Technical Manual

Manual for Bamboo Agroforestry Systems in Ghana


2020
Acknowledgements

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<table>
<thead>
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<th>Description</th>
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<tbody>
<tr>
<td>CSIR-CRI</td>
<td>Centre for Scientific and Industrial Research-Crop Research Institute</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organisation</td>
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<td>FORIG</td>
<td>Forestry Research Institute of Ghana</td>
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<td>IFAD</td>
<td>International Fund for Agriculture Development</td>
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<td>INBAR</td>
<td>International Bamboo and Rattan Organisation</td>
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<td>MOFA</td>
<td>Ministry of Food and Agriculture</td>
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1. Introduction

The decimation of natural forests through wildfires, logging, unsustainable practices, etc. calls for management options that include forest plantation development. However, most trees have long gestation periods (i.e. from seedling to maturity). There is therefore the need for options to narrow the wood deficit gap.

Bamboo is a valuable alternative due to its multiple uses and shorter rotation (3–5 years) (Akwada and Akinlabi, 2016). Known to be fast growing, bamboo can reach its maximum height in four to six months with a daily increment of 15 to 18 cm (5 to 7 in) (Raj and Lal, 2014). During the months of growth, each new shoot normally grows vertically into a culm with no branching out until the mature height is reached. Furthermore, bamboo sequesters carbon at a fast rate of 6–13 Mg/ha−1/yr−1 (Nath et al., 2015). Bamboo performs well even on marginal lands and can improve soil fertility through the production of large amounts of biomass (Kumari and Bhardwaj, 2017). Also, bamboo stands serve as habitats for soil microbial communities and other fauna. For short-to-medium-term benefits, trees and bamboos can be intercropped with food or cash crops and livestock, an approach called agroforestry.

This manual provides basic information about the development of bamboo resources through agroforestry systems in Ghana. The manual seeks to increase public awareness of how this important natural resource can be integrated easily and successfully with food crops. Practical guidelines for cultivating and sustainably managing bamboo species are offered herein to help farmers derive maximum outputs in terms of food crops, while managing bamboo stands for their intended objectives.

1.1 A brief description of bamboo

Bamboo is a perennial grass that has extensive economic and ecological value. The parts of a bamboo plant include the leaves, node, internode, culm, sheath, rhizomes, and roots (see Figures 1 and 2). Bamboos are multipurpose plants, with over 1500 documented uses. Often referred to as ‘poor man’s timber,’ bamboo is the oldest and cheapest building material used by man. Bamboo culm is used for diverse purposes, ranging from domestic products to industrial applications, such as food containers, skewers, chopsticks, handicrafts, toys, furniture, flooring, pulp and paper, boats, charcoal, musical instruments, bicycle frames, and weapons. In Asia, bamboo is principally used for bridges, scaffolding, skins of aeroplanes, bio-diesel, house construction, and temporary exterior structural material. Bamboo shoots are an important source
of food delicacies in Asian countries. Ghana has been recognised for the introduction of bamboo bicycles and windmills. Bamboo can thus create significant job opportunities.

**Figure 1:** Typical bamboo leaves (left) and the parts of a bamboo culm (right).
Figure 2: Young bamboo rhizome and root structure. *Photo credit: bamboo garden*

1.2 Types of bamboo

Based on the development of their rhizome system and culm habit, bamboo species can be classified into two groups: sympodial (clumping) and monopodial (running). However, there are cases in which species exhibit a blend of the two kinds. Examples of sympodial bamboo are *Bambusa vulgaris* (the common green bamboo plants dominant in Ghana), *Bambusa hetrostachya*, and *Bambusa vulgaris vitata*. The monopodial type includes *Guadua chacoensis* and most *Phyllostachys* and *Pleioblastus* species.
Figure 3: Types of bamboo found in Ghana. Left: a sympodial type (B. heterostachya). Right: a monopodial type (G. chacoensis).

It is uncommon to see a bamboo flower. However, bamboo can be classified into three groups, annual/continuous, sporadic, and gregarious, based on flowering patterns. Commonly, most bamboo flowering is sporadic or gregarious and occurs at an interval of between 50 and 120 years.

