

GUIDELINE FOR BAMBOO PLANTATION ESTABLISHMENT, MANAGEMENT AND UTILIZATION IN CAMEROON



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PRÉFACE

Bamboo is a multipurpose plant that is currently used in our day to day life. It is a sustainable and renewable natural resource which is used for construction material, for furniture manufacturing, textiles and as a food source. Given its numerous usages, bamboo provides an alternative to wood which could reduce pressure on our forest. Bamboo is also used in the pharmaceutical domain for the production of drugs and cosmetic products. It plays a vital role for socio-economic development and environment management. Bamboo has demonstrated its potential for socio-economic development as well as overall sustainable development of many countries. Bamboo is now seen worldwide as a timber substitute, energy substitute, food, feed and fodder (Bamboo shoots are consumed widely in Asia as a vegetable and bamboo leaves are also used as feed and fodder for cattle). Its rapid growth and regrowth rate and possibility for annual selective sustainable harvesting provides opportunities for growers, value addition enterprises and all actors involved in bamboo value chain to benefit.

The bamboo sector can contribute to the economy of many African countries via the development of Micro, small and medium scale industries (MSME) and as well as large industries for production of bamboo products for sustenance, domestic, agriculture, household and life style products cutting across various market segment both for domestic and international market. Bamboo positively impacts the environment as it is known for its potential to sequester carbon, control soil erosion, and increase water recharge. It is a substitute for timber and energy which can reduce pressure on the demand for timber, thereby encouraging forest protection. Bamboo is also used in the pharmaceutical domain for the production

of drugs and cosmetic products. It can be used to produce both wood fuel and charcoal for cooking and heating.

Cameroon is divided into five agro-ecological zones based on climate and topographic criteria suitable for bamboo growth. According to Hans Friederich, former Director General of the International Network for Bamboo and Rattan (INBAR) in his interview of 05 August 2016 realized by Godlove BAINKONG in Beijing, "Bamboo demonstrates significant potential as a strategic resource for sustainable development in Cameroon and across Africa. Cameroon has significant reserves of largely untapped indigenous bamboo, and excellent conditions for growing and cultivating a wide range of bamboo species. The plant provides a practical and rapid solution for environment and poverty challenges faced by many African countries".

There are two main types of bamboo growing form which are monopodial (running) and sympodial (clumping), we can also observe a form of bamboo growth having both running and clumping form called amphypodia. The most common bamboo species found in Cameroon are; *Bambusa vulgaris*, *Yushania alpina*, *Oxytenanthera abyssinica* (clumping or sympodial bamboo species) and *Phyllostachys aurea* (amphypodia bamboo species). Bamboo is considered as one of the neglected NTFPs in Cameroon, despite its rapid growth rate, and the vital economic and ecological importance it's proved to humans. This handbook is aim to contribute in promoting bamboo market enterprise and business development in Cameroon.

This handbook is will serve as a tool for the establishment and management of bamboo plantations in Cameroon. The handbook has been

developed based on the International Bamboo and Rattan Organization's technical bulletin on bamboo nursery techniques, plantation, maintenance and management, other bamboo publication and ongoing bamboo project in Cameroon. It provides a guideline on bamboo plantation management; from the production of bamboo seedling, planting, maintenance, sustainable harvesting and utilization.

This handbook is divided into seven chapters. Chapter one provides information on overview of bamboo. Chapter two provides information

on bamboo nursery development. Chapter three offers guidelines for propagating bamboo through seeds, rhizomes offset, culm cutting, branch cutting, air layering and macro-proliferation. Chapter four provides guidelines for bamboo plantations establishment and management. Chapter five provide techniques on bamboo sustainable management and harvesting. Chapter six provides guidelines for bamboo post-harvest treatment. Chapter seven is on bamboo utilization.



1. Bamboo taxonomy

Bamboo is a woody grass belonging to the family Poaceae (Gramineae) and from the tribe Bambuseae of the sub-family Bambusoideae¹. It is estimated that about 1642 bamboo species have been identified all over the world². Bamboo is recorded to be the fastest-growing woody plant on the earth since culms of some species, in just 4 months, can reach 40 m in height and 30 cm in diameter³. Furthermore, bamboo has an extremely wide range of distribution with a great variety of habitats in different agro-climatic regimes.

Some of them are found in high rainfall zones and others are found in deciduous and drier zones. With over 1642 species globally, bamboo has proven to grow in a wide range of ecologic and economic potentials. Worldwide, 38 bamboo species are commonly cultivated and use, these species include: *Arundinaria* sp, *Bambusa atra*, *Bambusa balcooa*, *Bambusa bambos*, *Bambusa blumeana*, *Bambusa heterostachya*, *Bambusa nutans*, *Bambusa oldhamii*, *Bambusa pervariabilis*, *Bambusa polymorpha*, *Bambusa textilis*, *Bambusa tulda*, *Bambusa vulgaris*, *Cephalostachyum pergracile*, *Lingnania chungii*, *Dendrocalamus asper*, *Dendrocalamus brandisii*, *Dendrocalamus giganteus*, *Dendrocalamus hamiltonii*, *Dendrocalamus hookerii*, *Dendrocalamus membranaceus*, *Dendrocalamus lati-*

florus, *Dendrocalamus strictus*, *Gigantochloa albociliata*, *Gigantochloa apus*, *Gigantochloa atroviolacea*, *Gigantochloa balui*, *Gigantochloa hasskarliana*, *Gigantochloa levis*, *Gigantochloa pseudoarundinacea*, *Guadua angustifolia*, *Melocanna baccifera*, *Ochlandra* spp, *Oxytenanthera* sp., *Phyllostachys glauca*, *Phyllostachys pubescens*, *Thyrsostachys siamensis*, *Schizostachyum* sp⁴.

2. Bamboo Ecological zones and distribution in the world

Bamboo is an ancient woody grass widely distributed in tropical, subtropical and mild temperate zones⁵, mostly found between 46°N to 47°S⁶. It is a highly adaptable plant that can grow at many different altitudes ranging from sea level to 4000 meters above sea level, on many different types of soil, as long as it has sufficient rainfall to sustain its growth. Bamboo is found in every continent except Antarctica and some European countries.

Normally, bamboo thrives at temperature range of 8.8 to 36°C and annual precipitation of 1020 to 6350 mm⁷ but some species can even grow in cold climate with temperature of about -20° C⁸. About 80% of bamboo forest land and species in the world is distributed in Asia and Pacific regions⁹. Asia has about 590 bamboo species in 44 genera compare

1. Zhu, S., Ma, N., Fu, M. 1994. *Compendium of Chinese Bamboo*: 8-9. China forestry publishing house, Beijing.; Ohrnberger, D. 1999. *The Bamboos of the World*. Elsevier.
2. Vorontsova, M.S., Clark, L.G., Dransfield, J., Govaerts, R., Baker, W.J. (2016). *World Checklist of Bamboos and Rattans*. International Network of Bamboo and Rattan & Royal Botanic Gardens, Kew. 454 pages
3. Fidel Antonio., Troya Mera.,Chenyang Xu. (2014). *Plantation management and bamboo resource economics in china*.
4. Rao, A.N. and V. Ramanatha Rao, editors. 1998. *Priority Species of Bamboo and Rattan*. IPGRI-APO, Serdang, Malaysia.
5. FAO, 2007. *World bamboo resources - A thematic study prepared in the framework of the Global Forest Resources Assessment 2005*.
6. Dransfield, S. 1992. *The Bamboo of Sabah*. Sabah Forest Records. Pp 1-10
7. Huberman, M.A. 1959. *Bamboo silviculture*. Unasylva FAO. 13 (1): 36-43. INBAR/BOTA/ABS (International Network for Bamboo and Rattan - Bamboo of the Americas - American Bamboo Society) 2009 *Constructing and conserving with bamboo*. Round Table Discussion at World Forestry Congress 13, Buenos Aires, Argentina, 18-23 October 2009. <http://www.bambooftheamericas.org/?p=138> (30 September 2010).

to Australia and the Pacific islands having fewer bamboo species with more scattered distribution¹⁰. America also has a high biodiversity of bamboos with approximately 400 – 500 species, among them about 300 species in 20 genera are woody¹¹. The island of Madagascar has 6 genera with about 32 species.

3. Bamboo trade in the world

INBAR estimates the total annual output value of the global bamboo and rattan sector at around USD 60 billion. Based on data from the UN Comtrade database, statistics shows that in 2017, the global export of bamboo and rattan products amounted to approximately USD 1.7 billion¹². Even though this figure was underestimate according to INBAR, with data provided by China Customs alone adds USD 600 million more to the total export of bamboo and rattan products, putting the global export value in 2017 at over USD 2 billion, we will highlight in this section product category for international trade.

According to INBAR, Asia remained by far the most important exporter of bamboo and rattan products: the export value of bamboo and rattan products from Asia accounted for 88 per cent of the global total. In 2017, industrialised bamboo products international market includes; bamboo flooring and panels, which comprised the main type of export, with an export value of USD 360 million. The second exported products were bamboo and rattan woven, which were exported at USD 550 million. The Third exported products were bamboo and rattan raw materials, which were exported at USD 120 million and bamboo shoots were exported at USD 320 million. China accounted

for 70 per cent of the world's export of bamboo and rattan products, with a value of USD 1.18 billion. The EU was the second largest exporter, with USD 153 million, roughly equivalent to 9 per cent of the total. The third largest exporter was Indonesia, with a market share of 8 per cent worth USD 130 million, followed by Vietnam, the USA and the Philippines. The EU is the largest importer of bamboo, buying 37 per cent of bamboo and rattan products on the international market, followed by Asia and North America, which imported 32 per cent and 25 per cent, respectively. Other countries involved in bamboo importation and exportation in the world are Japan, Malaysia, Australia, South Korea, Israel, Myanmar, Croatia and The USA.

