertiliser application is not necessary. Where planting soil is relatively poor in nutrients, fertiliser application is encouraged.

Fertilisers that are rich in phosphorus are usually recommended since it is often a limiting factor in tropical soil types, and because it encourages root development and stimulates the development of nitrogen fixing bacteria in nitrogen fixing tree species (*Leguminosae*).

The following must be observed when applying fertiliser:

1. Fertiliser for small seedlings should be applied in liquid form with a watering can
2. For potted plants, a few granules may be applied to each container
3. Ensure that granules do not remain on leaves since it may cause damage
4. Seedlings should be washed thoroughly after application of granule fertiliser to dissolve the granules and ensure root contact.

### 3.4.8 Root pruning

Seedlings that are pulled out from the nursery beds (bare-root seedlings) may be root-pruned before transplanting since:

1. A large spreading root system makes planting difficult
2. Deep roots are easily damaged when removing them from the nursery.

Seedlings in polythene bags should have their root occupying most of the pot volume. However, roots must not grow outside the pot and anchor the seedlings into the soil below.

Seedlings in polythene bags may be root-pruned by lifting the individual bags and cutting roots that have grown out of the polythene bag with a knife. Bag seedlings are root-pruned to:

1. Reduce overgrowth in the nursery
2. Facilitate the physical planting process
3. Promote side root formation.

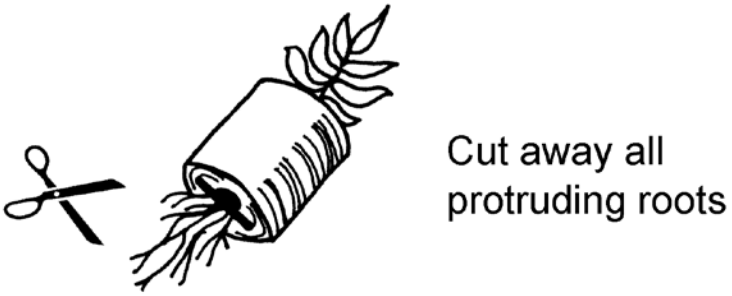



*Figure 13. Root pruning*

Frequent root pruning (every 7-14 days depending on growth rates) is better than delayed pruning, which shocks the plant. More frequent pruning is usually necessary by the end of the nursery season when the plants have grown large. The last pruning is usually done 2-3 weeks before transplanting.

If pruning involves cutting a lot of roots, seedlings must be shaded and watered thoroughly the first days after pruning to help seedlings recover from the shock. If planting is not done immediately and seedlings develop more roots out of the bag, a new pruning and recovery period must be allowed.

## 3.5 Tree planting

Before the seedlings are transplanted, the field needs to be cleared and the soil worked to allow the newly planted seedlings to get favourable soil conditions and enough sunlight.

### 3.5.1 Transplanting the seedlings

1. Water the seedlings before transplanting
2. Make a hole of depth 40cm and width 30cm in which seedlings will be planted
3. Transplant seedlings from the nursery bed and place in the hole
4. Make sure you do not bend the stem when planting
5. Use soil from each hole to fill the various holes after seedlings have been planted
6. Use your fingers to press the soil around the stem to hold it firm to the ground.

### 3.5.2 Transplanting seedlings in polythene bags

1. Remove polythene bag before planting
2. After taking the seedlings from the nursery plant as soon as possible.

*Figure 14. Removing polythene bag from seedling for planting. Source: McDonald et al. 2003*

*Seedlings in polybags ready for transplanting*

## 3.6 Tree management

Preservation or the introduction of trees on cocoa farm requires management to achieve the best possible combination that will ensure synergy under the given environmental conditions.

### 3.6.1 Tree pruning

This is the strategic removal of branches and stems from a large tree to give them a desired shape and make them healthy. In the case of cocoa farming, pruning can be practised to reduce shade and to allow air to move above and between cocoa trees. Pruning trees on a regular schedule improves tree health, controls growth, and enhances flowering, fruiting, and appearance.

#### When to prune

Pruning should be done for the first time 2 to 5 years after planting and thereafter, every 5 to 7 years. Pruning should be carried out during the dry season to the early parts of the rainy season, before new growth starts, since wounds close quickly as growth starts at the onset of the rains and insects and diseases infestation are less prevalent. Branches and stems that are removed may be used for firewood and the leaves used as mulch on the farm or on nursery beds.

#### How to prune

Closely assess the tree to be pruned and imagine it larger than it seems now. Bear in mind that the branches on the tree will only increase in diameter and length and will not move upwards on the trunk as the tree grows. Hence, the following should be observed when pruning:

- Do not cut more than 25% of the tree canopy since this will only serve to starve the tree, causing it to develop fast growing, weakly attached sucker growths, which will increase maintenance cost and break off easily in strong winds
- Make the final pruning cut just outside the branch collar (BC) as indicated in the diagram below. The BC is a swelling situated at the point where the branch attaches to the trunk and it acts as a valve that closes off the cut. It contains a chemical zone that inhibits the spread of decay in the trunk. When decay occurs in the branch, it spreads down towards the base until it reaches the protected chemical zone (BC). Once there it forms a protective shield when the branch falls off. The BC functions only when the final cut is made just outside the BC perpendicular to the branch. If stubs are left after cut, the valve will not function and insects, diseases and rot will attack the core of the tree and weaken it against any form of strong wind
- When removing large branches (see diagram below), make three or four cuts. Make the first cut on the underside of the branch about 18 inches from the trunk. Undercut one-third to one-half way through the branch, stopping before the saw binds. The second topside cut should be made

20 inches from the trunk. This cut cuts all the way through the branch. The third cut removes the stub by cutting next to the branch collar.

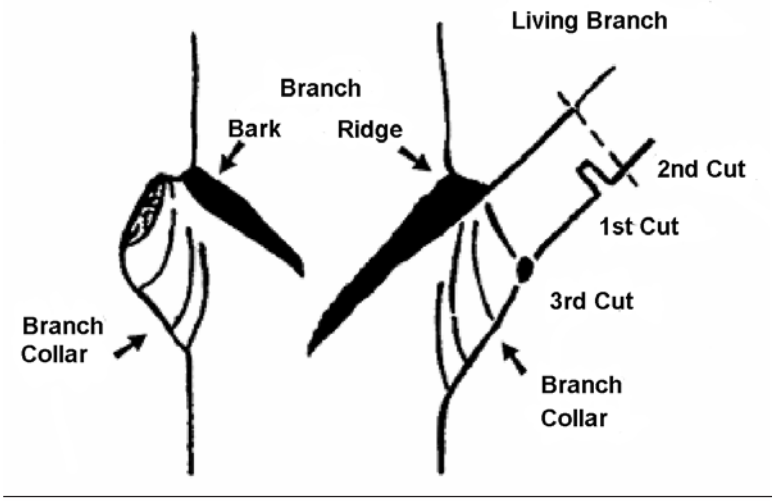



*Figure 15. How to remove a large branch from a tree*

Trees could be pruned for strength and form by removing:

- Multiple trunks to encourage the growth of one main trunk
- Water sprout and root suckers
- Branches that turn inward
- Damaged, diseased, and dead branches.

### 3.6.2 Coppicing

This involves cutting back a tree to about 50cm from the ground to encourage re-growth of new shoots. This procedure is beneficial for old trees and is also a useful method of natural regeneration. Coppiced trees can live longer than if the tree was not cut down at all. In newly established cocoa farms, coppicing of large old trees help to provide much needed initial shade as well as permanent shade.

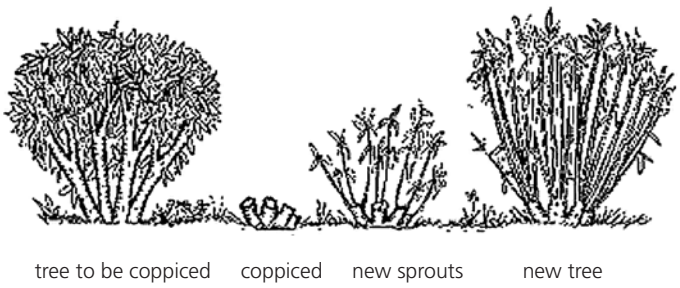



*Figure 16. Coppicing cycle*

### 3.6.3 Pollarding

This is the broad removal of all of the branches while the main trunk is left standing. This is done 2-3m from the base of the tree. This procedure stimulates the growth of shoots from the stem to form a new crown. Pollarding may be initiated when the tree is young and the process repeated throughout the life span of the tree.

*Figure 17. Pollarded tree*

## 3.7 Exercises on tree seed propagation in cocoa farming systems

*Introduction*

Planting the right trees in the cocoa farm can provide both environmental and economic benefits for cocoa farmers. There are distinct advantages in basing such plantings on species native to the planting area, since these are usually well suited to local conditions and in harmony with the landscape and wildlife. Such plantings also help to conserve genetic resources for future generations. However, this does not rule out the introduction of exotic species that can provide similar benefits and are suitable for the area.

Trees are generally propagated from seeds and their growth is greatly influenced by the choice of high quality seeds. Seeds or seedlings of many native tree species can be bought but may be costly or even ill adapted for local conditions. As a result it is best to collect own seeds from best sources to assure better quality. Collecting can be easy, inexpensive and rewarding.

### 3.7.1 Exercise on tree seed collection

*Learning objectives*

1. To promote trees of good genetic quality in cocoa
2. To encourage self-reliance in germplasm supply through seed collection.

*Material*

- Seed source (near by forest or farm with forest vegetation)
- Basket or container or paper bags
- Ladder
- Mat
- Knife or secateur
- Rope

*Procedure*

Divide participants into 3-5 groups. Ask groups to identify, locate and select 3-5 suitable timber trees. They should select and collect seeds from the best looking individuals that are healthy, vigorous, and from a reliable seed source. Ask participants to avoid individuals that are isolated.

However, they should collect similar quantities from several well-spaced trees between 50-100m apart and mix them together. Ask groups to record the nature of the seed and the method used to collect that particular type of seeds. Ask groups to raise a seedbed and sow them for future planting on field.

*Guided questions*

- What are the qualities to look for when selecting a tree for seed collection?
- What is the effect of selecting from any kind of tree?
- Why is it important not to select from a few isolated individuals?
- Is it important to select and collect from trees with similar geographic conditions, why?
- Why did you use this method and not the others?

### 3.7.2 Exercise on seed after collection

*Learning objective*

1. To determine various methods for processing and storing tree seeds
2. To strengthen knowledge on tree seed handling.

*Material*

- Seed source (near by forest or farm with forest vegetation)
- Basket or paper bags
- Air-tight container
- Small plastic bags

- Ladder
- Mat
- Knife or secateur
- Rope.