1.3 Bamboo species available in Ghana

Bamboo stands are mainly located in the southern part of Ghana. However, a few species are distributed in the northern part of the country. There are selected institutional and private nurseries producing plantlets for these bamboo species in Ghana.
**Table 1**: List of bamboo species presently found in Ghana.

<table>
<thead>
<tr>
<th>Bambusa species</th>
<th>Dendrocalamus species</th>
<th>Other species</th>
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</thead>
<tbody>
<tr>
<td><em>Bambusa arundinaceae</em>/<em>bambos</em></td>
<td><em>Dendrocalamus asper</em></td>
<td><em>Gigantochloa albociliata</em></td>
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<td><em>Bambusa balcooa</em></td>
<td><em>Dendrocalamus giganteus</em></td>
<td><em>Guadua angustifolia</em></td>
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<tr>
<td><em>Bambusa burmanica</em></td>
<td><em>Dendrocalamus membranaceus</em>/<em>Bambusa membranacea</em></td>
<td><em>Guadua chacoensis</em></td>
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<tr>
<td><em>Bambusa edulis</em>/<em>B. odashimae</em></td>
<td><em>Dendrocalamus barbatus</em></td>
<td><em>Oxytenanthera abyssinica</em></td>
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<tr>
<td><em>Bambusa heterostachya</em></td>
<td><em>Dendrocalamus brandisii</em></td>
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<td><em>Bambusa oldhamii</em></td>
<td><em>Dendrocalamus latiflorus</em></td>
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<tr>
<td><em>Bambusa nutans</em></td>
<td><em>Dendrocalamus strictus</em></td>
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<td><em>Bambusa textilis</em></td>
<td><em>Dendrocalamus perversialis</em></td>
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<td><em>Bambusa ventricosa</em></td>
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<tr>
<td><em>Bambusa vulgaris</em></td>
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<td></td>
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<td><em>Bambusa vulgaris vitata</em></td>
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2. An overview of agroforestry

Agroforestry is the deliberate integration of trees, crops and/or animals on the same piece of land, in order to optimise land utilisation. The practice is prevalent in areas with land hunger (examples in Ghana include: Bono, Bono East, Ashanti, Eastern Regions and the Northern part of the country). There are 3 main types: agro-silviculture (trees and crops), silvo-pastoral (trees with animals) and a combination of the trees crops and animals (i.e. agro-silvo-pastoral). Apart from addressing socio-economic issues, agroforestry also provides environmental services (e.g. soil stabilisation and fertility, windbreaks, landscape restoration, erosion reduction, underground water recharge, carbon sequestration, pollination, etc.) (FAO, 2018). Agroforestry is a land-use system in which woody perennials (e.g. trees, shrubs, palms, or bamboos) and agricultural crops or animals are used deliberately on the same parcel of land in some form of spatial and temporal arrangement. Agroforestry can also be defined as a dynamic, ecologically based natural resource management system that, through the integration of trees on farms and in agricultural landscapes or through the production of agricultural products in forests, diversifies and sustains production for increased economic, social, and environmental benefits for land users.

Agroforestry interventions include trees integrated with food or cash crops (agro-silvicultural), trees with livestock (silvo-pastoral), and a combination of the three components (food crops, trees, and livestock) (agro-silvo-pastoral). Agroforestry has long been practiced in many parts of the world. Its form varies considerably from landscapes, countries, and regions, depending on human needs and capabilities and the prevailing environmental, cultural, and socioeconomic conditions. Examples of agroforestry systems worldwide include: improved fallows; home gardens; alley cropping; boundary planting; shelterbelts; windbreaks; conservation hedges; fodder banks; live fences and apiculture with trees (FAO, 2018).