In Africa, the share of removals from forests used for fuel is substantially higher¹³. Although little quantitative information was presented on bamboo removals and products, several countries indicated that bamboo energy use is substantial in rural areas. Lack of knowledge of bamboo management and utilization is indicated as the main obstacle to developing the bamboo sector on the continent.

4. Bamboo as Non-Timber Forest Products (NTFPs) Importance for Livelihood

Bamboo and its related industries provide income, food and housing to over 2.2 billion people worldwide¹⁴, this could be explained by the socio-economic and ecologic development potentials of bamboo. In China about 10 million people are estimated to be directly involved in bamboo industries, and rural households' incomes in bamboo industries, having about \$330 per person.¹⁵

8. Wang, D., Shen, S.1987. *Bamboos of China*. Timber Press Portland/Oregon. 17: 1-17.

9. Fu, M., Xiao, J., Lou, Y.2000. *Cultivation and Utilization on Bamboo*. Beijing: China Forestry Publishing House.

10. Dransfield, S., Widjaja, E.A., (eds).1995. *Plant Resources of South-East Asia, No 7. Bamboos*. Backhuys Publishers, Leiden. Pp. 15-49

11. Fu, M., Xiao, J., Lou, Y.2000. *Cultivation and Utilization on Bamboo*. Beijing: China Forestry Publishing House.

12. *Trade Overview 2017: Bamboo and Rattan Commodities in the International Market*.

13. FAO.2006. *Food aid as part of a coherent strategy to advance food security objectives*, by C.B.Barret. ESA Working paper 06-09.Rome.

Asian Countries mostly use bamboo daily, for instance in Bangladesh, 73% of the population lives in bamboo houses¹⁶. In Taiwan alone 80,000 tons of bamboo shoots are consumed annually constituting a \$50 million industry¹⁷. In China the estimated annual production of bamboo flooring was 17.5 million square metres in 2004 with about 65% being exported¹⁸. In India the sticks making industry, which use bamboo to produce incense sticks situated in North Eastern Region of India is estimated to be worth US\$400 million¹⁹. In Laos, the bamboo processing factory in Vientiane, occupies the third position in the employment sector with a turnover of about 18400 tons of bamboo per year²⁰, the factory estimated annual production for the internal market net worth more than US\$ 7 million with annual bamboo production reaching some 50000 tons in 2008²¹.

Again, In Ecuador, bamboo grants have sparked a number of public-private partnerships that make furniture, flooring, crafts and construction products²². These public-private partnerships models have now also been shared with neighbouring regions in Northern Peru, with some 2000 people now employed²³. In the United States, several companies are growing, harvesting and distributing bamboo species such as *Phyllostachys nigra* and *Phyllostachys edulis*²⁴ for ornamental and crafting purpose.

Bamboo is also currently use in African countries, for instance, in Tanzania bamboo is also

used for land degradation restoration, reason why over 100 bamboo nurseries have been created, during which about 1000 individuals have received training to build their capacity in creating Bamboo Training Center that has led to micro-enterprises set up²⁵. In Rwanda, the government has developed a bamboo road map and has begun growing bamboo on a commercial basis²⁶.

In Ghana, three Bamboo Bicycle factories are established, among which the Boomers International limited company situated between Yonso and Jamasi. Founded in 2014, Boomers bicycle factory is the biggest in Africa regards to bamboo bicycle. They supply the biggest bamboo bicycle market in Europe and USA thanks to their new partners. Directly Boomers Company employs 40 workers at the factory. The Company shipped one container of bamboo bicycle every month and produce 3500 bicycle per year. The Boomers provides skill training and employment to youth in rural areas through manufacturing of bamboo bicycles and accessories, *Bambusa vulgaris* and *Oxytenanthera abyssinica* are mostly used, about 10.000 culms were harvested in 2018. In 2019 (after 5 years of existence) the Ghanaian Government support the company by giving a license which avoid them to pay cooperate taxes for the next 10 years” (the condition to obtain this license is that the company need to export at least 70% of the total production).

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14. Samir Jamatia, 2012. *Livelihood of the Bamboo base: Challenges and Opportunities*.
 15. INBAR (2015b). *International Network for Bamboo and Rattan. International Trade of Bamboo and Rattan 2012*.
 16. Samir Jamatia, 2012. *Livelihood of the Bamboo base: Challenges and Opportunities*.
 17. Samir Jamatia, 2012. *International Trade of Bamboo and Rattan*.
 18. Customs General Administration of China, 2004
 19. Samir Jamatia, 2012. *International Trade of Bamboo and Rattan*.
 20. IMF (2008). *International Monetary Fund. Lao People's Democratic Republic: Second Poverty Reduction Strategy Paper (EPub); UNDP (2015b). United Nations Development Programme. Lao PDR: Bamboo preservation enriches lives and the environment*.
 21. FAO (2014). *Food and Agriculture Organization of the United Nations. Enhancing the socioeconomic benefits from forests. State of the World's Forests 2014. Rome Italy*.
 22. IFAD (2013b). *Programme of work in 2013; INBAR (2015a). How small bamboo and rattan businesses can help drive new economies <http://www.inbar.int/2015/04/smalland-medium-sized-bamboo-enterprises>; INBAR (2015b). International Network for Bamboo and Rattan. International Trade of Bamboo and Rattan 2012*.
 23. Sythud Phimmachanh, Zhang Ying, and Mukete Beckline, "Bamboo Resources Utilization: A Potential Source of Income to Support Rural Livelihoods." *Applied Ecology and Environmental Sciences*, vol. 3, no. x (2015): 176-183. doi: 10.12691/aees-3-6-3.
 24. Sythud Phimmachanh, Zhang Ying, and Mukete Beckline, "Bamboo Resources Utilization: A Potential Source of Income to Support Rural Livelihoods." *Applied Ecology and Environmental Sciences*, vol. 3, no. x (2015): 176-183. doi: 10.12691/aees-3-6-3.
 25. Sythud Phimmachanh, Zhang Ying, and Mukete Beckline, "Bamboo Resources Utilization: A Potential Source of Income to Support Rural Livelihoods." *Applied Ecology and Environmental Sciences*, vol. 3, no. x (2015): 176-183. doi: 10.12691/aees-3-6-3.
 26. Bazivamo, C (2011). *National Bamboo Policy. Ministry of Forestry and Mines, Republic of Rwanda*

CHAPTER II: BAMBOO NURSERY DEVELOPMENT

Bamboo nursery development starts with the establishment and management of a nursery. A nursery project has two main components, namely: nursery setup and propagation techniques.

1. Bamboo Nursery set up

Setting up a bamboo nursery will enable a regular availability and supply of bamboo planting material for bamboo plantation establishment and reforestation projects. To establish a nursery, a site must be properly selected according to the following factors:

a. Site accessibility

The nursery site should be located near main road or a public road to facilitate operations, communication and transport. If possible the nursery site should be established close to plantation areas. This will reduce transport time and cost in delivering plants to the plantations and these young bamboo plants will undergo less stress during transport to planting areas..

b. Topography

It is important to take in to consideration the nursery site topography. It is advisable to establish a bamboo nursery on a flat land or in gently slope. In case of gentle slope, contours can be prepared. In general, hilltops and valley bottoms are unsuitable. Locations with water logging / flooding including flash floods are not suitable.

c. Water Supply

The bamboo nursery site should be located close to a permanent and abundant water source. The amount of daily water need depends on the nursery size, watering method and frequency, rainfall and temperature rate, and the quantity/type of propagation materials. During the dry seasons as well as to ensure water supply in all seasons, it is advised to have a storage tank for permanent supply of water.

d. Protection

It is important to create fencing around the nursery to protect the plants from cattle. It is important to note, bamboo is a good feed and fodder and the plants will be susceptible for grazing and damage from cattle.

e. Soil

The soil at the nursery site and/or potting soil must be porous, well drained with a pH value ranging between 5 and 6.5. Alkaline soils are not appropriate.

2. Types of Bamboo Nursery

A nursery is a managed site, designed to produce seedlings grown under favourable conditions until they are ready for planting. Bamboo nursery type depends on the objective of the nursery and the infrastructure and equipment required, that can be classified broadly into two

27. Samir Jamatia, 2012. *Livelihood of the Bamboo base: Challenges and Opportunities*.
28. INBAR (2015b). *International Network for Bamboo and Rattan. International Trade of Bamboo and Rattan 2012*.
29. Samir Jamatia, 2012. *Livelihood of the Bamboo base: Challenges and Opportunities*.
30. Samir Jamatia, 2012. *International Trade of Bamboo and Rattan*.
31. *Customs General Administration of China, 2004*
32. Samir Jamatia, 2012. *International Trade of Bamboo and Rattan*.

categories; temporary and permanent bamboo nurseries.

a. Temporary Bamboo Nursery

This type of bamboo nursery is usually established near the planting site, using low-cost and/or local materials. Temporary bamboo nursery is suitable for the creation of a bamboo plantation or to provide planting material to bamboo smallholder farmers for a period ranging from one to five years.

b. Permanent Bamboo Nursery

This can be large or small bamboo nursery depending on the production objective, usually constructed using contemporary nursery materials, and are well designed. A permanent nursery is needed for mass propagation of bamboo seedlings for a period ranging from five to ten years.

c. Bamboo Nursery Size

Bamboo nursery size depends on the production capacity targeted and the age of bamboo seedlings (usually between 6 to 12 Months) need to grow. In general, at least 200m² should be allocated for the production of at least 10,000 plants each year. In case the seedlings remain in the nursery more than a year, then nursery expansion is requiring or an adequate space is needed to maintain a stock of growing plants. Small nurseries could contain less than 10,000 seedlings each year while large nurseries contain more.