*Procedure*

Divide farmer participants into groups of 3-5. Ask groups to select and collect seeds from the best looking individuals that are healthy and vigorous from a reliable seed source. Ask participants to avoid individuals that are isolated.

Ask groups to collect similar quantities from several well-spaced trees between 50-100m apart and bulk them. Record the nature of the seed and the method used to collect that particular type of seed. Ask groups to process the seed according to the nature of the seeds using an appropriate method for each kind of seed lot.

After processing, divide the seeds into smaller quantities and place them in the small plastic bags for labelling. Place the plastic bags and their content in the air-tight containers for storage. Groups should determine the storage period, after which seeds can be planted or sold.

*Guided questions*

- What are the species?
- Where are they located?
- How are the seeds collected?
- Describe the stages for processing collected seeds?
- Why is it necessary to store the seeds and not plant them outright?
- How many days, weeks, or month will it take to store the various seed types?

### 3.7.3 Exercise on sowing seed

*Learning objectives*

- To strengthen knowledge on direct seed sowing in cocoa farms

*Materials*

- Fallow land or mature cocoa farm

*Procedure*

This exercise has to be done in stages at different times so as to ensure good establishment. Group participants into 4-5 groups.

**Stage I: seed collection**

Each group should identify 3-5 tree species that they will work with. Ask the group to list all the good attributes of the trees with respect to their compatibility with cocoa. Ask each group to select 10-20 of the desired trees and collect mature seeds and bulk them.

**Stage II: seedbed preparation**

Ask the groups to construct seedbeds corresponding to the different species.

**Stage III: sowing of seeds**

Ask groups to choose and sow seeds either in rows or broadcast seed in field. Planting should be done in the rainy season so as to ensure available soil moisture for germination and establishment.

*Guided questions*

- List 3-5 timber tree species that you would like to work with, which in your opinion are compatible with cocoa
- How many trees do you have to collect seeds from for each species and why does it have to be at lest 10 trees per species?
- Why is it important to collect mature seeds?
- Why should you sow at the beginning of the rainy season?
- What are some of the processes you need to undertake to enhance germination of the seed you have collected?
- How do you construct your seedbeds?
- In constructing the seedbeds what soil do you have to use and why?
- How are you going to shade the beds?
- What are the processes before and after transplanting of seedlings to the field?

### 3.7.4 Exercise on natural tree regeneration

*Learning objectives*

- To identify the appropriate model for a natural regeneration regime for rehabilitation
- To select the appropriate tree species for rehabilitation.

*Material*

- Abandoned old farm, fallow or degraded forest land

*Procedure*

Ask farmers to identify desirable timber trees from the remnant vegetation on the farm and demarcate an area of 10 x 10m around the trees. Ask participants to carefully remove weeds and other competing debris from the area. Ensure that if any wildlings are found they are those of the standing parent tree.

Remove these wildlings and transplant them in areas of the field agreed upon by participants. After that loosen the soil and add mulch on the surface in order to raise soil temperature and conserve soil moisture to promote easy germination in the area (seedbed). Observe the area for between 2-4 weeks to determine if more wildlings will germinate. When they do count and transplant them.

*Guided questions*

- Are there any remnant forest tree species in the farm?
- If there are, what are they and are they desirable for cocoa?
- Why is it necessary to use the seed in the soil and not cut the tree to induce sprouting?
- Why is it necessary to use mulch and not fire to increase soil temperature?
- Is the parent tree a pioneer or non-pioneer species?
- What is the mode of dispersion of the parent trees?
- What should be the planting distance of the trees?

# 4 Preferred forest tree species on cocoa farm

## 4.1 Farmer preferred and research recommended timber species

Traditionally, cocoa farms in West Africa are established by removing the forest understorey and thinning the forest canopy so that cocoa seedling can grow into productive trees by utilising the »forest resources« of the newly cleared area and the shade provided by the remaining trees.

Depending on tree species present on farm, farmers may also get additional income through sales of timber species and other products such as fuel-wood, fruits or non-wood forest products, e.g. honey.

Integrating trees in cocoa farms may offer resource-poor farmers a cultivation system that has lower risk compared to systems that are dependent on high investments cost through inputs purchase, which farmers have no access to or cannot afford. Table below presents a list of farmer preferred and research recommended forest tree species that are used cocoa growing system in West Africa.

*Table 5: preferred trees in cocoa*

| Species | Classification | Dispersal Mechanism |
|---|---|---|
| *Alstonia boonei* | Pioneer | Wind |
| *Antiaris toxicaria* | Pioneer | Wind |
| *Ceiba pentandra* | Pioneer | Wind |
| *Entandrophragma angolense* | NPLD | Wind |
| *E. cylindricum* | NPLD | Wind |
| *E. utile* | NPLD | Wind |
| *Milicia excelsa* | NPLD | Bird, bats |
| *Pycnanthus angolensis* | NPLD | Birds |
| *Terminalia ivorensis* | Pioneer | Wind |
| *Terminalia superba* | Pioneer | Wind |
| *Triplochiton scleroxylon* | Pioneer | Wind |

*Source: Asare (2005)*

## 4.2 Indigenous trees adapted in cocoa farms

Cocoa agroforests exhibit complex dynamics that involve the interaction of diverse tree species in the farm landscape. Hence, to improve the system requires an understanding of the autoecology of each species (since a species individual characteristics are vital to understanding tree regeneration patterns and tree diversity in the farm landscape). The subsequent sections are descriptions of preferred indigenous forest tree species used in combination with cocoa as indicated in Table 5.

### 4.2.1 *Alstonia boonei*

*Alstonia boonei.*
*Photo: Rebecca Asare*

*Key characteristics*

It is common in various forest types including moist evergreen, upland evergreen, moist semi-deciduous forest and secondary forest.

The tree is large and tall, reaching a height of 45m and maximum diameter at breast height (dbh) of up to140cm out of which a height of 15m and a dbh of 25cm is reached only after 10 years. It has a strongly layered crown and whorled leaves.

*Uses*

The wood density is 0.35g/cm$^3$. The wood serves as timber. The bark and leaves are used for medicinal purposes. In agroforestry, it is grown as shade for cocoa.

*Regeneration and propagation*

Regeneration may be natural or artificial. Seed germination is normal, but seedlings grow in medium-sized to large gaps and not in deep shade. Saplings are light-demanders with mature trees being strong light-demanders.

It is a pioneer light demanding species, but shade bearing when young. It occurrence increases significantly with soil water but its abundance decreases with decreasing rainfall. It is deciduous (sheds leaves periodically).

The fruit is dry dehiscent (2 on 1 stalk) and about 12cm long. It is green and contains many seeds. The seed is brown, flat and large with 1cm long hair on both ends. Flowering occurs from November to January with fruiting period occurring from January to February. The seeds are dispersed by wind over long distances in strong winds.

Mature, saplings, or seedlings of *Alstonei boonei* may be associated in cocoa (as shade) at a planting distance of 12 x 12m and thinned to 24 x 24m (if needed) in a triangular arrangement with cocoa at 3 x 3m resulting in densities of 69 or 17 trees/ha of *Alstonia boonei* and 1111 trees/ha of cocoa respectively. However, these densities should be applied with attention to soil and climatic features of the particular cocoa field.

### 4.2.2 *Antiaris toxicaria*

*Key characteristics*

It is found in upland evergreen forest, wet evergreen forest, moist evergreen forest, moist semi-deciduous forest, dry semi-deciduous forest, and secondary forest. It is a highly variable species found from the wettest to the driest forest types. It has a cylindrical bole, sometimes with buttresses.

*Uses*

It has a wood density of 0.47g/cm$^3$ and is used for timber. In agroforestry, it is grown as shade for cocoa.

*Regeneration and propagation*

Regeneration may be natural or artificial. Seed germination is normal. Seedlings are usually very abundant near the parent tree. Exposure to sunlight is required for further growth. A lot of seedlings die in the first year and they can not tolerate dense climbers and shrubs.

It is a strong light demander and common in secondary forests. Its abundance decreases with rainfall. It is not selective of soils but prefers well-drained soils in some areas.

Under exposed conditions it grows rapidly about 50cm or more per year on old farms, but only half as much in areas where seedlings are shaded. It sheds its leaves between November and February. Flowering and fruiting occur at same period from February to March or December to April. The fruit is fleshy and contains 1 seed. The seed is round and dispersed by birds and bats.

Seedlings, saplings and mature trees may be used as initial and permanent shade for cocoa. Planting in association with cocoa may occur in similar arrangement and density as *Alstonia boonei*.

### 4.2.3 *Ceiba pentandra*

*Key characteristics*

It is found in moist evergreen and deciduous forests and also in dry forests and in gallery forests. It is common on coastal plains up to 500m altitude, with rainfall of 1000-2500mm and temperature from 20-27°C.

The tree is 25-70m tall, with a diameter of 100-300 cm. The trunk is cylindrical to slightly convex. The crown is spherical to round, with bright green and open foliage; branches are verticillate and abundant, sloping upwards.

*Fruit of Ceiba pentandra. From Plant Resources of South-East Asia.*

It is cultivated widely in the tropics and can grow on a variety of soils, ranging from sand to clay provided they are well drained. It prefers alluvial soils, slightly acidic to neutral. It tolerates drought and for short periods tempera-

tures below zero. It is sensitive to fire. At the time of fruit setting, temperatures below 15°C can be damaging.

*Uses*

The fibre makes an excellent material for a number of purposes; the foliage is used for fodder and oil is extracted from the seed and used industrially. The wood is very light with specific gravity of 0.2g/cm$^3$. When dry, the colour varies between grey and yellow, with white parts. It has a high durability, easy to work and preserve. The wood is used for making boxes and crates, plywood, pulp and paper products.

The tree is an important source of honey and also suitable for soil erosion control and watershed protection. In agroforestry it is grown with cocoa, and coffee. It is also used in taungya systems.

*Regeneration and propagation*

Regeneration may be natural or artificial. It is a light-demanding pioneer. The fruit is leathery, 10-30cm long, 3-6cm wide, rarely dehiscing on the tree. The capsules split open into 5 valves, revealing a mass of grey woolly hairs in which the 120-175 seed are embedded. There are about 600-900 fruits per tree. The trees will begin to produce fruits when they are 4-5 years. The seed is black or dark brown, covered with wool. There are 10000-45000 seed/kg depending on the provenance. When the fruits have turned dark brown, they can be collected from the ground or cut from the tree using hooked knives. Birds, bats and bees pollinate the flowers.

To process the seed the fruits are left on sieves or in boxes to dry in the sun for 3-4 hours every day for 2-3 days until they open. Extraction and cleaning is done manually by shaking the fruits in a bag.

The seeds are most likely orthodox. They contain large amounts of oil that tend to go rancid quickly and the viability diminishes rapidly. When the seeds are stored at 10-12% moisture content in closed plastic bags at 15°C, they retain viability for 5-6 months.