Agroforestry systems are multifunctional systems that can provide a wide range of economic, sociocultural, and environmental benefits. Agroforestry can be particularly important for smallholder farmers because it generates diverse products and services on a limited land area. Agroforestry systems also have limitations, and a careful analysis should be carried out before their introduction. Bamboo agroforestry practice should be conducted on marginal lands that weakly support crop farming. Farmers are advised not to convert fertile croplands into bamboo agroforests.
2.1 Agricultural crops

In Ghana, a variety of agricultural crops are cultivated based on climatic zones, which range from dry to wet. Some food crops produced and adopted in agroforestry systems in Ghana include yams, grains, maize, plantains, cassava, potatoes, oil palm, and cocoa, amongst others. A farmer is at liberty to choose his or her preferred crop. It is advised that leguminous crops, such as groundnut, beans, and cowpea, be added to the selected crops. Seeds or planting materials for food crops can be acquired from the Centre of Scientific and Industrial Research-Crop Research Institute (CSIR-CRI), Ministry of Food and Agriculture (MOFA) offices, or other agricultural shops.

2.2 Bamboo seedlings/plantlets

Every successful plantation depends on healthy seedlings. For large plantations, it is advisable to have an associated nursery. A particular farm may have its own temporary (also known as flying) or permanent nursery. Otherwise, bamboo seedlings can be acquired from reliable and trusted nurseries. The CSIR-Forestry Research Institute of Ghana, private organisations like Kwamoka Farms, Global Bamboo, and other experienced individuals have been identified to
produce bamboo seedlings. The West Africa Regional Office of the International Bamboo and Rattan Organisation (INBAR) can provide more information on bamboo seedling suppliers.

![Bamboo seedlings ready for lifting and planting.](image)

**Figure 5**: Bamboo seedlings ready for lifting and planting.

### 2.3 Planting bamboo in the field

In the field, consider the size and growth behaviour of the selected bamboo species. Ideally, spacing between bamboo plants (clump centres) should be 5 x 5 metres (m) or 400 plants per hectare (ha). However, for species like *O. abyssinica*, the recommended spacing is at least 7 x 7 m or 204 plants per ha. Although growing bamboo is relatively inexpensive, culms are too small and cannot be sold during the first two or three years of stand growth. However, farmers can raise other crops within the stand to recover the initial capital input. Bamboos are fairly resistant to diseases, insects, and climatic injuries, which allows easy intercropping and movement during bamboo stand/clump management. Certainly, individual farmers’ resources and objectives plus the availability of land can influence spacing and the choice of the design.
2.3.1 Planting out bamboo seedlings

The following guidelines are suggested to aid the establishment of a productive bamboo plantation.

i. Soil acidity must be corrected before planting starts. An application of 300 to 400 kg of lime per acre will neutralise acid soil. Otherwise, make insoluble nutritive elements available to hasten the decomposition of organic matter.

ii. Preferably, soil should be fertile and have good drainage with moderate slopes. However, most bamboo species do well even on waste and marginal land.

iii. Weed land by any accepted method appropriate for the locality and the season.

iv. Prepare a layout for the land so that the holes are dug at the specified intervals. The holes should be positioned in a north-south orientation to provide an optimal distribution of sunlight to all plantlets.

v. Planting holes should be dug with the size of the polypot in mind. There should also be allowances for hand-firming the soil at the base.

vi. Planting should coincide with the start of the rainy season. If available, organic fertiliser or manure should be placed into each hole and mixed with the topsoil.

vii. The plantlets should be planted in an erect position with the polypot removed. The holes should be properly covered, firmed, mulched, and watered.

viii. Dead seedlings should be replaced immediately at the start of the rainy season.
A well-planned field layout is essential to facilitate the management and enhance the yield of a bamboo plantation. The field layout should account for the habit and size of the bamboos, such that small-culm species are spaced more closely, and large-culm species are given wider spaces. A spacing of 4.5 x 4.5 to 5 x 5 m may be sufficient for many bamboos, but is inadequate for large species like *Dendrocalamus giganteus*, *Dendrocalamus brandisii*, and *Dendrocalamus asper*. For larger species, spacing should be widened and plants per hectare should be reduced, especially when the objective of the plantation is to harvest bamboo timber. Spacing of up to 10 x 10m (100 clumps/ha) is suitable for large bamboos; wider spacing will allow the clumps to reach their full potential.

When determining the spacing of plants, it is advisable to provide extra space between rows. The spacing of plants within a line may be reduced, while the spacing between lines can be increased. The aim is to have easy access and mobility between rows of clumps so that felled culms can easily be stacked and hauled away. The following table shows suggested spacing for small, medium, and large bamboos.