3. Nursery Infrastructure and Equipment

Nursery construction can be undertaken according to following steps. The nursery site layout



Photo 1: Ekali Community Nursery i



Photo 2 : Pépinière de l'ANAFOR à Mbalmayo

is the first step, it consists of cleaning the site land surface, levelling ground if the nursery site is on a slope more than 5° to ensure water runoff, clear the areas surrounding the nursery site like excavating gutters and layout foundation by preparing pathways. The second step is the construction of the nursery structure: shade structure, storage shed and nursery bed. General tools used daily in a nursery for manual operations are pruning scissors/ secateurs, rake, digging shovel, pruning saw, wheelbarrow, hoe and hand trowel.

33. IMF (2008). International Monetary Fund. Lao People's Democratic Republic: Second Poverty Reduction Strategy Paper (EPub); UNDP (2015b). United Nations Development Programme. Lao PDR: Bamboo preservation enriches lives and the environment.

34. FAO (2014). Food and Agriculture Organization of the United Nations. Enhancing the socioeconomic benefits from forests. State of the World's Forests 2014. Rome Italy.

35. IFAD (2013b). Programme of work in 2013.; INBAR (2015a). How small bamboo and rattan businesses can help drive new economies <http://www.inbar.int/2015/04/smalland-medium-sized-bamboo-enterprises>; INBAR (2015b). International Network for Bamboo and Rattan. International Trade of Bamboo and Rattan 2012.

4. Preparation of Polyethylene Bags and Soil Medium

a. Soil Mixture

The amount of soil mixture needed in the nursery will depend on planting material production target. The soil mixture is usually prepared on site, using the right proportion of materials to create a good balance of nutrients and porosity (drainage, root formation and respiration). A good soil mixture or potting medium can be in proposition of 1: 1: 1 (Soil: Sand: Manure). If the soil is porous, the proposition can be 2:1:1 (Soil: Sand: Manure). The organic manures could be cattle and chicken manure, fish residues, groundnut shells, etc. Soil should be sieved to remove large lumps and stones.

Sand has a number of advantages as bamboo propagation medium, including the fact that sand is relatively available and affordable, it provides good drainage, enables rooted plant parts to be dug up easily and maintains a uniform temperature in the bed.

b. Potting containers/ Polyethylene Bags

Polybags are generally used in bamboo nursery for bamboo propagation, various sizes of polybags should be available at the nursery to fulfil potting requirements. On the market we have various sizes of polybags; 25 cm × 15 cm, 30 cm × 20 cm, 40 cm × 25 cm and 45 cm × 30 cm.



*Photo 3 : Polyethylene Bags with mix soil
(photo source: INBAR, 2019)*

It is advisable to use a potting container large enough to allow root development of plants. Polybags of 30 cm height × 20 cm diameter are good for seedlings, larger polybags of 30 cm height × 25 or 30 cm diameter will be needed to transplant the propagules produced from cuttings or off-sets.

CHAPITRE III: PRODUCTION DE PLANTS DE BAMBOU

Bamboo can be propagated using two methods, through seeds and by vegetative propagation. Seed propagation methods are rarely used because of the irregular/ cyclical flowering nature of bamboo species: which flowers once in an interval of 40 to 100 years.

There are two types of bamboo flowering, which include gregarious flowering and sporadic flowering. When gregarious flowering occurs, the clumps of an entire species flower, produce seed, and then die, although large quantities of seed are produced during gregarious flowering, they are viable only for a short period, sometimes only for a few days or months. Meanwhile, sporadic flowering occurs in

few clumps of a bamboo forest, where they produce seed but not always followed by the death of the entire clump or forest. Bamboo flowering is not well studied or understood.

Furthermore, due to the non-availability of these seeds during the year and their poor viability (viability ranging from weeks to six months), it is advisable to collect and sow the seeds without delay. Because of lack of regular availability of seeds, bamboo vegetative propagation methods are important for bamboo propagation. Different bamboo vegetative propagation method uses different vegetative parts of bamboo plants such as rhizomes, culms and branches to produce bamboo plants.



Photo 4 : Bamboo seeds



Photo 5 : Bamboo clump

If bamboo seeds are available, it is important to buy them from sellers who are able to guarantee the seed's origin and viability. Bamboo seeds are collected using a net, made from cloth or plastic material large enough to cover the clump surface for the seeds to fall on the material to be used. Bamboo seeds are stored

in a dry environment and in cold storages for prolong the viability. Bamboo seeds are short-lived and it is important to test the viability before purchase and /or sowing. The main advantage with this method is massive propagation of bamboo. The following steps are needed for bamboo propagation by seeds

36. 27 Bernard N. Kigomo (2007). *Guidelines for Growing Bamboo*. KEFRI Guideline Series: No. 4. Kenya Forestry Research Institute; Nairobi, Kenya

1. Bamboo propagation by seeds

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Photo 6 : Different germination bed

a. Germination bed preparation

- Establish a raised germination bed (1.2 M width X 2/5/10 M length depending on requirement).
- Raise beds of 15 to 20 centimetres above the ground,
- Establish boundaries between the raised beds by using local material like bamboo and/or wood and /or a permanent structure as illustrated on photo 6.
- Level and smoothen the surface of the raised beds.

Sand can also be used as propagation medium for bamboo seeds on a nursery/ germination bed and mist propagator. The definition of Mist Propagation is the mechanical spraying of water to maintain a film of water on the leaves and stems of cutting²⁸

A mist propagator construction: Mist propagation set up can be established for both seed propagation and vegetative propagation methods.

- Start by building the mist propagator structure using wood or bamboo using the dimension mention on figure 1,

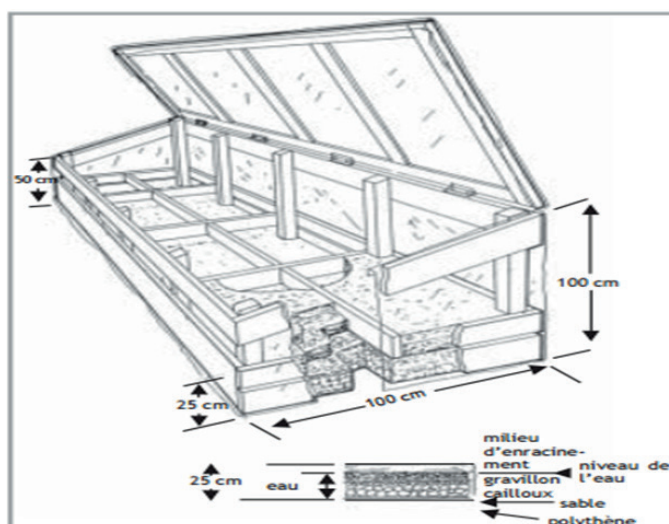


Figure 1: Mist propagator schematic illustration (Source: Longman, 1993)

37. <http://www.allotment-garden.org/store/equipment/propagation/mist-and-hydroponic-propagation>

- Cover the inner part of the structure using a polythene sheet,
- The mist propagator substrate is composed of 3 layers - 25 cm (Bottom layer: sterilized small stones, Middle layer: pea sized gravel and top layer: sand,

Mist propagator could be used for bamboo propagation due to the main advantages its offer to the plant; it maintains high humidity thereby reducing loss of water by evaporation and transpiration, and maintains a cooling effect which reduces respiration rate.



Photo 7: Bamboo mist propagator or on germination bed

After collecting bamboo seeds, soak them in to clear water for at least 6 hours



Photo 8: bamboo seeds soak in water

- Sow seeds on the nursery bed or directly in polyethylene bag filled with soil mixture. Please note, if the seeds are directly sown in polybags, it is necessary to test the viability before sowing.
- Sowing on germination beds / polybags can done by using either a stick or finger to slightly open the soil and placing the seeds at depth equal to its shortest dimension. The soil is then covered with a thin layer of soil.

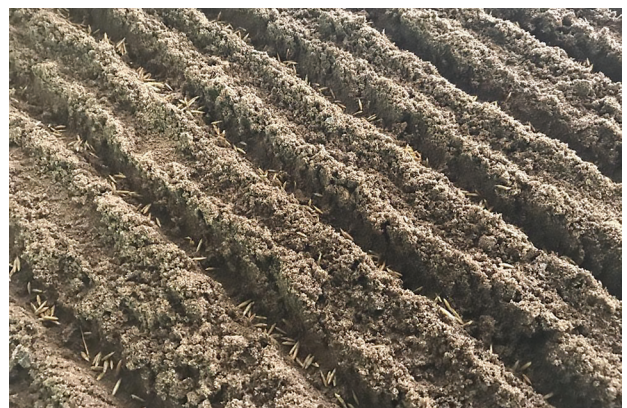


Photo 9: Sow bamboo seeds on the nursery bed or in polyethylene bag



Photo 9: Sow bamboo seeds on the nursery bed or in polyethylene bag

Water them regularly: twice per day using fine rose capped can.



Photo 10: fine rose can

- Seedlings can be separated and transplanted into polybags when they reach three leaf stage
- The transplanted seedlings should be kept in partial shade for 1-2 months and watered at least 2 times per day. After 1-2 months the seedlings can be exposed to direct sunlight

After 6 - 9 months' bamboo seedlings can be used for plantation purpose.



Photo 11: bamboo seedling

2. Bamboo propagation by wildings

Bamboo propagation by wilding is a natural regeneration method. Bamboo wildlings usually grow on the ground surface after bamboo flowering. The wildlings should be carefully collected by scooping the soil on which it stands and quickly taken to the nursery and transplanted in polyethylene bags or nursery bed partial shaded and watered regularly. This method can raise many seedlings in case bamboo flowering and bamboo seeds are not for sowing.