Immersion in boiling water for 1 min and then left in cooling water for 24 hours has been reported to break dormancy and improve germination. The seeds are sown in seedbeds or in sandboxes. Fresh seeds normally germinate 90-95%. When the first pair of leaves appears and the seedlings are 12-15cm, the roots are pruned and the seedlings transferred to polythene bags.

The plants are ready for planting in the field 4-6 months after sowing when they are 30-35cm tall. The tree can easily be propagated vegetatively by cuttings. Saplings and mature trees are used for temporary and permanent shade for cocoa. The tree maintains moisture in the soil around it thereby ensuring high humidity in cocoa farms. This characteristic is beneficial in the dry season but negative in the wet season since it encourages fungal diseases. It could be incorporated at a planting distance of 24 x 24m in a triangular with cocoa at 3 x 3m.

### 4.2.4 *Entandrophragma angolense*

*Young tree of E. angolense. Photo: Rebeca Asare*

*Key characteristics*

It is a large tree with huge, high buttresses, and its crown is usually not as large as the bole might indicate. It occurs in upland evergreen forest, moist semi-deciduous forest, dry semi-deciduous forest and is a vulnerable species. Their numbers increase in areas with rainfall of about 1800 mm/yr. Their abundance decreases when rain exceeds 2300 mm/yr.

Their numbers is dependent on good soil fertility and high water holding capacity. It is a non-pioneer shade demander, and known to be the most shade-bearing of all *Entandrophragma* spp., especially in better-drained sites.

*Uses*

It has a wood density of 0.56g/cm$^3$ and is a valuable timber tree. In agroforestry saplings and mature trees are used for temporary and permanent shade for cocoa.

*Regeneration*

Regeneration occurs naturally or by artificial means. It has a normal germination pattern. The seedlings require temporary shade for the first few years. Afterwards, they require greater exposure to sun. Saplings are commonly seen in gaps of all sizes. Natural seed dispersal is a limiting factor. Seedlings are found close to parent trees.

It is deciduous and sheds it leaves in September to November. It flowers in December coinciding with sprouting of new leaves. It fruits throughout the wet season from July to September. The fruit is nearly black, capsule-like, woody and pendulous (4 x 18cm) with 25-30 seeds. The seed is red brown, approx. 7cm long with a papery wing and dispersed by wind. Planting in association with cocoa may occur similar to *Alstonia boonei*.

### 4.2.5 *Entandrophragma cylindricum*

*Key characteristics*

It is a large tree with no or small buttresses and a round crown that does not spread. It occurs in upland evergreen forest, moist semi-deciduous forest, dry semi-deciduous forest and it is a vulnerable species.

Their numbers increase in areas with rainfall of about 1800mm/yr. Their abundance decreases when rainfall exceeds 2300mm/yr.

The species prefers good soil fertility with high water holding capacity. It is a non-pioneer shade demander.

*Uses*

It has a wood density of 0.66g/cm$^3$ and is used as a timber tree. In agroforestry systems, saplings and mature trees are used as temporary and permanent shade for cocoa.

*Regeneration and propagation*

Natural regeneration of this species is difficult since it has a tendency to produce few seedlings. Established seedlings grow more slowly about 20-40cm a year in height. Seedlings grow best at 50% sunlight. Shade is required for germination and increased light levels desired when tree growth progresses.

The species is deciduous. It flowers from February to March and fruiting occurs from May to August. The fruit is purplish black, dry dehiscent (8cm long), and has an opening at the base. It contains about 5-20 seeds. The seed is pale brown, 5-8cm long including wing. The seed is dispersed by wind. Planting in association with cocoa may occur similar to *Alstonia boonei*.

### 4.2.6 *Entandrophragma utile*

*Young tree of E. utile. Photo: Rebecca Asare*

*Key characteristics*

It occurs in upland evergreen forest, moist semi-deciduous forest, dry semi-deciduous forest and it is a vulnerable species.

It is a tree with clustered leaves at the tips of stout twigs and has heavy buttresses up to 3 m. Its rainfall requirements is similar to that of *E. cylindricum*. The species prefer fertile soil with high water holding capacity.

*Uses*

It has a wood density of 0.62g/cm$^3$ and is used as a timber tree. In agroforestry, saplings and mature trees are used for temporary and permanent shade for cocoa.

*Regeneration*

It has been described as the most light-demanding of all *Entandrophragmas* spp. and more drought tolerant than the others. It is a deciduous species. Regeneration occurs naturally or by artificial means. Germination is strongly depressed in large gaps suggesting that some form of shade is needed for maximum germination. Adequate water in the soil is also a requirement for germination. Seeds remain viable from the time of sowing or dispersal to the onset of rain.

Seedlings are well suited to the deep shade of the forest floor. Seedlings do well under some form of shade since unshaded seedlings die. Mites and other insects can also attack seedlings when they are not shaded in nurseries.

However, light availability is critical for seedling growth. Light levels of about 25% are needed for maximal growth. In good soils (like forest soils) root competition and nutrient are not limiting factors for growth. Seedlings grow slowly because root development is slow.

Flowering occurs from January to February, while fruiting occurs from December to March. The fruit is dry dehiscent woody, black and club-shaped (6 x 23m). It has an opening from the top and contains about 20-30 seeds. The seeds are medium to dark brown about 8-10cm long including wing and are dispersed by wind. Planting in association with cocoa may occur similar to *Alstonia boonei*.

### 4.2.7 *Khaya ivorensis*

*Khaya ivornesis.*
*Photo: Rebecca Asare*

*Key characteristics*

The species occurs in wet evergreen forest, moist evergreen forest, and moist semi-deciduous forest. It is common in Ghana and it has been labelled as a vulnerable species.

It prefers areas with rainfall about 1800mm/yr, and cannot do well in areas with rainfall exceeding 2300mm/yr. It is not suited for high altitudes. It prefers heavy or rich alluvial soils near water courses and damp areas but it needs good drainage. It is a deciduous species.

*Uses*

It has a wood density of 0.51g/cm$^3$ and is an important source of timber. The bark is used for medicinal purpose. Saplings and mature trees are used for temporary and permanent shade for cocoa.

*Regeneration and propagation*

It is light-demander with a narrow crown and so it suited for small and medium-sized gaps. Germination is depressed in large gaps. Seedlings require light shade in nurseries for about 2 years. If exposed to high light intensity seedlings suffer from insect and diseases attack. None the less, seedlings require some light for survival. In natural forests, seedlings can germinate and survive below dense layers.

Flowering period occurs from July to January and fruiting occurs from February to May. In the moist evergreen forest, flowering and fruiting occur throughout the year. In the moist semi-deciduous forest flowering occurs from June to September and fruiting from October to March. The fruit is woody, capsule-shaped, has a diameter of about 12cm and has many seeds. The seed is flat and winged. It measures 2 x 3cm, including the wing and is dispersed by wind. Planting in association with cocoa may occur similar to *Alstonia boonei*.

*Milicia excelsa.*
*From Hines and Eckman. 1993.*

### 4.2.8 *Milicia excelsa*

*Key characteristics*

*Milicia excelsa* is widespread in tropical Africa and it is found in lowland rainforests and wetter savannah woodland areas. West Africa continues to export large quantities. As a result the species has been heavily exploited and it is now considered close to being vulnerable.

It can grow with about 700mm rain/year provided it has access to a supplementary source of water and it tolerates a wide range of soil types but not soils that are prone to waterlogging or have impeded drainage.

It is a deciduous tree up to 50m tall and with a diameter up to 10m. The bole is straight and cylindrical, branchless up to 20m or more. The bark is dark, fairly rough and flaking off in small scales but rarely fissured. When cut, the slash exudes white latex.

The crown is umbrella-shaped and fairly flat at the top. Leaves are simple and alternate, 10-20cm long. The species is dioeciuos and male and female trees are slightly different in appearance. Male trees have longer and more slender trunk and crown. Forking is more common in male than in female trees.

*Uses*

The wood of *Milicia excelsa* is equivalent to teak and is one of the most important timber trees of tropical Africa. The heartwood is durable, workable and resistant to termites and marine borers. It is also extremely resistant to preservative treatments whereas the sap is permeable. The gravity is about 0.55g/cm$^3$. It is mainly used for outdoor construction work, furniture, boats, cabinet-work, panelling, frames and floors.

The bark, its ashes, leaves and latex are used in local medicine and the tree plays a major role in many local cultures where it is considered sacred, or where parts of the tree serve ceremonial purposes.

The leaves are edible and are used as mulch. It is often planted as a shade tree and along roads as an ornamental. It is also used as shade for cocoa. Due to its open canopy structure, it allows adequate aeration and sunlight to reach crops underneath its canopy. It also maintains enough foliage in the dry season, which reduces excessive desiccation of cocoa trees.

*Regeneration and propagation*

Regeneration may be natural or artificial. Flowering generally takes place at the end of the dry season after the trees have shed the leaves or it occurs with the new leaves. Male trees often set flowers before female trees and normally male trees flower every year whereas some female trees only flower every two years.

After pollination, which is by wind, the fruits take 5-6 weeks to mature. The ripe fruits are dispersed by bats, birds and squirrels that readily eat the fruits.

The fruits have a short ripening period and once ripe they fall to the ground where they begin to ferment immediately. So timing of seed collection is crucial. During the flowering season, it is advisable to record the sex of the trees in the seed source in order to facilitate seed collection.

The fruits do not change colour during maturation and a cutting test is necessary to determine maturation. When the seed are mature the fruit pulp softens and the endosperm inside the seed becomes white and firm. Seed collection is best done from the tree by cutting down small twigs with fruits. If the fruits are collected from the ground, it must be done daily on tarpaulins. The fruit is green, 5-7cm long, 2.5cm thick, wrinkled and fleshy and resembles a fat green caterpillar. There are about 70 seeds per fruit. The seed is small and light brown, about 1.5mm long and 1.0mm wide. It is thinner at the scar end and has a thin seed coat. There are 400000-500000 seeds per kg. The seed is not dormant and pre-treatment is not necessary.

As the fruits begin to ferment rapidly, they will not tolerate temporary storage and must be transported to the processing site as quickly as possible. During transportation the fruits should be kept in open bags with small amounts in each bag. The bags should be protected from direct sunlight and, to avoid overheating, the bags must not be stacked or packed tightly. Fruits should be spread out in a single layer, preferably on a rack to allow air circulation at the processing site. If the fruits are not fully mature, they should be left in the shade for a few days ripen. Fully mature fruits should be extracted immediately.

To remove the pulp, fruits should be soaked in water for about one day and then macerated by hand. Empty seed float on the water and so do some viable seed. Pulp and other impurities are removed by skimming. Depulping can also be done in a depulper, seed thresher or in a cement mixer where seed and gravel are mixed 2:1. About 40kg fruit produces 1kg clean seed.