**Figure 6:** Bamboo and cassava agroforestry backyard garden (bamboo growth of less than one year).
Table 2: Plant spacing (m) and plants per hectare.

<table>
<thead>
<tr>
<th>In line</th>
<th>Between lines</th>
<th>Plants per ha</th>
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<tbody>
<tr>
<td>4</td>
<td>5</td>
<td>500</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>417</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>333</td>
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<tr>
<td>5</td>
<td>7</td>
<td>286</td>
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<td>6</td>
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<td>9</td>
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<td>111</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Kigomo (2007)

2.3.1 Mulching

Mulching is achieved by uniformly spreading a layer of leaf litter or other organic materials on the surface of the soil around the planted bamboo. Mulching has the following advantages.

i. It helps conserve soil moisture and contributes organic nutrients to the plant.

ii. It protects young shoots from direct sunlight and keeps them moist, thus allowing them to grow to an optimal size without hardening and losing their edible quality.

iii. It greatly encourages growth by reducing the evaporation of soil water and sustaining warmth.

iv. Effectively prevents profuse weed growth.
Figure 7: Watering of a newly planted bamboo seedling.

Figure 8: A stand of planted bamboo.
3. Bamboo-based agroforestry systems

Bamboo-based agroforestry systems can play an important role in enhancing productivity, sustainability, and resource conservation. Many of the useful bamboo species are well suited for agroforestry. Bamboos have many advantages over trees, including the following:

i. Versatility of use that exceeds most tree species.
ii. Ability to provide building materials and edible products for many years or even decades.
iii. A much faster growth rate and earlier maturation than most tree species.

Bamboos, if grown from offshoots, require four to five years to yield their first harvest, which is much less maturation time than any other woody species. If grown from seedlings, then the first harvest can be obtained after seven years. Farmers can use this initial period for growing intercrops and enhancing sustainability and income. Under agroforestry systems, the planted bamboo also benefits from sharing resources, such as fertilisers, weeding, etc., with intercrops. As a result, the quantity and quality of bamboo is much higher than in monoculture or unmanaged plantations. Bamboo, if well managed, can be grown in agro-silvicultural, silvo-pastoral, agro-silvo-pastoral, and agro-silvo-horticultural systems.

3.1 Bamboo agroforestry models

Bamboo agroforestry models can be categorised under the following headings.

3.1.1 Bamboo in home gardens

In home gardens, bamboo is found either mixed with many other tree species or growing alone in patches. In village homesteads, bamboo mostly occupies the backyard and periphery of the holdings and is one of the most important crops for the farmer. Most of the bamboo species in home gardens are clump forming and congested in nature with large, tall branchy culms. Bamboos easily grow as inter- and under- crops with many trees.

3.1.2 Block plantation/agro-silvicultural systems

In this model, bamboos are planted at a spacing ranging from 4 x 4 m (for small-sized species) to 9 x 9 m (for large-sized species). The space between culms can be used for growing annual crops (e.g. maize, cowpeas, soya beans, groundnuts, vegetables, etc.). Intercropping with bamboo can
be practiced for a maximum of four years after planting the bamboo. After this period, competition for resources may be very high, making intercropping no longer profitable.

Bamboo species should be chosen depending on the climatic conditions and soil type of the area. In planting bamboo, full soil preparation may be employed on flat land. On sloping land, strip preparation, leaving alternate unprepared strips to prevent water runoff and soil erosion, is recommended. Under an agro-silvicultural system, cowpeas, soya beans, groundnuts, maize, vegetables, cassava, and yams can be intercropped during the initial stages of growth (the first four years). It is also possible and economically feasible to intercrop matured bamboo clumps with shade-tolerant crops such as ginger, black pepper, grains of paradise, turmeric, shade-tolerant varieties of sweet potatoes, cinnamon, etc. By adopting wide spacing between the bamboo clumps and judicious manipulation of the bamboo canopy, farmers can further extend the period of intercropping. Intercrops can also be increased by keeping large spacing between lines and smaller spacing between plants or within lines of bamboo.