3. Bamboo vegetative propagation

Due to the lack of regular availability of seeds, bamboo plants are commonly produced through vegetative propagation methods. Various methods of vegetative propagation are available namely: off-set /rhizome, branch and culm cuttings, layering, macro-proliferation and tissue culture. In this handbook propagation through tissue culture will not be described.

a. Propagation through Off-set / Rhizome:

The rhizome is the underground part of a bamboo culm; the following steps are needed for bamboo propagation using rhizome / off-sets

- Selection of bamboo culm which is 1 year-old
- Cut down identified bamboo poles at three to five nodes above the ground. Check for prominent culm buds at the nodes. If buds are not available, cut after the node locations with buds and/or branches.
- Excavate the ground (surrounding covering soil) without damaging the rhizome and buds and identify the rhizome neck.
- Cut the neck portion with a saw or sharp knife without harming the rhizome buds or emerging shoots
- Detach the rhizome with roots and culm from the clump.
- Immediately cover the rhizome portion with wet rice sacks or any locally available material and store the offset in the shade and transfer the offsets to the plantation field or nursery.
- Off-sets should be transplanted immediately after the extraction from mother clump and kept in moist bag during transport,
- Rhizome off-set transplanting is best taken and planted during the rainy season, so that they are able of establishing roots easily and growth,
- In the planting area, it is advised to put in a cow-dung cap on the cut end.

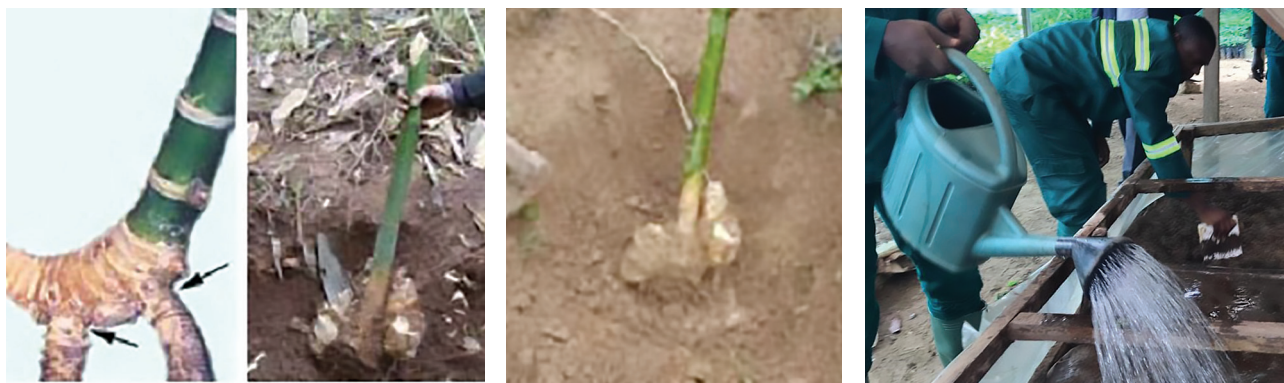


Photo 12: Bamboo Rhizome off-sets vegetative propagation (photo source: INBAR, 2019. <https://www.inbar.int/>)

The main advantage of rhizome offsets is that, the new culms emerging from the offset will almost be of the same size. Rhizome off-set extraction and transportation has special challenges. This vegetative method is an extremely laborious and tedious process; not more than 2 to 3 rhizomes can be extracted per day. There-

fore, this method cannot be used for large scale bamboo plantation establishment. Bamboo off-sets extracted during the dry season should be transplanted in a mist bay (a bay containing soil or sand and well drained) in a nursery, to be later transplanted during the rainy season.

b. Propagation through branch and culm cuttings

Culms with well-developed branches (branches with strong branch base or ball like structure along with aerial roots) can be used for vegetative propagation. This method is effective for various bamboo species, including *Bambusa vulgaris*. The following steps are needed for bamboo propagation through culm cuttings: :

Culm Cuttings

- Culm to be selected for cutting should be 1 to 2 years old,
- Cut the selected culm near the base,
- Trim of the branches after 3-5 branch nodes,
- Cut of the culm (with a saw or sharp knife) into segments having 1, 2 or 3 internodes with the cut positioned 5 to 10 cm below the basal node,
- Fill the internodal portions on cut ends with soil to reduce water loss.
- (a) Planting of the cuttings in black polyethylene bags (planted vertically) with culm nodes below the soil, as illustrated on photo 13.



Photo 13: Propagating bamboo through Culm Cuttings

OR

- (b) Ensure that the culm cuttings are placed flat on the sand bed at a distance of 10 cm to avoid overcrowding and root overlap. Cover the cuttings with sand/soil.
- Watering of the cuttings daily at least 2 times per day,
- Depending on species and season, root development will occur in 1 to 3 months,
- Separate the plants (along with roots, stems and foliage) in polybags.
- Harden then under shade for 30 – 45 days before exposing it to direct sunlight.
- Once the plants are established, plant them in plantation during early rainy season.

Branch Cuttings

- Cut the selected branches from a culm that is 1 to 2 years old,
- Use saw to extract the cuttings. Take care not to damage or break the rhizome base
- Trim of the branches to 3 or 5 internode lengths from the branch base

- Before planting, dip the cut ends of the branch cuttings in water or in fungicide solution if possible,
- Use cow dung or clay soil to cap the cut end of the branch cuttings to reduce water loss.
- Planting of the cuttings in black polyethylene bags or on propagation plots (planted vertically) at a depth of 2-3 cm with at least one node below the soil,
- Shower or watering of the cuttings daily at least 3-5 times per day,
- Depending on species and season, root development will take about 1 to 3 months,
- Transplant the plant into polybags, harden

them under shade for 30 – 45 days before exposing to direct sunlight.

- Once the plants are established, plant them in plantation during early rainy season.

Culm and branch cuttings have the same advantages. These methods are effective in bamboo with strong culm and branch buds. These are relatively non-destructive, reduces the cost of manpower and transport. Even though these methods are advantageous, they are not suitable for bamboo species, which are thin walled, and without prominent branch base (ball like structure) and without prominent culm and branch buds.



Photo 14: Bamboo branch Cuttings vegetative propagation

c. Propagation through Marcotting or air-layering on the culm

This is bamboo propagation where branch base (ball like structure) are covered with a propagating medium (Soil, sand and manure composition; or coconut coir). This method has advantages as derives water and nutrients for its growth into an independent plant from mother culm. Unfortunately, this method is not appropriate for bamboo species with less prominent bamboo branch base. It can be used to produce

large quantities of young bamboo plants. The following steps are used in Marcotting:

- Select of the culm's branch (from 1-2-year-old culms),
- Trim the branches and leaves after 3-5 branch nodes.
- Cut one-third portions on both sides of branch base (joining location of culm)

- Apply the propagating medium on the branch base without plastic or rope being tied to the culm,
- In case using plastic and rope to tied propagating medium to the branch make sure to create holes in the plastic for rainfall water accumulation to increase rooting success rate,
- Depending on the species and season, complete roots development is achieved between 1 to 3 month,
- Separate the rooting branch from the culm,
- Transfer the rooted cuttings into polybags

d. Propagation through Culm soil layering

This method involves introducing a bamboo

culm into the soil. This method has advantages as derives water and nutrients for from mother culm. The following steps are used in bamboo culm layering:

- Identify bamboo culms of one to two years of age.
- Make a partial cut at the bottom portion of the culm (two to three nodes above the ground) to enable bending.
- Bend the culm to the ground; chop the top portion of 2–3 m of the culm to induce lateral branches.
- Keep branches (two or three inter-nodes) close to the culm.
- Trim the leaves and branches to avoid water transpiration.
- Place the culm on the shallow trench and



Photo 15: Bamboo marcotting or air-layering on the culm vegetative propagation (photo source: INBAR, 2019. <https://www.inbar.int/>)

peg with stone or any other local material.

- Cover with soil or any other rooting medium (5 cm deep in sand, soil, dense leaf litter, etc.). Rooting medium should be kept moist
- When watering (if no rain), there should not be waterlogged.
- Once the new plant is established (roots, rhizome, stem and leaves), the plants can be separated and transplanted to polybags.

e. Propagation through Macro-proliferation

This propagation technique is practiced to multiply the bamboo seedlings (both from seedlings and vegetative propagation methods) the following steps are needed for bamboo propagation using Macro-proliferation:

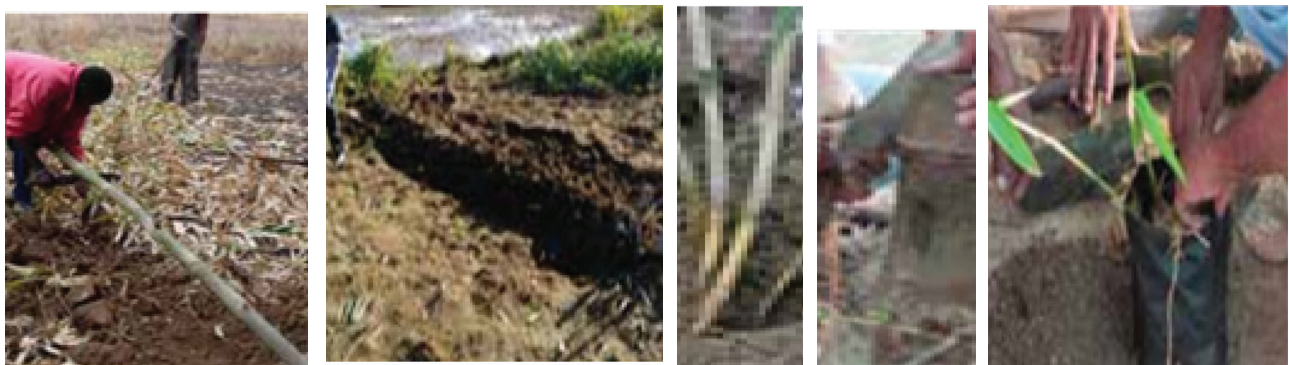
- Select bamboo seedlings of about 6 months

old with multiple culms.