When the seeds are completely cleaned, they are dried in the shade for a few days in a well-ventilated place. Seeds are best dried on a piece of plywood or paper, which can absorb some of the excess water. During the drying, seeds must be turned from time to time and the board or paper under the seeds changed when wet.

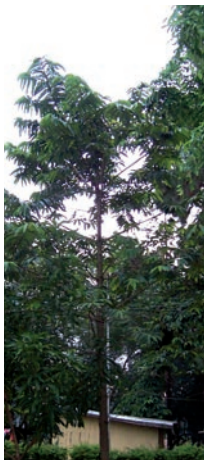
The seed are tolerant to desiccation and low temperature. If dried to 8% moisture content or less and stored in airtight containers at 0-5$^{o}$C, full viability can be retained for at least one year. However, storage of this species can be problematic and when possible, the seed should be sown within one year of collection. Seeds may germinate in a seedbed and transplanted to containers after three weeks. Germination is usually good, attaining about 30% after two weeks and 60-90% after four weeks.

The germination percentage depends largely on the number of empty seed.

In the nursery, the seedlings must be grown under shade cloth or screen to be protected from gall-forming psyllids.

After about four months when the seedlings are 30cm tall, they are ready for planting in the field. Stumps (27cm root length, 2cm diameter) or striplings (2.4cm tall) are generally transplanted in the field but in some places the most common technique is to plant in polythene bags. Planting in association with cocoa may occur similar to *Alstonia boonei*.

### 4.2.9 *Pycnanthus angolensis*



*Pycananthus angolensis. Photo: Rebecca Asare*

*Key characteristics*

It is found in upland evergreen forest, wet evergreen forest, moist evergreen forest, moist semi-deciduous forest, dry semi-deciduous forest, secondary forest, and disturbed forest.

The species prefers areas with rainfall between 2000 to 2600mm/yr. It can also withstand infertile soils. In countries like Ghana the tree does well in areas of high rainfall and infertile soils. This tree does not have buttresses.

*Uses*

It has a wood density of 0.25g/cm$^3$ and is used for timber. Saplings and mature trees are used for temporary and permanent shade for cocoa.

*Regeneration and propagation*

Regeneration may occur naturally or by artificial means. It is a light demander but prefers partial shade when young. It has a poor germination, which might be due to short viability of the seeds. Seedlings are commonly found in complete shade. The species is capable of rapid and healthy growth when large gaps occur in the canopy.

Flowering occurs from November to April and fruiting occurs during the next flowering season. The fruits appear in large bunches. It is dry dehiscent and woody (2.3 x 3cm) and contains 1 seed. The seed has a red aril. Animals like birds and elephants disperse the seeds. Planting in association with cocoa may occur similar to *Alstonia boonei*.

### 4.2.10 *Ricinodendron heudelotti*

*Key characteristics*

It occurs in moist evergreen forest, moist semi-deciduous forest, dry semi-deciduous forest, and secondary forest.

It prefers areas of good rainfall distribution. A reduction in rainfall affects tree growth. It also prefers soils with high water holding capacity and is typically found along timber extraction routes and disturbed forests environments.

It is a medium-sized tree with a maximum height of about 30m and a diameter of 112cm. It has weak, wooded branches and is self-pruning. It has a dense crown, sometimes with buttresses. It is deciduous.

*Uses*

It has a wood density of 0.25g/cm$^3$ and saplings and matured trees are used as shade for cocoa. The fruit is also eaten in Côte d'Ivoire, Cameroon and Nigeria.

*Regeneration and propagation*

Regeneration occurs naturally or by artificial means. It is a pioneer and a light demander. Flowering occurs in February, while fruiting occurs from July to October. The fruit is a fleshy drupe, 3 x 4.5cm, yellow and contains about 3 seeds. Seed is large, 1.9 x 2.3cm, and dispersed by bats.

Exposed sunlight stimulates germination. However, seeds are capable of germinating in the dark. Seedlings need partial shade since over exposure to sunlight leads to leaf curl. Seedlings have a response to low levels of light. They cannot survive in a densely shaded understorey. Seedlings respond well to medium-sized to large gaps in the canopy. Trees can attain about 10m height in 4 years. Planting in association with cocoa may occur similar to *Alstonia boonei*.

### 4.2.11 *Terminalia ivorensis*

*Key characteristcis*

It occurs in evergreen forest, moist semi-deciduous forest, secondary forest and it has been listed as a vulnerable species in West Africa.

It is a large tree with maximum height of about 45m and a diameter of 124cm. It has black bark and a graceful, spreading crown of whorled boughs and clustered leaves. Lower branches are self-pruning giving a clear bole even in open conditions. The base of older trees has high but small buttresses.

It prefers moist conditions, but does not show any preference for wet or dry forest soils and is not drought sensitive. Its performance increases with altitude and decreases with poor soil fertility.

*Uses*

It has a wood density of 0.53g/cm$^3$ and is used for timber. Saplings and mature trees are used as shade for cocoa.

*Regeneration and propagation*

Regeneration may be natural or artificial. It is a pioneer species and a strong

light demander. It flowers from May to June and fruits from December to January. Trees carry ripe fruit to the end of the dry season until flowers and new leaves appear at the start of the rainy season. Flowering in places like Nigeria is dependent on rainfall. Fruits are produced in large quantities. However, fruit failure and production of unripe fruits account for poor regeneration.

The fruit is bright brown, winged, 1.8 x 6cm, dry indehiscent and contains 1 seed. The seed is large, 0.8 x 1.5cm. There is seed dormancy that can be partly broken by soaking the seed in water. Germination can take place in both light and darkness. In the forest, germination is successful in large gaps. Seedlings are susceptible to drought.

Seedlings from large seeds grow faster than those from small seeds. Seedlings grow rapidly in medium-sized to large gaps with trees reaching a height of 17m and 25cm dbh in 8 years. The species is affected by frequent dieback in single stands. Planting in association with cocoa may occur similar to *Alstonia boonei*.

### 4.2.12 *Terminalia superba*

*Terminalia superba. Photo: Rebecca Asare.*

*Key characterisctics*

It occurs in moist evergreen forest, moist semi-deciduous forest, dry semi-deciduous forest, farmlands, along roads, and in secondary forest.

It is a large tree with a maximum height of about 45m and a diameter of 150cm. It has strong whorled boughs and clustered leaves due to its marked rhythmic growth. It has steep buttresses, up to 3.5m when fully grown. It is deciduous.

It performs well at altitudes between 200-300m and intermediate soil fertility but shows no preference for wet or dry soils, especially in Ghana. Optimum growth occurs at a pH of 5.9-6.1. Its performance declines with decrease in rainfall.

*Uses*

It has a wood density of 0.48g/cm$^3$ and is used for timber. Saplings and mature trees are used as shade trees in cocoa. It is also used for reforestation.

*Regeneration and propagation*

It is a pioneer species and a strong light demander. Regeneration may be natural or artificial. It flowers from February to April and fruits from December to February. The fruit is golden brown, winged, 2 x 5.5cm, dry indehiscent and contains one seed. The seed is large, 0.7 x 1.5cm, winged, rounded-triangular on cross-section and dispersed by wind.

Germination is similar to *T. ivorensis* and involves breaking of seed dormancy. There is no difference between germination in darkness and light. New seedlings appear at the start of the April-May and October-November rainy seasons, shortly after seed dispersal.

Young plants are shade tolerant. Seedlings and saplings are abundant along roads and in medium-sized to large gaps. It has a regular bole diameter increment, and periodic crown growth components. It is widely used as a plantation species. Planting in association with cocoa may occur similar to *Alstonia boonei*.

### 4.2.13 *Triplochiton scleroxylon*

*Key characteristics*

It is found in moist evergreen forest, moist semi-deciduous forest, and dry semi-deciduous forest. It is absent in wet evergreen forest.

It is a large tree with maximum height of about 50m and a diameter of 136cm and with buttresses. It is deciduous.

It does well at altitudes between 200-400m and performs well in areas with two rainy seasons and rainfall between 1100-1800mm. Performance declines with decreasing rainfall. It prefers fertile soils. Growth is reduced in low fertility soils and it is absent in wet evergreen forest.

*Triplochiton scleroxylon.*
*Photo: Rebecca Asare*

*Uses*

It has a wood density of 0.39g/cm$^3$ and it is used for timber. It is often used as a tree component in taungya system due to its fast growing ability. Saplings and mature trees are used as shade trees for cocoa even though research indicates that it is not compatible with cocoa.

*Regeneration*

It is a pioneer species and a light demander. Regeneration may be natural or artificial. It germinates well in light shade. It flowers from December to January and fruiting occurs from January to March. It flowers in the dry season and fruits around the beginning of the rainy season. Mast years occur every 4-5 years. It produces seed irregularly on both an annual and seasonal basis.

Unusually, low rainfall periods during the rainy season may stimulate flowering and this explains why the species range is associated to areas with some dry periods. The fruit is a dry, indehiscent, winged mericarp with one seed per mericarp. The seed is large, 1 x 2cm, with 4cm wings and is dispersed by wind.

Germination rate is not high compared to many species (55%). Seedlings occur in gaps of all sizes except the smallest. It grows better in a mixture with other trees than when it grows in a single stand. In Nigeria, 50% of an-

nual increment takes place from mid-April to mid-July. It can reach a height of about 8m and 13cm dbh in 3 years. Planting in association with cocoa may occur similar to *Alstonia boonei*.

## 4.3 Exotic species adapted in cocoa farms

### 4.3.1 *Gliricidia sepium*

*Gliricidia sepium.*
*Photo: Dorthe Jøker, FLD*

*Key characteristics*

*Gliricidia sepium* (mother of cocoa) is exotic to West Africa. It is suggested to have originated from Central America and Mexico. For many centuries it has been introduced outside tropical America and it is now distributed all over the tropics.

In many places where it grows as an exotic tree, the introduction originated from a narrow genetic base and several local land races suffer from inbreeding. It is a single to multi-stemmed tree, rarely shrubby. It is between 2-15m tall. It has an erect stem of 5-30cm diameter at base.

It can grow in a wide range of habitats and soil types ranging from pure sand to deep alluvial lakebed deposits, with rainfall from 600-3500mm/year and from sea levels up to 1200m altitude. It is rarely found in higher altitudes as prolonged frost will kill the trees and even occasional frost may cause leaf drop and dieback.

Although it grows well in areas with high rainfall, a dry season of 8-13 weeks is necessary for seed production. As an aggressive coloniser, it has the potential to become a weed, but this rarely occurs because in most places it is coppiced regularly and therefore not permitted to set seed.