3.1.3 Bamboo with livestock/aquaculture/beekeeping (silvo-pastoral)

This model combines bamboo with poultry, small ruminants (e.g. sheep and goats), or fish farming. In this model, while the bamboo provides shelter and feed for the animals, the animal droppings act as fertiliser to boost the growth and productivity of the bamboo stand. Apiculture (i.e. beekeeping) can also be introduced for honey production.

![Diagram of silvo-pastoral model](image)

**Figure 9**: Silvo-pastoral model (bamboo as shelter and feed for the animal components).
3.1.4 *Bamboo with food crops and livestock (agro-silvo-pastoral)*

This model combines bamboo with food crops (e.g. rice) and poultry, small ruminants (e.g. sheep and goats), fish farming, or apiculture. Bamboo can be intercropped with some maize, groundnuts, etc. While the food crops are young, the small ruminants can be kept in a pen, where they can be fed using bamboo leaves and other fodder. After harvesting the food crops, the small ruminants can be allowed to roam through the stand and graze. At the same time, beehives can be placed at specific points, while fishponds can also be placed in other blocks of the stand. The planting interval for bamboo should be at least 6 m.

![Agro-silvo-pastoral model (bamboo used as a boundary planting).](image)

**Figure 10:** Agro-silvo-pastoral model (bamboo used as a boundary planting).

3.1.5 *Bamboo with timber trees*

This model can be established in two ways: by converting semi-naturally mixed stands and by planting new ones. The ratio of bamboo to trees is important. In semi-naturally mixed stands, the ratio may be 7:3 or 8:2. The planting time for the bamboo and the trees should be determined by the growth rate of the tree species involved. Tree species most suitable for intercropping with bamboo are those with deciduous, light crowns and those with narrow crowns. Tree species with deep, spreading, and evergreen crowns should be avoided.
3.1.6 Bamboo as a windbreak

Bamboo can be planted as a windbreak on the boundaries of agricultural fields and orchards. For instance, mango orchards can be intercropped with agricultural crops and the boundaries planted with one or two rows of bamboo. The planting interval for the bamboo in this case should not be more than 4 m.

Figure 11: Agro-silvo-pastoral model (bamboo serving as a windbreak).
4. Suggested plot layouts

Several designs are possible for plot layouts. Farmers’ design choices will depend on their desired income, the size of their land, and their objective for incorporating bamboo into their farms. Figures 12–14 below illustrate typical layouts of bamboo agroforest setups. Additionally, Figures 21–25 (see Appendix, pg. 32) illustrate bamboo-based agroforestry designs developed by the INBAR West Africa Regional Office for a pilot project at Jeduako in the Ashanti region of Ghana.

![Diagram of a plot layout]

**Figure 12**: Plot layout 1. A bamboo mixed agroforestry farm.
Figure 13: Plot layout 2. A = agricultural crops, B = bamboo, and P = path.

Figure 14: Plot layout 3. A bamboo agroforestry farm along a stream. P = path.
5. Intercropping

Intercropping can serve several purposes, including the provision of intermediate income to farmers. Food crops can be planted between bamboo rows. Vegetable crops provide greater stability to the soil and help control erosion. Intercropping can also help to control weeds and pests in the plantation. During the third year, leguminous crop species such as groundnuts, cowpeas, and soya beans can be planted to serve as ground cover and return nitrogen back into the soil. When the bamboo canopy closes, the cultivation of intercrops may no longer be viable.

5.1 A few pictorial examples of bamboo agroforestry

![Figure 15: Bamboo intercropped with cowpea.](image)
Figure 16: Bamboo intercropped with soya beans (2nd year).

Figure 17: An agroforestry model with bamboo and vegetables.
**Figure 18**: Bamboo intercropped with pepper (2nd year).