- Seedlings with 4-5 culms are taken out from the nursery bed or from the polyethylene bag,
- Trim nearly 75% of leaves and branches to minimise water loss.
- The soil medium is removed by pressing, shaking and then washed to clear view the rhizomes and roots.
- Each plant with a piece of rhizome and roots are carefully separated using sharp knife or secateurs, avoid damaging the rhizome. The separation is done carefully at rhizome neck or joint.
- Each young plants (with roots, rhizomes and stem) should be immediately replanted in polyethylene bags and watered.



Photo 16: Bamboo culm soil layering vegetative propagation (photo source: INBAR,2020. <https://www.inbar.int/>)



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- Each young plants (with roots, rhizomes and stem) should be immediately replanted in polyethylene bags and watered.



Photo 17: Bamboo Macro-proliferation (photo source: INBAR, 2020.<https://www.inbar.int/>)



4. General nursery management practices

a. Watering

It is advisable to supply water needed by seedlings and cuttings in beds and/or polythene bays at least 3 times. For temporal nursery, manual watering is possible, but for permanent nurse-

ry with a production capacity of thousands of plants, there is a need to invest in to irrigation equipment like pump and sprinkler irrigation system.

b. Weeding

Weeding in the nursery is very important because weeds compete with bamboo young plants for nutrients, water, and sunlight, therefore competition from weeds should be minimized. Weeding should be done regularly when the soil is moist.

c. Shading

The nursery should be shaded to keep moisture and protect seedlings and/or cuttings from direct sunlight.

d. Primary and secondary hardening

Hardening is a critical factor before planting, primary hardening is practice immediately after the seedlings and cuttings are transplanted polythene bays, where these young plants are kept under 60% shade for about one month. Shade and watering rates gradually decrease in the **secondary hardening** process the seedlings and cuttings should be exposed to more sunlight as long as the seedlings and cuttings is at the nursery. Hardening enables the plants withstand weather conditions similar to those in the planting field.

CHAPTER IV: BAMBOO PLANTATION ESTABLISHMENT AND MANAGEMENT

Bamboo plantations positively impact the environment. Bamboo is a substitute to wood, it can reduce pressure on natural forests. Moreover, bamboo contributes in soil protection with their root and rhizome system with extensive canopy.

1. Types of Bamboo Plantations

We can distinguish two main types of bamboo plantations, which are bamboo commercial plantation and bamboo agroforestry plantation

a. Bamboo commercial plantation

Bamboo plantations of any scale (from 1 ha to thousands of hectares) can be aimed at commercial production of bamboo poles for generation of timber, shoots, pulp, bio-energy and so on, as well as ecological restoration (degraded lands, mined sites, ravines, riverbanks, etc.) . Bamboo commercial plantations are well structured and the bamboo species planted in such plantation are selected to generate economic income. These plantation type are usually monoculture plantation.

38. Jayaraman Durai and Trinh Thang Long, (2019). *Manual for Sustainable Management of Clumping Bamboo Forest*, International Bamboo and Rattan Organisation (INBAR)

39. *FAO.2005. Domestic Support, trade related issues and the empirical evidence. FAO Trade Policy Technical Notes on issues related to WTO negotiations on Agriculture No.5 Rome* (available at <http://FTR.FAO.ORG/DOCREP/FAO/JS012E/JS01200.PDF>).

b. Bamboo agroforestry plantation

Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units along with agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence³⁰. Therefore, agroforestry is an agro-ecological intensive farming system approach which integrates woody species on agricultural production farms (crops and/ or livestock) for economic, ecologic and social benefits.

For bamboo agroforestry plantation establishment, bamboo species should be selected according to the plantation area, soil type, climatic condition and ecological zone. Intercropping with bamboos, however, can be done for a maximum of four years after bamboo planting, after which there is huge competition for the resources³¹. We can distinguish 2 main bamboo agroforestry plantations and their sub-systems as follows;

Bamboo Agrisilviculture

Agrisilvicultural systems are a combination of crops and trees. In bamboo agrisilvicultural we replace trees by bamboo, this system will consist to associate bamboo with agricultural food crops like soy, peppers, watermelon, vegetables, sweet potato, etc. during the first and second year of the plantation establishment. During the third and fourth year, food crops that tolerate shade like coco-yams are suitable. Food crops cultivation with bamboo also depends on the sub-system to be used. We can have sub-systems as Bamboo windbreak farming system, Bamboo Alley cropping farming system Bamboo improved fallow farming system and Bamboo canopy cover farming.

- **Bamboo windbreak farming system:** This is

a farming system which involves the association of Bamboo and crops on a given land unit, where bamboos are planted in a linear direction. Bamboos provide crops with shelter, protects them from heavy winds and wild animals. Bamboo also improve the soil physical, biological and chemical properties through their roots and leaves, thereby increasing soil fertility.

- For example, in Cooch Behar, Dinajpur, Hal-dibari, Mayanaguri and Jalpaiguri areas in India, the clumps of *B. balcooa*, *B. bambos* and *B. nutans* have been cultivated in close spacing in one to two rows along the north western sides of rice fields as windbreaks against the dry and cold wind blowing from Nepal and Bihar³²
- **Bamboo Alley cropping farming system:** This is a farming system which involves-Planting crops between managed bamboo rows. These trees provide crops with input (bio-fertilizer). Bamboo will improve the soil physical, biological and chemical properties through their roots and leaves, thereby increasing soil fertility. This system can be designed to produce fruit, vegetable, and grain crops.
- **Bamboo improved fallow farming system:** In this farming system, bamboo species are planted and left to grow during fallow. Bamboo planted in this system improve farming land given that bamboo is a fast growing species with high biomass production and abundant litter fall and accumulation. This helps in maintaining and improving physical and bio-chemical soil properties. Nutrient availability in bamboo litter are N, Ca, K, Mg and phosphorus (P13)³³, therefore bamboo litter greatly influence soil fertility and could be used as a bio fertilizer in this farming system. Bamboo in this system will also reduce soil erosion especially the one caused by

40. INBAR. 2000. *The Tropical tree crops and their uses*. International Network Research.

41. Tewari, S. et al. 1993. "Bamboo Based Agroforestry Systems." 24. Retrieved (<http://www.frienvivis.nic.in/WriteReadData/UserFiles/file/Content-Page/Books/Bamboo/Bamboo-Based-Agroforestry.pdf>).

run-off thereby favouring water infiltration and retaining soil minerals.

- **Bamboo canopy cover farming:** This is a system which consists in associating bamboo with agricultural cash and food crops, like in home garden farming system with bamboo associated and cash crop (coffee, tea and cocoa) farming with bamboo associated.

Bamboo Silvopastoral system

Bamboo Silvopastoral system which consists

in associating bamboo with animals that feed on bamboo leaves (bamboo as forage), having sub-systems as Bamboo pasture plantations farming system and Bamboo Sylvo- Fishing farming system.

- **Bamboo pasture plantations farming system:** It is the combination of bamboo and livestock on a piece of land. These bamboos will provide shelter, shade, and fodder for livestock such as cattle and goat which feed on bamboo leaves.

- **Bamboo Sylvo - Fishing farming system:**



Photo 18: Bamboo Alley cropping farming system and Bamboo windbreak farming system (photo source: INBAR, 2020. <https://www.inbar.int/>)

It is the association of bamboo with fish ponds on a unit area. Bamboos are found or planted around the fish ponds to serve as forage for herbivorous fish. Bamboo also creates, improves and maintains a micro-climate condition around fish ponds favourable for fish development.

2. Bamboo plantation establishment

a. Site Preparation

Bamboo plantation site preparation according to the Technical Manual on Sympodial Bam-

boos Cultivation³⁴ says there are different ways of soil preparation depending on types of planting land, conditions of terrain, topography and ecological environment. According to the Technical Manual³⁵ on sympodial Bamboos cultivation there are three methods as follows;

Ploughing: A plough or plow is a farm tool for loosening or turning the soil before sowing seed or planting³⁶. First, clear away shrubs and weeds in the land. Then plough soil (30 cm deep) across the planting site. This method is favourable to interplant inside stands the very year and the following year after planting, but

it is labour and time consuming, with the disadvantage of large investment, high cost and restriction from terrain and economic condition. The high frequency of ploughing had a considerable impact on the fertility of the land and on yields in general³⁷;

Strip Preparation or farming: is a method of farming which involves cultivating a field partitioned into long, narrow strips which are alternated in a crop rotation system. It is used when a slope is too steep or when there is no alternative method of preventing soil erosion. In order words it is repairing soil in strip parallel with contours, usually having width of 2 - 3m, decided by the standard of slope condition and whether growth of damaged vegetation in one or two years will influence the development of planted bamboos. However, all strips are alternated on an annual basis .³⁹;

Spot Preparation: This method is a way to save labour and greatly flexible. Though with slight improvement of site condition, it can help to select areas with better soil condition to achieve higher productivity for planted bamboos.

b. Plantation Layout

It is important to plan the field layout to easy bamboo culms harvesting and hauling when they are matured. A well planned field layout is essential to facilitate the management of a bamboo plantation. Bamboo planting in lines and rows is advisable, according to the plantation site characteristics (gentle or steep slopes).