*Uses*

*Gliricidia sepium* is a multipurpose tree. Under optimal conditions it can produce an annual biomass as high as 12t dry weight per ha. The ability to resprout vigorously and repeatedly after cutting allows a high production of animal fodder, fuelwood and poles. It is also used as live fencing.

It has nitrogen fixing properties and it leaves can be used as mulch and green manure. As a result it is highly suitable in agroforestry systems. The name »mother of cocoa« is due to the species being used as shade tree for cocoa, coffee, and tea.

The tolerance to cutting allows manipulation of the canopy to vary the intensity of shading at different times of the year. Seedlings and cuttings are planted as initial shade for cocoa in the nurseries or on farm.

It is also used in rehabilitating old cocoa farms or in improved fallows intended for cocoa cultivation due to its nitrogen-fixing abilities.

The wood is hard and durable with a density of 0.5-0.8g/cm$^3$. It burns slowly, with little smoke and no sparks and has calorific value of 4900 kca/kg.

*Regeneration and propagation*

It is a pioneer species, which readily colonises open ground and is used for reclaiming *Imperata* grasslands. Regeneration may be natural or artificial. Fruit is a 10-17cm long pod, light to dark reddish-brown, with short stalk and slightly constricted between the seed. The valves are woody at maturity and the pod is explosively dehiscent. There are 3-10 seeds per pod. Seed is round, 8.5-11.5mm in diameter, uniformly brown. The number of seeds per kg varies between 4500 and 11000, typically about 8000. The seed is orthodox and at low moisture content (6-10%) at 4°C it can be store for over 10 years without loss of viability. The seed has no dormancy and pre-treatment is not necessary.

The species is strongly out-crossing. Although mating between related individuals may occur, it does not tolerate a high level of inbreeding. It is believed that the closer the parent relationship is, the smaller the seed:ovule ratio.

In its native range nectar-seeking bees pollinate the flowers, especially the large black bee, *Xylocopa fimbriata*. The low seed setting that is seen in some areas outside of its native range may be caused by lack of pollinators.

In areas with pronounced dry season, the trees are deciduous, shedding the leaves during the dry season and flowering and fruiting while leafless. In Central America flowering occurs in December-March in the beginning of the dry season and seeds mature one or two months later. In non-seasonal, humid areas the trees may be evergreen and flowering is sporadic. In these areas seed setting is often low.

The pods are normally harvested just before they open when they are dry. However, it is also possible to collect the pods up to two weeks before opening. The green pods must then be after-ripened in the shade in a well-ventilated place.

The ripe pods are dried in the sun until they open. As the pods almost explode when they open, the drying patio must be covered with nets or alternately the pods can be dried in mesh bags.

Seeds are sown in containers and the seedlings are ready for planting out after 2-3 months when they are about 30cm tall. Direct sowing is possible with 2-3 seed per hole at a depth of 1-2cm. Site preparation must be carried out before sowing and followed by weeding until the trees are established. Vegetative propagation by cuttings is easy as long as the cuttings are of sufficient size and age. Both large and small cuttings can be used but it is important that the cuttings are taken from branches that are straight and healthy and without side branches. Trees that are established from cuttings have shallow root systems and short bole and are less resistant to strong winds.

For improved fallows, cuttings or seeds may be planted at a distance of 3 x 3m for 3 years. After this period the stand may be thinned and a distance of 12 x 12m is maintained and cocoa planted in between the spaces at a distance of 3 x 3m.

### 4.3.2 *Gmelina arborea*

*Gmelina arborea.*
*Photo: H. Keiding, DFSC*

*Key characteristics*

As natural forest trees they are usually found scattered in association with other tree species.

It is found in evergreen forests in Myanmar and relatively dry mixed deciduous forest types in India. It has been introduced as a plantation species in many countries in West Africa, South America, and South-East Asia. It is a medium sized tree, 30-40m tall, with an average diameter of 50cm but sometimes reaching 140 cm.

*Uses*

The wood is used mainly for light construction and pulp. Several parts of the tree are used for medicine and the leaves are used for cattle fodder.

It is used in enrichment planting on cocoa farms to fill in gaps in the canopy due to its fast growing nature. Cuttings and seedlings are planted as shade for young and old cocoa trees.

*Regeneration and propagation*

Regeneration may be natural or artificial. Gmelina flowers and fruits every year. In the natural distribution area with a seasonal climate, flowering starts in the dry season when trees are leafless. In seasonal climates, outside its natural area of distribution, there is distinct flowering and fruiting period. In West Africa flowers and fruits can be seen more or less throughout the year. Fruits mature 1½ months after flowering. The species is predominantly out-crossing and flowers are pollinated by large bees. Fruits are picked from the ground. The mature fruits may fall from the tree while they are still green. Green fruits turn yellow within a week. Two weeks after the fruit has fallen, it turns brown and then black three weeks after falling.

The fruit is a succulent drupe, 20-35 mm long, with a shiny, leathery skin and a sweet, pulpy mesocarp. The stone (endocarp) is 10-25 mm long, with one round and one pointed end. The stone normally contains four seed chambers, in rare cases five. One or more of the chambers contain seed but there are rarely more than two filled seeds per fruit. The size of the seed increases with stone size, e.g., from 6-9 mm in length. The weight of 1000 stones is approximately 400 g.

It is best to collect the fruits when they are still green or yellow, as germination of brown and especially black fruits is low.

As fruits do not fall and mature at the same time, fruits should be collected frequently, e.g., twice every week during the collection period that may stretch over several months.

Cleaning of shrubs and weeds from the forest floor is recommended to ease seed collection. Production of fruits varies with age of stand, ecological conditions and stand conditions. There are reports of seed production from 30 kg cleaned stones/ha/year to around 170 kg/ha/year.

Fruits should be transported to processing sites in open baskets or nets, not in plastic bags. To avoid fermentation, fruits should be cleaned with 24 hours. This is important for fully ripe fruits, i.e., yellow and brown. Fermentation is more likely to start among damaged fruits, hence, avoid damage to fruits.

During processing, fruits should be sorted into those that are ready for immediate processing (yellow and brown colour) and green and green-yellow fruits, which will benefit from after-ripening. After-ripening is done in shade by spreading the fruits in a 10-15cm thick layer until they have turned yellow. This may take up to two weeks.

Depulping of small quantities of fruits can be done manually by mashing the fruits until the pulp is loose from the stone, and rinsing with water. For larger quantities of fruits depulping is normally done in a coffee-depulper. Soaking the fruits in water for 24 hours before depulping will facilitate the process. After depulping the fruits are spread out on a wire-mesh tray and rinsed with water to remove juice and pulp.

Traces of pulp usually remain on the stones after depulping and further cleaning or polishing of the stone is required. This can be done manually by rubbing the stones with sand and water or mechanically in a concrete mixer (also with sand). The stones are finally washed and dried well in the sun.

Fruits, which have been dried to moisture content of 5-8% and kept below this moisture content in a cold storage (4-5$^{o}$C) can be stored several years without reduction in viability.

It is difficult to sun dry the stones below 10% moisture content, so additional drying in an oven (35-50$^{o}$C) may be required for long term storage.

Soaking of the seed in cold water for 24-48 hours before sowing is recommended. The seeds germinate in seedbeds, covered by a thin layer of sand or soil. The germination of gmelina seed is epigeous with the radicle emerging first and the cotyledons shortly after.

Seeds normally germinate quickly and at high levels. Often the germination will be above 100% as more than one seed will germinate from each stone. The optimal temperature for germination is about 30$^{o}$C; lower temperatures will reduce germination. The seedbed should be exposed to sunlight, as partial or full shade will reduce germination. After germination, the seedlings can be transplanted. Planting distances just like that of *Alstonia boonei* can be used.

*Albizia lebbeck.*
*Photo: David Lea, CSIRO Forestry and Forestry Products*

### 4.3.3 *Albizia lebbeck*

*Key characteristics*

This species is indigenous to South-East Asia and Australia but has been widely cultivated. It grows well in areas with 600-2500mm rain/year but tolerates as little as 300mm. The altitudinal range is 0-1800m with a mean annual temperature of 20-35°C. It is a deciduous tree, that is usually 15-20m tall but can reach up to 30m. The bark is grey, corky, fissured, and somewhat flaky.

The tree grows well on fertile, well-drained loamy soils but poorly on heavy clays. It tolerates acidity, alkalinity, heavily eroded soils, and waterlogged soils. It is nitrogen fixing, tolerant to drought and older trees can survive grass fires and intense night frost. While fire and frost will kill off above-ground growth of young trees, new growth will normally follow.

*Uses*

*Albizia lebbeck* is one of the most promising fodder trees for the semi-arid regions. It has leaves during a large part of the rainy season and digestibility of the twigs is considerably higher than that of most fodder trees.

It is an excellent fuelwood and charcoal species and the wood is suitable for construction, furniture and veneer. Its shallow root system makes it a good soil binder and it is recommended for soil conservation and erosion control.

Seedlings and cuttings are planted as initial shade for cocoa in nurseries or on-farm. It is also used in rehabilitating old cocoa farms or in improved fallows intended for cocoa cultivation due to its nitrogen fixing abilities.

*Regeneration and propagation*

Regeneration occurs naturally or artificially. The growth pattern follows the seasonal changes. It stops growing early in the dry season, loses its leaves 2-3 months later and remains leafless for 1-2 months. Towards the end of the dry season growth continues and flowering begins.

Flowering and seed setting occur in the wet season and unless the trees have been frequently coppiced, they will produce large amounts of seed every year.

Within its natural area of distribution, flowering occurs from September-October and pods mature in May-July in the beginning of the dry season. Insects pollinate the flowers. The fruits or pods are pale straw to light brown at maturity, 15-25cm long, 3-5cm wide, papery to leathery, flat and not raised or constricted between the seeds. The pods are indehiscent. Seed is brown, flat, 8-10 x 6-7mm. The 6-12 seeds are placed transversely in the pod. There are 7000-12000 seeds per kg. The seed is hard coated but pre-treatment is not always necessary. If the seed coat is very thin, boiling water may be harmful.

The pods are mature when they have turned light yellow and should be harvested when the last patches of green are disappearing.

It is important that collection is not delayed as insects can very quickly infest the mature pods. It is possible that early collection followed by after-ripening in the shade could minimise the damage.

Even when the pods are collected early, many are infested by insects and temporary storage should be as short as possible as the insects develop during this phase.

If the pods are collected when they are still green, the bags should be kept open during transport to ensure ventilation.

The pods are dried directly in the sun until they rattle and become brittle. The seed is extracted by beating or in a flailing thresher, which is very effective for this species.

After extraction the seed is dried in the sun and pod segments and debris removed in a seed-cleaning machine.

Seed storage is orthodox and viability is maintained for several years in hermetic storage at room temperature with low moisture content. The seed can be heavily attacked by insects, but it is not known whether insect attacks proceed during storage.