**Figure 19**: Remnants of a bamboo and cassava agroforestry model.
Figure 20: A bamboo-yam agroforestry model.
6. Management of a bamboo agroforestry farm

6.1 Management of bamboo stands

Some bamboo species are very fast growing. Young bamboo culms grow to full maturity in about five years. Individual bamboo culms maintain their height and diameter after maturity and do not replace any growth lost from pruning or natural breakage. Bamboos have a wide range of hardness depending on species and locality. Small or young specimens of an individual species will produce small culms initially. However, as the clump and its rhizome system mature, taller and larger culms are produced each year until the plant approaches its maximum height and diameter. Rarely, a harmful fungus may form on the outside of the matured culm and eventually penetrate the culm wall. The bamboo clumps should be inspected periodically, and any sign of infestation should be reported to the CSIR-Forestry Research Institute of Ghana. Five years after planting, culms on good soil should have about 2,000 mother culms per hectare. Between 1500 and 2,000 mother culms per hectare is desirable. Maintaining this culm density is best for the health of the plantation. A higher density produces too many overcrowded rhizomes, which reduces shoot quality. Ideally, culms must be carefully marked with the year of their emergence so that there will be no uncertainty at cutting time. At age seven, culms should be harvested to about 500 shoots per hectare, allowing the remaining shoots to grow into new culms each year. To harvest the bamboo, neatly cut matured culms at the base with a portable chainsaw. During harvesting, it is advisable to select and remove only matured culms. Among the adopted sustainable harvesting methods for bamboo are the ‘horseshoe’ and ‘V-type’ approaches.

6.2 Management of agricultural crops

Farmers usually have rich experience in managing their various food crops. Moreover, the nearest District Offices of the Ministry of Food and Agriculture are readily available to provide management assistance if necessary. Additionally, CSIR institutions such as the Crop Research Institute and the Soil Research Institute can help with addressing farmers’ challenges related to crops and soils.
7. Challenges of bamboo-based agroforestry

There are some challenges or constraints likely to be encountered with bamboo agroforestry systems. These include the following:

i. Bamboo, being a perennial grass, has a higher root-length density than dicots. This makes it more competitive when grown in association with agricultural crops in agroforestry.

ii. Due to their fast growth, bamboos close their canopies in a relatively short period compared with other tree species and compete heavily with the intercrops for light.

7.1 Overcoming the challenges

Before beginning a bamboo intercropping endeavour, farmers should properly consider resource competition. Resource competition in bamboo-based agroforestry systems may be minimised in the following ways.

i. By giving due consideration to plant population and the geometry (i.e. the arrangement) of the planting.

ii. By using root management practices like trenching to reduce belowground competition.

iii. By planting bamboo at adequate spacing when intercropping. (For bamboo agroforestry, bamboo rows should be spaced at least 8 to 9 m apart.)

Bamboo root competitiveness is usually a function of its rooting intensity together with crown radius. Larger clumps have wider foraging zones, usually extending to about 8–9 m. Therefore, canopy reduction treatments, such as pruning and culm thinning, are recommended to overcome inter-species competition.

Pruning up to the height of 1.5 m above the ground is recommended for plantings of four or more years. The removal of dry and dead culms from the centre of the clump to reduce congestion is also recommended. Finally, for the successful integration of bamboos into intercropping systems, farmers should screen for species of bamboo that are high yielding.
8. Conclusion

Bamboo-based agroforestry systems have a wide scope and can be integrated into farmlands, homesteads, degraded lands, riparian strips, etc. They can help in augmenting farmer’s income in addition to efficiently conserving resources. The systems, however, are not popular due to significant above-ground competition with intercrops. The competition, therefore, needs to be reduced by choosing suitable species, adopting wider spacing, or using canopy management practices. Interactions in bamboo-based agroforestry systems also need to be studied to scale up bamboo cultivation in Ghana.
9. References


10. Appendix

Figure 21. Plot layout of a bamboo-based intercropping system (non-fertilised).

Field size = 35 x 83 m
Blue ovals are bamboo plants
Red-shaded plots are hypothesised competitive zones
Blue-shaded plots are hypothesised complementary zones
Figure 22: Plot layout of a bamboo-based intercropping system (fertilised).

Field size = 35 x 83 m

Blue ovals are bamboo plants

Red-shaded plots are hypothesised competitive zones

Blue-shaded plots are hypothesised complementary zones
Figure 23: Plot layout of a bamboo monocrop (designed for destructive sampling).

Field size = 15 X 35 m
Blue ovals are bamboo plants

Figure 24: Plot layout of different monocropping systems (non-fertilised).
Field Size = 35 x 35 m
Figure 25: Plot layout of different monocropping systems (fertilised).

Field size = 35 x 35 m