c. Spacing

According to Durai and Long⁴⁰ , spacing is important to reduce above-ground competition

for light and below-ground competition for water and nutrients. If spacing is too narrow, bamboo will mostly grow tall, but it will not produce large-diameter stems/culms and if the spacing is too large, sunlight will penetrate the canopy, allowing grass to colonise the site and increasing the risk of fire in the dry season. Again, to spacing of plants depends on the species and purpose as follow;

- 4 × 4 m for small-diameter bamboo species (4 to 8 cm diameter) (e.g. *Oxytenanthera abyssinica*, *Dendrocalamus strictus*, *Bambusa multiplex* and *Thyrsostachys oliveri*).
- 5 × 5 to 7 × 7 m for medium-diameter bamboo (8 to 15 cm diameter) (e.g *Yushania alpina*, *Bambusa vulgaris*, *Dendrocalamus asper*, *Dendrocalamus hamiltonii*, *Dendrocalamus membranaceus*, *Bambusa tulda*, *Bambusa polymorpha*, *Cephalostachyum pergracile*, *Dendrocalamus brandisii*, *Bambusa balcooa*, *Bambusa bambos*, etc.).
- 7 × 7 to 10 × 10 m for large-diameter bamboo species (diameter >15 cm) (e.g *Dendrocalamus giganteus*).

d. Planting material selection and transportation

Select healthy seedlings and/or rhizomes (bamboo seedlings: six to nine months old; 50–80 cm in height; with multiple stems) with well-developed rhizome and root systems and harden the selected plants in direct sunlight (similar to the plantation site) for about two to four weeks to acclimatize the plants to field conditions. Again, according to Durai and Long (2019), bamboo planting material should be trimmed about 50% of the foliage to minimize water transpiration

42. Fu Maoyi, Xie Jinzhong, Zhou Benzhi, Li Zhengcai ,Xiao Xiantan 2007. *Technical Manual on Sympodial Bamboos Cultivation*. First Published in the P. R. China in 2007 by China Forestry Publishing House.

43. *Technical Manual on Sympodial Bamboos Cultivation: Fu Maoyi, Xie Jinzhong, Zhou Benzhi, Li Zhengcai ,Xiao Xiantan, China Forestry Publishing House 2007*

44. *Cambridge English Dictionary*. Retrieved 16 September 2018.

45. *Cambridge English Corpus Extract*

46. *Minnesota Department of Agriculture*. Retrieved 8 December 2015.

47. Frederick R. Troeh, J. Arthur Hobbs & Roy L. Donahue (2003). *Soil and Water Conservation for Productivity and Environmental Protection* (4th ed.). Prentice Hall. p. 226. ISBN 978-0130968074.

loss, then always carry the plants by holding the polybags/pots to minimize disturbance to the rhizome and roots and avoid breakage of stems.

e. Bamboo planting

According to Durai and Long, (2019) the size of the planting pits/hole (length, width and depth) is crucial as it facilitates initial growth of the plant rhizomes and roots. The size of planting pits depends on the type of bamboo planting material; seedlings in polybags need a pit of 30 × 30cm and rhizomes/ offset need a pit of 60 × 60cm.

The pits should be prepared at least 15 days before planting to facilitate weathering of soil. According to them, during the hole preparation, a ropes or measuring tape is use to accurately position the planting holes in the required spacing using bamboo splits or sticks to post or mark the location of pit digging. It is important to keep the top and bottom soil separate. During planting, organic manure can (if available) be applied by mixed with topsoil before the plants is planted vertically in an erect position. Top soil along with manure mixture can be placed in bottom portions of pit and around the soil medium of plant base and bottom soil can be placed above it. The pits should be completely covered and mulched. Planting period should coincide with the start of the rainy season to ensure a high survival rate.

3. Bamboo plantation management

a. Replanting

Given that not all planted seedlings will survive the new environment (planting site), the plantation should therefore be visited regularly to check on the survival of plants. Dead seedlings should be replaced as early as possible.

b. Intercropping

Cash and food crops could be intercropped during the first two years from the time of planting the bamboo. These crops could be planted between the rows of bamboo. Intercropping is encouraging because it provides a source of income to farmers. Again when cultivated between rows of newly planted bamboo, crops provide greater stability to the soil and help control erosion. When the plantation bamboo canopy has developed, sunlight will be mostly absorbed by bamboo plants and crops cultivation will no longer be viable. During Year 3 onwards, shade loving crops (crops that grow without full sunlight) can be planted.

c. Soil Maintenance and weeding

During the first year, it is advisable to loosen the soil (about twice a year) around the plant to improve soil aeration and enhance its growth. During this practice care should be taken not to disturb the rhizome system of the plant. It is also important to control the growth of weeds around each bamboo by weeding in order to reduce competition for light and nutrient.

d. Fertilizer application and Irrigation

If available, it is also important to apply manure and/or fertilizer during the first two years from the time of planting the bamboo to stimulate the rapid growth of plants. It should coincide with peak rainy or wet season. Watering drastically improves the survival of plants, as well as productivity. It is therefore advised to at least water during Year 1 and 2 of planting.

e. Mulching

Mulching is the act of spreading a layer of litter (dry or fresh) on the surface of the soil around

48. Jayaraman Durai and Trinh Thang Long, (2019). *Manual for Sustainable Management of Clumping Bamboo Forest*, International Bamboo and Rattan Organisation (INBAR)

the bamboo plant. Mulching help in preventing weed growth, conserve soil moisture and contributes with organic nutrients to the plant when the litter decompose.

f. Plant protection

It is also important to carry out protection measures to ensure protection from grazing animals by partial or total build of a fence around the plantation using local materials. Moreover, create a fire break around the bamboo plantation.



1. *Bamboo culm selection for harvesting*

- Selective harvesting of bamboo is very important both for bamboo sustainable management and the production of good quality bamboo products. Bamboo can grow to full length in less than 3-4 months of shoot emergence, the reason why it is considered as the fastest-growing plant on earth and records growth rates of up to one meter per day for some species. Attaining its full length does not mean it can be harvested and used because at this stage, the inside of the bamboo fibres has not fully developed. The main criteria for selecting mature bamboo for harvesting are: culm colour or appearance, and position in a clump. Young bamboo (Year 1) is shiny, smooth and has a bright colour without blemishes. At this stage, it is not ready to be used. Due to weathering (fungal and mould growth starts increasing over age). It is advisable to harvest 3+ year old bamboo culms for value addition, and to ensure sustainability of clump.
- New culms are commonly produced on the periphery of the clump (young culms/ rhizomes are the ones that produce new shoots (one to two years old). The tendency of bamboo collectors and harvesters is to harvest the bamboo poles on the outside periphery of the bamboo clump, which is young and immature, affecting the sustainability of the clump and durability of the bamboo products/poles used.
- Mature bamboo poles in sympodial bamboo clumps are commonly found at the inner core of the bamboo clump.
- In the case of sympodial bamboo with a long rhizome neck, such as *Yushania alpina*, penetrating inside the clump and harvesting mature bamboo poles is relatively easy due to the sparse nature of the plant's growth.
- In the case of unmanaged sympodial bamboo with a short-neck rhizome (genera like *Bambusa*, *Oxytenanthera*, *Dendrocalamus*, *Cephalostachyum* and others), the bamboo clump is congested, prohibiting the entry into the clump.
- Two techniques for managing congested or clustered bamboo are as follows: (a) the tunnel technique and (b) the horseshoe technique.

Tunnel technique

Make a 60-cm-wide path from one end of the clump to the other. Make sure the tunnel created passes through the central part of the clump. As most of the mature bamboo poles are placed in the centre of the clump, the tunnel is created so that one can enter, harvest and drag the bamboo poles.

Horseshoe technique

Make a 60–100-cm-wide path from the periphery or outside of the bamboo to the centre of the clump. Select the location or side of the clump where there is the smallest number of young bamboo poles, to avoid cutting of young poles.