Germination starts within a few days and is complete in a month. The best seedling development is obtained in full sunlight. It can be established by direct sowing, using container-grown stock or as bare-rooted seedlings or stump plants. When sown directly, it is necessary to weed the rows for several years.

To reduce the field establishment period, seedlings can be raised in nursery beds for one year or more and transplanted as stumps with about 25cm root and 10cm shoot.

For production of bare-rooted seedlings or stumps, seed is sown in lines about 15cm apart with the seed spaced about 2-3cm in lines and about 1cm deep. About 40g seed is required for sowing 1m$^2$ of nursery bed. Planting conditions with cocoa is similar to that of *Gliricidia sepium*.

### 4.3.4 *Acacia mangium*

*Key characterisctics*

This tree is exotic to West Africa. It is a fast growing tree adapted to a wide range of acidic soils in moist tropical lowlands. It is an evergreen tree up to 30m tall. The bole can be unbranched for more than half of the total tree height. It is sometimes fluted at the base and the diameter rarely exceeds 50 cm.

*Acacia mangium. Photo: Maurice McDonald, CSIRO Forestry and Forest Products*

The bark is roughly furrowed, and either grey or brown. Small branches are winged. It does not tolerate frost or shade and grows better on fertile soil with good drainage but it can tolerate soils of low fertility and impeded drainage. Young trees are susceptible to fires. It can become a weed under certain conditions.

*Uses*

It is grown as a plantation tree mainly for paper pulp in Asia. It is also used for fuelwood, construction and furniture wood, wattle timber, erosion control, shade and shelter.

A valuable feature is its ability to compete with *Impereta cylindrica* reducing the grass to a sparse ground cover.

Seedlings and cuttings are planted as initial shade for cocoa in the nurseries or on-farm. It is also used in rehabilitating old cocoa farms or on improved fallows intended for cocoa cultivation due to its nitrogen-fixing abilities.

*Regeneration and propagation*

Regeneration may be natural or artificial. Time of flowering differs throughout its natural and planted range. As an exotic, the normal flowering cycle may be disrupted and flowering can occur throughout the year - however, a distinct peak is usually marked. The species is generally out-crossing and is pollinated by insects.

The fruit is a dehiscent pod, tightly coiled when ripe, slightly woody, 7-8cm long, 3-5mm wide. The seed is black and shiny, elliptical, 3-5 x 2-3mm, with a bright yellow or orange funicle folded beneath the seed. There are 66000-120000 seed/kg. Mature seed are pre-treated by immersion in boiling water for 30 seconds followed by soaking in cold water for 24 hours. Alternatively, they can be manually scarified. The germination rate is high (75-90%) after suitable treatment.

Viable seeds can be harvested 24 months after planting from the tree or from the ground. The pods should be processed as soon as possible after harvest. Pods and seeds should not be left long to dry in the sun, as temperatures over 43$^{o}$C can reduce viability. The seeds are orthodox and can remain viable for several years when stored in airtight containers in a dark, cool room. The recommended moisture content for storage is 5-7%.

Seed can germinate in seedbeds, germination trays (wet towel method) or directly in containers. Vegetative propagation by cuttings and tissue culture is very important for this species. Planting conditions similar to that of *Gliricidia sepium* can be used in cocoa.

# 5 Policy and legal implication of forest timber trees in cocoa fields

## 5.1 Introduction

Policies concerning forest trees on farms have served as a disincentive to farmers who tend timber trees on farmland. Until recently, in countries like Ghana, farmers had no rights to naturally occurring as well as planted timber trees. In some cases, this resulted in farmers, especially cocoa farmers, devising various means of eliminating valuable timber trees from cocoa farms. The negative environmental impact of these attitudes has had widespread consequences.

Nonetheless, in recent times there has been a realisation that more than half of harvested timber trees comes from farms, including cocoa farms. Hence, policies and legislation concerning timber ownership on farm have shifted slightly in favour of farmers. This change has generated a new enthusiasm in farmers, especially cocoa farmers who incorporate timber trees in their farming for agronomic, social and economic benefits.

Despite the positive shift in timber right policies by government, there has not been a concerted effort to create awareness and sensitise farmers on the implication of the new policies.

This section presents a case study that describes the current legislative framework in Ghana pertaining to timber trees, with a focus on those aspects of the legislation, which are of key relevance to the cocoa farmer. The legislation[6] is complex, and only key issues are highlighted. The section therefore provides a starting point for individuals and organisations involved in timber tree plantation on farms to critically examine policies concerning planting of timber trees in order to promote awareness.

## 5.2 Timber tree tenure

In Ghana, naturally occurring timber trees are in principle 'owned' by the stools[7], who hold the land and the timber resources on behalf of the people. In reality, since 1962, the rights to timber trees have been taken over by the President, acting on behalf of the stools. This is stated in the Concession Act, which states that:

*'All rights with respect to timber trees on any land is vested in the President in trust for the stools concerned'* (Concession Act, No. 124, 1962, section 16 (4).

[6] The interpretation of the legislation is the view of the authors and may not necessarily correspond with the official interpretation of the legislation, e.g. by the Forestry Commission.

[7] Traditional landholding authorities normally represented by a chief.

### 5.2.1 Legislation about naturally occurring and/or planted trees

There are two major legislative frameworks that seek to empower farmers on the right to timber trees on farm. These are:

1. Timber Resources Management Act, 1997 (Act 547), whose procedures are detailed in the legislative instrument, L.I. 1649 – Timber Resources Management Regulation, 1998;

The regulation states that;

*»No person shall harvest timber from any land unless he holds timber rights in the form of a timber utilisation contract«*

2. Timber Resources Management Act (Amendment), 2002 (Act 617), whose procedures are detailed in a legislative instrument, L.I 1721 – Timber Resources Management (Amendment) Regulations, 2003;

The regulation states that:

*No timber rights shall be granted in respect of'*

- Land subject to alienation holding
- Land with farms without the written authorisation of the individual, group or owners concerned
- Land with private forest plantation
- Land with any timber grown or owned by any individual or group of individuals.

### 5.2.2 Farmers' veto rights

The legislative frameworks (Timber Resources Management Act and the Amendment Act) mentioned above empower farmers who have timber trees on farm to do the following:

- Participate in the inspection team responsible to determine the quality, quantity, and the value of the timber to be harvested from their farmland – the team should comprise officers from the Forest Services Department, the timber contractor, two members from the stool, and the farmer on whose land the trees are to be felled
- Provide a written consent for timber to be felled from his farm
- Refuse felling of timbers trees that may cause damage to crops on farm
- Refuse felling of timber trees considered for soil conservation and improvement, e.g. against soil erosion.

The above serve as veto rights for the farmer and could be used as bargaining power to refuse felling of timber on farm or negotiate a price for each timber to be felled by a concessionaire in the form of compensation.

## 5.3 Commercial harvest of timber trees

Commercial harvest of timber requires the so-called Timber Utilisation Contract (TUC). The Forestry Commission issues TUCs after a competitive bidding procedure, where eligible timber companies submit their bids for a certain area of concession. Seen from the perspective of the farmer, even small TUC areas are large, as are the technical and financial requirements of the bidder. Farmers in practice therefore have no opportunities to participate in bidding for TUCs.

It follows, that a farmer is not allowed to commercially fell naturally occurring timber trees located on the land which he/she cultivates, i.e. a farmer is not allowed to fell timber trees for commercial purposes. However, a farmer is allowed to fell timber trees when it is necessary for agricultural use, i.e. to expand the area under cultivation or to reduce shade. A farmer is not however, allowed to sell trees or the resulting timber from such activities.

The Timber Resources Management Act as it stands now deprives farmers of access to commercial utilisation of naturally occurring timber trees. However, as stated earlier it does provide the farmer with a right/stake in the decision making to fell timber trees on his/her farm. This is because timber trees located on farms cannot be felled without the consent of the farmer, and the consent has to be in writing. The farmer thus – at least in principle – may veto felling of timber trees from his or her farm where felling is perceived to seriously damage crops, or felling of timber trees which are considered important for e.g. soil improvement or erosion control.

## 5.4 Legislative framework on benefit sharing

Payment of compensation on felled timber trees on farmland has always been a bone of contention between timber contractors and cocoa farmers.

There has always been a mistrust on the part of farmers about how much they receive from contractors and contractors also believe farmers demand unreasonable compensation for their damaged crops.

These problems have arisen due to the non-transparent nature by which compensations are demanded and paid.

There is therefore the need to provide farmers with certain basic information on compensation to lessen the tension and potential income loss regarding the felling of timber trees from farmland.

### 5.4.1 Legislative framework on compensation

There are two legislative frameworks that indirectly address the issue of compensation payment for damaged crops, especially cocoa. These are:

1. The Economic Plants Protection Decree, 1979. It states that:

»*No felling rights with respect to timber shall be granted where such timber trees stand in farms where specific crops like cocoa are cultivated« (section 4* (1))«.

However, if for some reasons felling rights are granted to timber concessionaires on cocoa farms the decree empowers the Ministries of Food and Agriculture and Lands, Forestry and Mines to decide compensation rate according to crop and age (sections 4 and 7)

2. The Timber Resources Management Act, 1997, with its legislative instrument Timber Resources Management Regulations, 1998, L.I. 1649. This states that:

*»Under the terms and conditions of the timber utilisation contract, the contract shall make provision for prompt payment of compensation of royalties, compensation and forest management service charges« (L.I. 1649, section 14 (1e)«.*

These laws as mentioned above indirectly touch on compensation but fail to specify how the compensation should be determined. However, they give the farmer the right to object to felling of trees on his farm and provides as basis to negotiate a price for felled trees with timber contractors holding concession contracts.

### 5.4.2 Benefits sharing (revenues) from timber trees

Concessionaires with a right to fell timber must pay a fee on each cubic meter of timber felled, which is called stumpage fee. The stumpage fee varies according to species, and is set by the Minister of Forestry. The stumpage fees (2003 revision) vary between 508,725-cedis[8]/m$^3$ for *Pericopsis elata* and 23,919 cedis/m$^3$ for *Morus mesozygis*. Stumpage fees are considered as 'revenue accruing from stool lands' and are shared in accordance with rules laid down in the Constitution of Ghana (Constitution of Ghana, 1992; Section 267(2)):

*»Ten per cent of the revenue accruing from stool lands shall be paid into the office of the Administrator of Stool Lands to cover administrative expenses; and the remaining revenue shall be disbursed in the following proportions«*

- Twenty-five percent to the stool through the traditional authority for the maintenance of the stool in keeping with its status
- Twenty percent to the traditional authority
- Fifty-five percent to the District Assembly, within the area of authority of which the stool lands are situated.