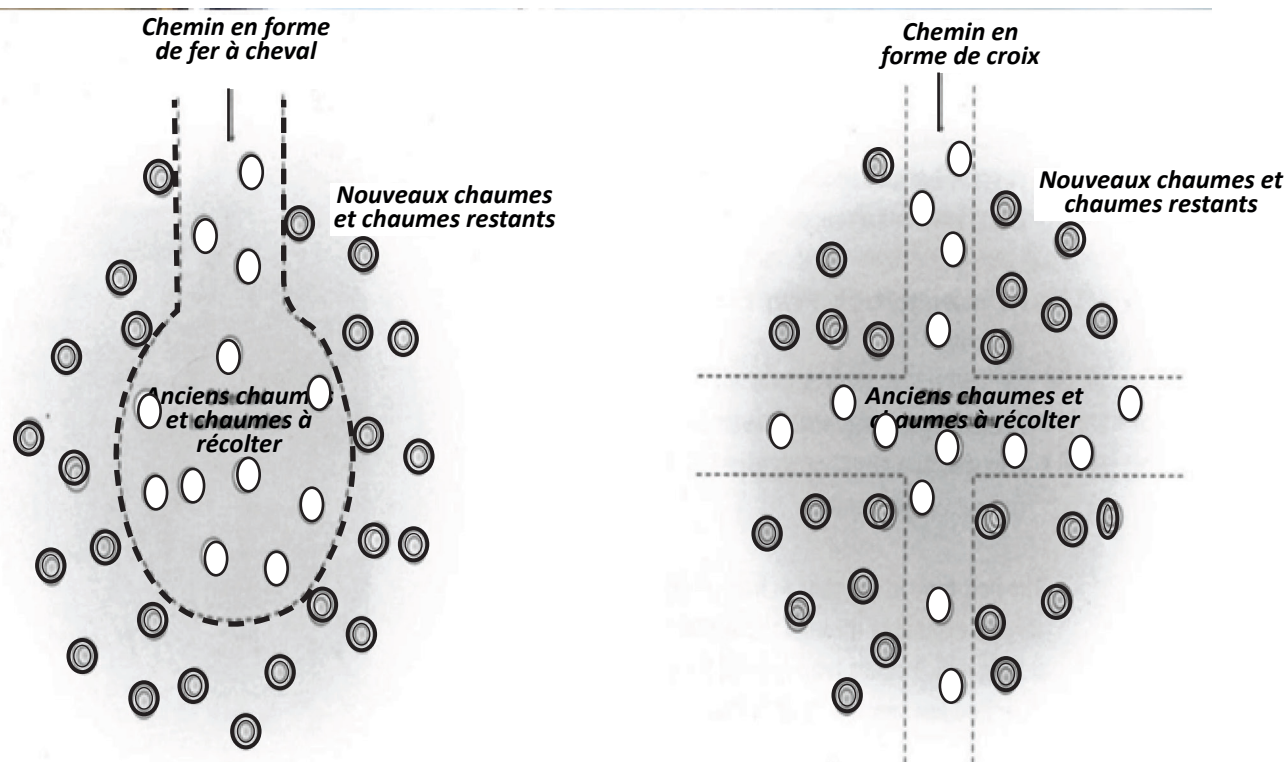


Figure 1: Two ways for sustainable bamboo harvesting: the horseshoe clump (left) and cross tunnel (right) harvesting method ⁴¹

2. Bamboo culm harvesting

Harvesting should not be done during the rainy season because during this period bamboo shoot grow (harvesting will break or disturb the new emerging shoots). Moreover, the culms at this period have high moisture and starch content which makes them susceptible to fungal and insect attacks. Therefore, the early dry season is the best period to harvest bamboo poles.

Also, when harvesting bamboo, we need to take into consideration that new culms are produced towards the periphery of the clump as observed in the case of clumping species. Therefore, harvesting of mature bamboo culms should be done from the centre to the periphery of the clump.

Mature bamboos of 3 - 4 years old, should be selected for harvesting because at this age range,



Photo 19: Bamboo harvesting

they shrink less when drying; and its starch/ sugar contents are lower, so there is less chance for insect infestation. Culms should be cut as low as possible (height), between the first or second node above the ground using a saw or cutlass, leaving only one internode above the ground.

49. NMBA. (2004). *Cultivating Bamboo Training Manual*. New Delhi, India: National Mission on Bamboo Applications -Technology Information Forecasting and Assessment Council (TIFAC) Department of Science and Technology Government of India.

CHAPTER VI : BAMBOO POST-HARVEST TREATMENT

Freshly harvested bamboo when drying contracts and shrinks, this could reduce its diameter and wall thickness. After harvesting all bamboo culms needed, we have to keep the harvested bamboo with all its branches and leaves vertically leaning against another bamboo tree or timber species found on the site with the base part on a stone or other material to avoid direct contact with soil at the harvesting site for at least a week for the first drying process. This enables the bamboo culm to lose its humidity progressively through transpiration via the leaves. This process (Post-harvest bamboo drying via transpiration) reduces the quantities of starch found in bamboo culms thereby reducing the risk of bamboo being infected by fungal or borers.

When coming back to collect the harvested bamboo, the culm branches should be removed cautiously without damaging the culm using a knife or cutlass. Also, the culm could be cut using a saw or cutlass to facilitate its transportation to the working area for treatment, storing and processing

1. *Bamboo treatment techniques*

Bamboo like other plants and trees contains starch/ sugar, which is a source of food for some living organisms like fungi and insects. Therefore, harvested bamboo culms are highly exposed to fungi and insect attacks. To reduce or control insect and fungal infestation, harvested bamboo culms (between 3 – 4 years old) should be treated before processing. This considerably increases the durability of the processed bamboo products. Bamboo need to be treated traditionally (with no chemicals) and/



Photo 20 : bamboo drying via transpiration (Photo source: bellobamboo.com, 2019)

or chemically (with chemicals) to guarantee its durability. Selecting the treatment to apply on bamboo depends on the bamboo culm status (it is split or whole cane, dry or green), its future application, quantity to be treated and the time available..

2. *Non-chemical / traditional bamboo treatment*

These are ancient bamboo treatment methods, widely used for centuries by bamboo small-holder farmers in countries where bamboo grows. There are numerous traditional bam-



Photo 21 : bamboo healthy and infested culm (Photo source: guaduabamboo.com, 2019)

boo treatment methods. However, we will look at commonly used methods such as soaking in water or leaching treatment method, drying by smoking treatment method and drying by baking treatment method.

a. Soaking in water or leaching treatment method

This is a traditional bamboo treatment method commonly used by Asian and Latin American bamboo smallholder farmers. According to the training manual on Preservation of Bamboo Bundle culms/splits are store in running water or tanks. Use sinker loads for complete immersion. In the case of tanks, change the water weekly to prevent growth of bacteria which will cause staining and bad odour.

- This reduces the starch content in bamboo culms, making them less susceptible to insects and fungi attacks and increases its durability. The following steps are applied when using this bamboo treatment method:
- Bamboo culms after the 3 days drying at the



*Photo 22: Soaking bamboo in water or leaching
Photo source: bellobamboo.com, 2019*

harvested site, are transported to the treatment area.

- These culms are cut using a saw according to the processing outcome.
- Fill the tank with clean water (if not, use running water (streams, rivers)).

50. *Training Manual on Preservation of Bamboo, 2006 National Mission on Bamboo Applications*

- Bamboo culm nodes should be punctured (Making a longitudinal hole in the culm) before horizontally immersing them into the water. This is to ease the running of water through the bamboo culm.
- Make sure bamboo culms are immersed completely in the tank or running water by using a load.
- When immersing in a tank with stagnant water, change the water weekly to prevent bacteria propagation and bad odours.
- Bamboo culms should remain soaked in the water for at least 3-4 weeks and pay attention not to exceed 3 months. This could negatively affect the epidermis (skin) of the bamboo having as consequence a decrease in the physical and mechanical properties of the bamboo.
- After about 3-4 weeks, the bamboo culms are pulled from the tank and stacked vertically for bleaching for at least 3 days according to the sunshine intensity.
- These bamboo culms are often rotated twice per day to avoid cracks on culms during periods of intensive sunlight.
- Bamboo culms are ready to be stored for future processing. This method is recommended for bamboo use in craft making and mat processing. However, bamboo leaching does not guarantee long term bamboo culm protection. This method is efficient to remove starch from the culm and enhance permeability for future treatments.

This method is appropriate for treating any quantity of bamboo, it is also recommended for craft and mat applications where pliability is required⁴³.

b. Drying by smoking treatment method

According to the training manual on Preservation of Bamboo, culms are stored over the hearth or fireplace. The moisture content in smoked culms is thus reduced so that biological degradation cannot take place. Built-up deposits from smoke form a protective layer on the culm. Smoke drying also reduces splitting.

This protects the bamboo from fungi and insect attacks. The following steps are applied when using this bamboo treatment method:

- Freshly harvested bamboo is transported to the treatment area.
- For round bamboo, nodes should be punctured if possible before leaching .
- Bamboo culms should be placed on a fire source, frequently turn/rotate to avoid cracks on culms due to heat intensity.
- Bamboo passed on the fire (smoking) is clean with a dry clean tissue.



Photo 24: Drying bamboo by smoking

51. *Training Manual on Preservation of Bamboo, 2006 National Mission on Bamboo Applications*

- Bamboo culms are ready to be stored for future processing.



Photo 25: Drying bamboo by baking (Photo source: guaduabamboo.com; 2019)

c. Drying by baking treatment method

According to the training manual on Preservation of Bamboo, baking on open fire has been used to straighten crooked bamboo culms. Bamboo is rotated on an open flame to prevent localised heating. The high temperatures destroy the starch and other sugars and also produce tar in the structure. It kills existing infestations if any. Stresses produced during heating gives dimensional stability to the culm. A lower equilibrium moisture content regime prevents any subsequent fungal attack if bamboo is used in interior application.

3. Chemical bamboo treatment

Although traditionally treated bamboo reduces insects and fungi attacks compared to the

freshly cut culms, these methods do not, however, provide complete satisfaction in the long term. Chemical bamboo treatments are more efficient preservatives used on bamboo culms to protect bamboo products from degradation for many years. There are a number of methods, however, we will look at commonly used methods such as the soaking treatment method, the pressure tank (“Boucherie”) treatment method and the 6 Hot and Cold Treatment method using chemicals such as boric acid and borax/sodium borate.

a. Dip Diffusion / Soaking method

Boric acid and borax/sodium borate are chemicals that can be used for the treatment of bam-

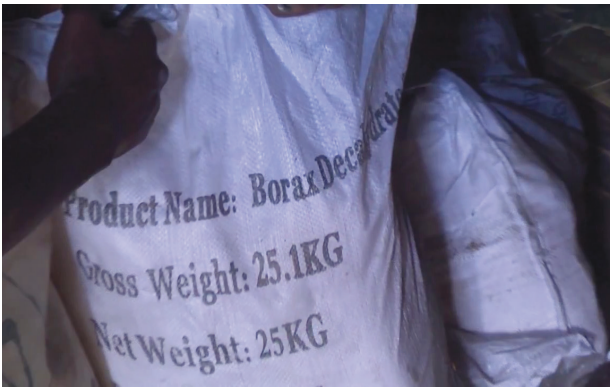


Photo 26: Borax and boric acid, (Photo source: guaduabamboo.com, 2019)

boo. A mixture of boric acid and borax results in the formation of disodium octaborate. Borax or sodium borate is a colourless and powdery mineral, which is easily soluble in water. They are insect repellent and environmentally acceptable preservatives compared to other preservatives such as Copper Chrome Arsenic (CCA) and Copper Chrome Boron (CCB).