In practise, the Forestry Commission defines revenues from stool lands exclusive of their management costs, i.e. they are deducted before the revenue is shared in the proportions mentioned in the Constitution. Presently, the Forestry Commission deducts 60 % of stumpage fees on reserve and 40 % off reserve to cover the management and regulation costs of the Commission.

[8] 1 US$ = 9.700 Cedis (Ghc) Dec 2005

*Table 6: effective distribution of stumpage fees among the stakeholders.*

| Stakeholder | On reserve | Off reserve |
|---|---|---|
| Forestry Commission | 60 % | 40 % |
| Administrator of Stool Lands | 4 % | 6 % |
| District Assembly | 19.8 % | 29.7 % |
| Stool | 9 % | 13.5 % |
| Traditional Council | 7.2 % | 10.8 % |

A Timber Rights Fee was introduced with the amendment of the Timber Resources Management (Amendment) Regulations in 2003. This is the annual amount that the concession holder has to pay for the timber right. It is determined by competitive bidding among eligible timber companies.

*Table 7: stumpage rates (%) and fees (cedis) of some valuable timber species in Ghana*

| TRADE NAME | LOCAL NAME | SCIENTIFIC NAME | STUMPAGE RATE | STUMPAGE FEE |
|---|---|---|---|---|
| **High Demand** | **Depleted Species** | **Class 1** | **20%** | |
| African Walnut | Dubini-Biri | *Lovoa trichiloides* | | 226,100 |
| Afrormosia | Kokrodua | *Pericopsis elata* | | 508,725 |
| Aningeria | Asanfina | *Aningeria altissima/robusta* | | 252,042 |
| Black Hyedua | Hyeduanini | *Guibourtia ehie* | | 330,344 |
| Candollei | Omu | *Entandophragma candollei* | | 216,866 |
| Iroko | Odum | *Milicia excelsa/regia* | | 251,685 |
| Mahogany | Krumben/Odupon/Dubin | *Khaya spp.* | | 242,760 |
| Makore | Baku/Makore | *Tieghemella heckelii* | | 267,155 |
| Opepe | Kusia | *Nauclea diderrichii* | | 180,252 |
| Sapele | Penkwa | *Entandophragma cylindricum* | | 273,700 |
| Utile | Efuobrodedwo | *Entandophragma utile* | | 316,064 |
| **Moderate Demand** | **Available Species** | **Class 2** | **10%** | |
| Afara | Ofram | *Terminalia superba* | | 59,500 |
| Afzelia | Papao | *Afzelia africana/bella* | | 119,595 |
| Albizzia | Awiemfo Samina/Okoro | *Albizzia ferruginea* | | 63,784 |
| Ayan | Bonsandua | *Distemonanthus benthamianus* | | 103,238 |
| Avodire | Apapaye | *Turreanthus africanus* | | 106,519 |
| Bombax | Onyina-Koben | *Rhodognaphalon brevicuspe* | | 47,838 |
| Canarium | Bediwonua | *Canarium schweinfurthii* | | 63,784 |
| Ceiba | Onyina | *Ceiba pentandra* | | 47,838 |
| Ekki | Kaku | *Lophira alata* | | 87,703 |
| Gedu-Nohor | Edinam | *Entandophragma angolense* | | 82,441 |
| Idigbo | Emeri | *Terminalia ivorensis* | | 106,838 |
| Mansonia | Oprono | *Mansonia altissima* | | 119,595 |
| Obeche | Wawa | *Triplochiton scleroxylon* | | 61,761 |
| Ogea/Daniella | Shyedua | *Daniella ogea/thurifera* | | 65,378 |
| Pterygota | Kyere/Koto | *Pterygota macrocarpa* | | 126,437 |
| Antrocaryon | Aprokuma | *Antrocaryon micraster* | | 63,784 |
| Guarea | Kwabohoro/Kwadwuma | *Guarea spp.* | | 95,676 |
| Longhi (Blanc) | Akasa | *Chrysophyllum albidum* | | 103,649 |
| Niangon | Nyankom | *Heritiera utilis* | | 124,378 |
| **Low Demand** | **Abundant Species** | **Class 3** | **5%** | |
| Celtis | Esa | *Celtis mildraedii/zenkeri* | | 31,892 |
| Danta | Danta | *Neosogordonia papaverifa* | | 46,243 |
| Homba | Otie | *Pycnanthus angolensis* | | 34,284 |
| Missanda | Potrodum | *Erythronphleum guineense* | | 35,879 |
| Okan | Denya | *Cylicodiscus gabonensis* | | 43,852 |
| Sterculia | Wawabim | *Sterculia rhinopetala* | | 35,879 |
| Wonton | Wonton | *Morus mesozygia* | | 23,919 |
| Antiaris | Chenchen | *Antiaris africana* | | 31,493 |
| Dahoma | Dahoma | *Piptadeniastrum africanum* | | 35,879 |
| Other species | | | | 23,919 |

*Source: Forestry Commission of Ghana (2003)*

At the time of writing of this manual the Timber Rights Fee is not fully implemented in practise. Among other things, uncertainty remains with regard to the distribution of the revenue from the Timber Rights Fee, i.e. is the revenue to be considered as 'revenue accruing from stool lands' and hence distributed among the stakeholders as described above.

### 5.4.3 Social Responsibility Agreement

The Timber Resources Management Act of 1997 introduces the concept of Social Responsibility Agreement (SRA). It is an agreement between the local communities in the concession area and the concessionaire. The SRA forms an integral part of the Timber Utilisation Contract (TUC), i.e. a SRA is required before a TUC can be issued, and breach of the SRA may lead to termination of the TUC.

Under the SRA, the concessionaire must provide the local communities with amenities (e.g. road construction/maintenance, school or community buildings) amounting to not less than 5 % of the annual stumpage fee due. The SRA is still a relatively new concept, and a number of issues need further consideration and work. Among those issues are:

- Who negotiates the SRA on behalf of the local communities?
- How to secure that all communities within the concession area are equally considered?
- Who should monitor the implementation of the SRA and how should it be done?

### 5.4.4 Timber Utilisation Permit

As mentioned above, farmers are in reality restricted from applying for a TUC. The Timber Resources Management Act holds another option: The Timber Utilisation Permit (TUP). A District Assembly, town committee, a rural community group or a NGO may apply for a TUP to harvest a specified number of trees to be used for social and community purposes – they must not be sold commercially. The TUPs can only be issued in areas not subject to TUCs, which presents a serious limitation for its practical application.

Between 2001 to 2002 the Forestry Commission issued several hundred TUPs to timber companies, each covering an area of 10-30 square kilometres and with a standard duration of 5 years.

### 5.4.5 Chainsaw operators

Chainsaw operators are very common, especially on cocoa farms. It is estimated that the amount of timber originating from chainsaw operators exceeds the official harvest figures 2-3 times. The chainsaw operators supply local and domestic timber needs, while most of the official concession holders focus on the export market.

The Timber Resources Management Act grants rights to timber resources in the form of TUC and TUPs. The chainsaw operators have no such permits, and their operations are therefore illegal. They pay none of the official fees and taxes on the harvested timber.

However, seen from the perspective of farmers, there may be a number of advantages with chainsaw operators:

- They create less damage on the farm than legal concessionaires, because they process the logs into sawn lumber rather than hauling the logs away
- The farmer may negotiate felling of unwanted trees, or trees needed for local purposes
- They give the farmer some remuneration in money or in kind (sawn boards)
- Relatively well paid labour opportunities may be available, assisting in carrying the boards to the roadside.

It should be noted, however, that the business of chainsaw operators is changing from small-scale informal operators to larger-scale, urban-based operations, run by powerful individuals. In some cases, farmers may be intimidated by large-scale chainsaw operators and as a result timber trees are felled on farmlands, sometimes at night, without farmers' consent, and without any remuneration to the farmer.

### 5.4.6 Determining compensation on timber trees felled on cocoa farms

Harvesting and hauling of timber trees will lead to damage and losses to such crops as cocoa, coffee, etc. With reference to customary law, any person (timber contractor) who harvests timber and hauls it from a farm that does not belong to him or her, must provide appropriate compensation for any such damage and loss. The Timber Resources Management Act recognises this principle by stating that:

*»[The Timber Utilisation Contract]…shall provide for terms and conditions including provision for prompt payment of royalties, compensation and forest management service charges«* (Timber Resources Management Regulations, 1998; section 14).

What the legislation lacks, however, is specific regulations on how to determine compensation and how to secure that farmers are properly compensated. Although little specific information is available, anecdotal information suggests that farmers in many cases receive little or no compensation at all.

The Land Valuation Board issues at regular interval lists of compensation payment for various crops. This information and the rates need to be used in settling compensation matters over timber harvest.

*Simple formula for determining compensation on felled timber trees*

Negotiated price for felled timber trees must reflect the extent of damage

to crops and its influence on yield loss. This depends on farmers' bargaining skills. In the absence of authentic rates from the Lands Valuation Board on how much a contractor needs to pay to a farmer for damages incurred by felled timber trees, farmers may use the following logic:

In order to estimate the compensation one needs to assess the damage resulting from the removal of a timber tree from a cocoa farm. To estimate loss through damage, the following may be useful:

It must be noted that this is just a crude calculation and a rough estimation and it is different from charging for incentive from tending timber trees on farm. This formula only caters for the damage caused by the felled tree and the loss incurred as a result of the removal of the timber tree for that particular time and does not factor in future reduction in yield due to the felled tree.

Damaged cocoa trees (DCT) = trees affected by felled timber trees

Loss incurred = number of DCT x average kilo of dry cocoa beans/tree (Cedis/kg)

**Convert this into present monitory terms using the formula:**

Loss incurred in cedis = price/kg of cocoa x Cedis/kg x DCT + cost of establishing new trees for at least 5 years

## 5.5 Exercises on timber policies, legislation and compensation

*Introduction*

Policies about trees on farms have been a disincentive to farmers who tend timber trees on farmland. Until recently farmers had no rights to naturally occurring as well as planted timber trees.

None the less, in recent times there has been a realisation that more than half of harvested timber trees come from farms including cocoa farms. Hence, policies and legislation concerning timber ownership on farm have shifted slightly in favour of farmers.

Even though policies have shifted, awareness creation has not been intensified to empower farmers on their rights. Hence, there is the need to embark on a sensitisation mission to raise farmer awareness on the prevailing policies and legislation in order to encourage farmers to actively incorporate reasonable numbers of timber trees in their cocoa farms and also to develop a new attitude towards naturally occurring timber trees.

### 5.5.1 Exercise on farmers' rights to timber trees on cocoa farms

*Learning objectives*

- To create awareness on tree rights and ownership
- To build farmer confidence on tree rights and ownership

*Materials*

- Cocoa farm with timber trees
- Timber Resources Management Act, 1997 (Act 547)
- Timber Resources Management Regulation, 1998, L.I. 1649
- Timber Resources Management Act (Amendment), 2002 (Act 617)
- Timber Resources Management (Amendment) Regulations, 2003, L.I 1721
- Case study

*Procedure*

Ask farmer participants to discuss the legislative framework on farmers' rights on tree ownership in details and ensure that they understand the laws very well. Also, initiate a discussion on their veto rights to enable them to know that they can veto concessionaires' right to fell trees.
Read the case study below to farmers. Read it such that each farmer can comprehend the story and can narrate it to each other.

*Case study*

Opanyin Kwaku Menka has a 10-acre cocoa farm situated on private land in Ashanti Region. His farm sits on a slope and has many valuable timber trees (about 5-7 per acre) that he left during the establishment of his cocoa farm some 20 years ago.

In recent years the environment has changed and these trees have helped Opanyin Menka to shade and protect his cocoa from the harsh sun, drier conditions, and strong winds that come with erratic rainstorms. When Opanyin Menka's father became ill, the trees also provided him with medicine that helped to cure his ailments.

One morning, as Opanyin Menka was pruning his cocoa trees two men arrived carrying a piece of paper that they claimed was a concession contract to fell five of the timber trees on his farm—two mahoganies and three odum. Opanyin protested and pleaded with the men not to cut the trees as they would damage his crop, but the men refused to listen.

The next morning the men returned, and he watched as they felled and dragged away the trees, damaging many of the surrounding cocoa trees. From then on, Opanyin's cocoa field encountered many problems from the loss of shade, including capsid attack and soil erosion.

*Guide questions for discussion*

- What can you say about the case study and the conducts of the timber contractor and Opanyin Menka?
- Is it allowed for timber contractors to fell trees on private farmlands? If yes, what is the normal procedure?
- Did Opanyin Menka participate in the inspection of the trees on his farm before the concession contract was granted? What should have been the procedure?
- Could Opanyin Menka have refused to let the men fell the trees? If yes, what would have been his major reasons against the felling?
- Did Opanyin Menka exhaust all his options to prevent the felling of trees from his farm? If no, what were some of his options?
- What were the consequences of Opanyin Menka's inability to stop the timber contractor from feeling those trees?
- What are some of the major lessons drawn from this case study?

### 5.5.2 Exercise on how to assess cocoa tree damage by felling of timber trees

*Learning objective*

1. To establish a simple model for assessing damage by felled timber trees
2. To identify factors needed for assessment.

*Materials*

- 1 ha cocoa farm with timber trees
- Measuring tape
- Rope
- Record of cocoa variety on farm.

*Procedure*

Divide farmers into two groups of between 5-10 participants and apportion each group to one side of the farm. Ask farmers to identify the timber tree species on their side of the farm. Also ask farmers to identify the variety of cocoa on their side of the farm.

Ask each group to determine the size of the trees by measuring the dbh by passing a rope around the tree and measuring it using the measuring tape. Ask participants to randomly sample 10-20 cocoa trees around a timber tree and count number of pods and estimate the number of kilos of dry cocoa beans to be obtained from the cocoa tree and then find an average.

Through this exercise ask farmers to determine the potential damage that a felled tree can cause by estimating the number of cocoa trees to be affected and calculate the loss incurred.

*Guided questions*

- Identify valuable timber trees on farm
- How many are there per unit area?
- Determine the dbh of the biggest and the smallest timber tree found on the farm
- With the dbh estimate the number of cocoa trees that will be damaged if the trees were felled today
- Of the cocoa trees that could be affected what is the average pods and beans production per year?
- Estimate the cost of establishing cocoa trees for 5 years
- Assess the damage caused and calculate a reasonable compensation due.

### 5.5.3 Exercise on farmers' veto on timber trees to be felled on cocoa farm

*Learning objective*

- To identify factors involved in determining compensation
- To develop a simple formula that farmers can use to rapidly determine compensation.

*Materials*

- Shaded cocoa farm of about 2 acre
- Average yield/kg per cocoa tree
- Current figures on variety of cocoa trees damaged as a result of felling
- Current figures on stumpage fee of timber
- Number of timber trees felled
- Case study.

*Procedure*

Ask farmer participants to discuss the legislative framework on compensation for damaged crops to ensure that they understand the laws very well. Also take up the discussion on the factors taken into consideration for calculating compensation to enable them know what they negotiate for with regards to tree felling by concessionaires.

Read the case study below to farmers. Read it such that each farmer can comprehend the story and can narrate it to each other.

*Case study*

Opanyin Kwaku Menka has a 10-acre cocoa farm situated on private land in Ashanti Region. His farm has many valuable timber trees (about 7-9 per acre) that he left during the establishment of his cocoa farm some 20 years ago.

In recent years the environment has changed and these trees have helped Opanyin Menka to shade and protect his cocoa from the harsh sun, drier conditions, and strong winds that come with erratic rainstorms. When Opanyin Menka's father became ill, the trees also provided him with medicine that helped to cure his ailments.
One morning, a team from the Forestry Services Department approached him as he was weeding his cocoa farm. These men told him that the timber trees on his farm have been given to a concession and they would like him to be part of the team that will go round to inspect the trees to be felled. Even though Opanyin Menka was apprehensive in the beginning, he joined the team the following day, inspected the trees. Out of all the timber trees, three odum trees were deemed suitable and were selected for felling.

After that Opanyin Menka submitted a letter of consent to the inspection team in which he stated that he would claim compensation for every cocoa tree damaged and also received an incentive for tending those timber trees. After felling the trees the next day 120 cocoa trees were destroyed. The timber contractor agreed to pay C 600000 for each tree and C 12000 per cocoa tree damaged.

*Guide questions for exercise*

- What can you say about the case study and the conducts of the forestry services departments, the timber contractor and Opanyin Menka?
- What was the amount Opanyin received for every cocoa tree damaged?
- What was the compensation Opanyin Menka received from the felled odum trees? Show how you arrived at the figure
- Could Opanyin Menka have refused them from felling those trees? If yes, what would have been his major reasons against the felling?
- Did Opanyin Menka have good bargaining skills? If yes, did he have all the necessary information he needed to negotiate compensation for his damaged crops and the timber felled?
- What were the consequences of Opanyin Menka's ability to negotiate with the timber contractor from felling those trees?
- What are some of the major lessons drawn from this case study?

# 6 References

*Ahenkorah, Y., Halm. B.J. and Akrofi, G.S. 1979.*
Some agronomic factors affecting cocoa rehabilitation in Ghana. Proceedings of the 5th International Cocoa Research Conference. Ibadan, Nigeria. pps. 199-203.

*Asare, R. 2005.*
Cocoa agroforests in West Africa: a look at activities on preferred trees in the farming systems. *Forest & Landscape* Working Paper no. 6-2005

*Anglaaere, L.C.N. 2005.*
Improving the sustainability of cocoa farms in Ghana through utilization of native forest trees in agroforestry systems. Ph.D. Thesis, University of Wales, Bangor, UK. 340pp.

*David, S. 2005.*
Learning about sustainable cocoa production: a guide for participatory farmer training. 1. Integrated Crop and Pest Management. Sustainable Tree Crops Program, International Institute of Tropical Agriculture, Yaoundè, Cameroon. March 2005 version.

*IFSP. 2004.*
A guide to seed quality. Directorate of Forest Tree Seed. Jakarta, Indonesia.

*Forestry Commission. 2003.*
Adjusted stumpage. Forestry Commission, Ghana

*Manu, M. and Tetteh, E.K. (ed). 1987.*
A guide to cocoa cultivation. Cocoa Research Instittute of Ghana.

*McDonald, M.A., Obiri, B.D., Jatango, J.A., Anglaaere, L.C.N., Cobbina, J., Moss, C., Nolte, C., Weise, S., Gockowski, J., Sinclaire, F. L., Bright, G. and Young, E.M. 2003.*
Shortened bush fallow rotations for sustainable livelihoods in Ghana. (DFID Project R7446) Final technical report. 25 pp + appendices.

*Mularwarman, Roshetko, M.J., Sasongko, S.M. and Iriantono, D. 2003.*
Tree seed management: seed sources, seed collection, and seed handling. A field manual for field workers and farmers. Winrock International and World Agroforestry Centre. 54 pp.

*Rice, A.R. and Greenberg, R. 2000.*
Cacao cultivation and the conservation of biological diversity. Ambio. vol. 29. no. 3.1.

*Timber Resources Management Act, 1997;*
Act 547. Forestry Commission of Ghana. Assembly Press Accra.

*Timber Resources Management Regulations, 1998.*
L.I. 1649. Forestry Commission of Ghana. Assembly Press Accra.

*Timber Resources Management (Amendment) Act, 2002.*
Act 617. Forestry Commission of Ghana. Assembly Press Accra.

*Timber Resources Management (Amendment) Regulations, 2003.*
L.I. 1721. Forestry Commission of Ghana. Assembly Press Accra.

# 7 Additional Reading

*Amanor, K.S. 1996.*
Managing Trees in the Farming System: The Perspective of Farmers. Kumasi, Forestry Department.

*Forest & Landscape Denmark. 1998-2006*
Seedleaflets. *Forest & Landscape Denmark.*

*Forestry Commission (undated).*
Forestry Laws Simplified. Abridged Version for Educational Purpose only. Forestry Commission 4 Third Avenue, P. O. Box M434, Acra-Ghana.

*Forestry Commission and FAO. 2004.*
Guidelines on Social Responsibility Agreement Negotiations. 24 pp.

*Jøker, D. 2000.*
*Acacia mangium.* Seedleaflet no. 3. Danida Forest Seed Centre, Humlebaek, Denmark.

*Jøker, D. 2000.*
*Albizzia lebbeck.* Seedleaflet no. 7. Danida Forest Seed Centre, Humlebaek, Denmark.

*Jøker, D. and Salazar, R. 2000*
*Ceiba pentandra.* Seedleaflet no. 22. Danida Forest Seed Centre, Humlebaek, Denmark.

*Jøker, D. 2002.*
*Gliricidia sepium.* Seedleaflet no. 51. Danida Forest Seed Centre, Humlebaek, Denmark.

*Jøker, J. 2002*
*Milicia excelsa.* Seedleaflet no. 63. Danida Forest Seed Centre, Humlebaek, Denmark.

*Poorter, L., Bongers, F., Kouamé, F. N'. and Hathorne, W. D. (eds). 2004.*
Biodiversity of west African forests: an ecology atlas of woody plant species. CABI Publishing, Cambridge, MA. Pp 521.

*Rachmawati, H., Iriantono. D. and Hansen. C.P. 2002*
*Gmelina arborea.* Seedleaflet no. 62. Danida Forest Seed Centre, Humlebaek, Denmark.

*Schmidt, L. 2000.*
Guide to handling of tropical and subtropical forest seed. Danida Forest Seed Centre. Pp 510.