The soaking treatment method is the immersing of bamboo culms in a tank (with an outlet for draining) full of water and chemicals to load them with salt. This leaches starch and sugar content in bamboo culms, thereby making them less susceptible to insects and fungi attacks and increases its durability. The following steps are applied when using this bamboo treatment method:

- Bamboo culm after 3 days drying at the harvested site, are transported to the treatment area.
- Fill the tank with clean water and add the chemicals (mix 1 kg of Boric acid and 1 kg Borax in 100 litres of water), then mix up the water to get a solution.
- Bamboo culm nodes should be punctured (Making a diagonally hole in the culm opposite to one another) before horizontally

immersing them into the water solution. This is to ease the flow of water through the bamboo culm.

- Make sure bamboo culms are immerse completely by using a load.
- Bamboo culms should remain soaked in the water solution for at least 48 hours.
- After about one week, the bamboo culms are pulled from the tank and stacked vertically to further encourage salt diffusion (the water evaporates leaving the salts inside the bamboo), aired bamboos in a dry and shade area.
- Bamboo culms are ready to be stored for future processing.

NB: The soaking treatment is similar to the method described in section 5.2.1, except of the fact that chemicals are added to the water tank



53. *Training Manual on Preservation of Bamboo, 2006 National Mission on Bamboo Applications*

b. Pressure tank (“Boucherie”) treatment method

Boucherie bamboo treatment method is the pumping of preservative solution using pressure into bamboo culms. The main aim of the boucherie treatment method is to force the preservative into the bamboo tissue.

- The following steps are applied when using this bamboo treatment method:
- Freshly harvested bamboo culms are used;
- Bamboo culm edge is cut at the node using



Photo 27: Bamboo boucherie treatment
Photo source: INBAR, 2019 <https://www.inbar.int/>.

a saw to ease the connection to the pressure tank and to avoid slipping due to pressure during the treatment;

- Mix up boric acid and borax with water in a container (1.5kg boric acid and 1.5kg borax is sufficient for 30 litres of water), to get a water solution;
- Add the water solution into the pressure tank;
- Connect the pressure tank to bamboo culms, pump the tank to 30 - 35 psi pressure and maintain the given pressure;

- Pump the solution into bamboo culms using the pressure for at least 1 hour;
- A container or barge should be placed under bamboo culms to collect the solution at the end of the treatment;
- Bamboo culms are ready to be stored (20 to 30 days) for future processing. This method is advantageous because it is mostly used to treat large quantities of bamboo, it is portable (can be used directly on the bamboo farm) and takes less amount of chemicals (boric acid and borax) for bamboo treatment.

c. Hot and Cold Treatment method

According to the training manual on Preservation of Bamboo, Hot and Cold Treatment method is based on the principle that on heating, air from the cells will expand and partially escape. During cooling a slight vacuum is created due to contraction of the residual air and causes the entry of preservative into the cell. Large quantities can be treated at one time. The following steps are applied when

using this bamboo treatment method:

- For round bamboo - make two holes on opposite walls of each internode near the node or rupture the nodal diaphragm;
- Air dry the material;
- An open tank fitted with steam coils or other alternate heating arrangement is required,
- Load culms into tank.
- Fill tank with hot oil - creosote oil or mixed with furnace oil (50:50),

- Heat to 900 C and maintain for 2-3 hrs,
- Allow to cool to ambient temperature,
- Drain excess preservative (Creosote for exterior uses (can be heated to 9000°C) and Boric Acid-Borax (should be heated to 5000°C)),

N.B: Treatment with creosote is most suitable for bamboo used as reinforcement in mud/cement. Viscosity of preservatives like creosote decreases on heating easing penetration. Do not use Dichromate containing salts like CCA and CCB as they precipitate on heating.

4. *Bamboo culm storage*

After bamboos have been treated, bamboo culms should be stored for at least 2 weeks (better dry) before processing in a ventilated shelter and not in a closed area. When storing, bamboo is usually stacked either vertically or horizontally. Vertical stacking gives less chance to fungal infection and it is best for storing small quantities of bamboo. Horizontal stacking works better for large quantities of bamboo culms. In this case, we need to stack bamboo on large platforms and place a thick plastic sheet under stacks to prevent fungal infections. The bamboo culms should be stacked based on their size, diameter, and quality.



CHAPTER VII: BAMBOO UTILIZATION

Bamboo is divided into 3 main components, which are bamboo leaves, bamboo culm and bamboo rhizome. All the part of a bamboo culm is useful as illustrated below.

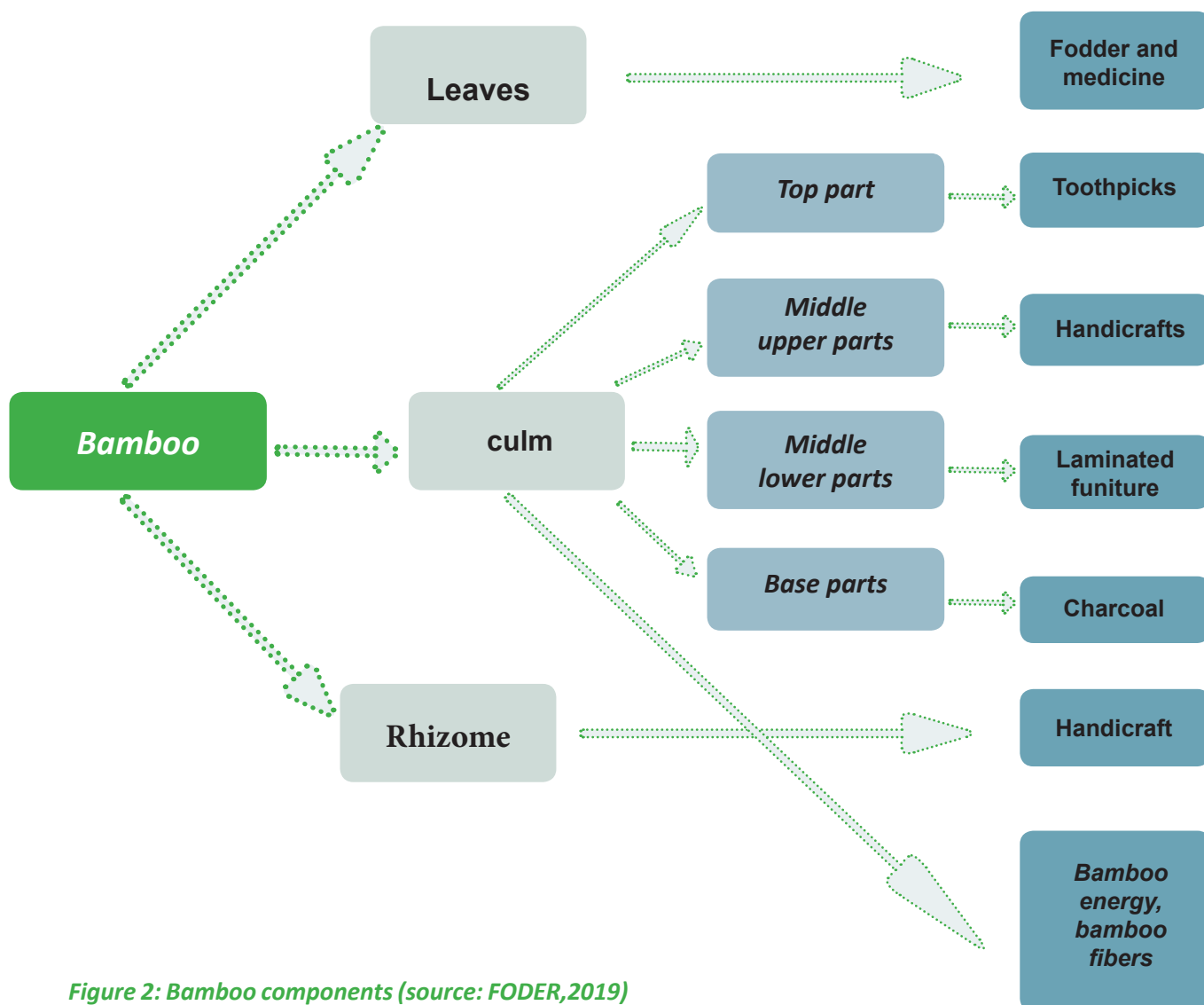


Figure 2: Bamboo components (source: FODER,2019)

The development of bamboo industry can be divided in to three stages; including the Traditional utilization (handicrafts, woven articles, scaffoldings), Industrial utilization (bamboo plywood, bamboo floorings) and value-added utilization (bamboo scrimber, bamboo structural lumber, bamboo textiles, bamboo carbon stock)⁴⁶.

Yongde, Yue. 2012. "Research for Value Chain Development Overview I of F Bamboo B B Utilization U Ili I in China."

1. *Bamboo traditional/domestic utilization*

All the part of bamboo (bamboo leaves, bamboo culm and bamboo rhizome) are used worldwide for domestic utilization. Some of the traditional uses/domestic utilization of bamboo are mostly for handicrafts like mats, musical instruments, match-sticks, beds, boats, bottles, tables, arrows, baskets, caps, chairs, chicks, chopsticks, coffins, combs, containers, cooking utensils, fans, fences, fish-traps, flutes, flower-pots, food, lamps, net floats, ornaments, paper, pens, toys, tool handles, tubes, umbrella- handles, walking-sticks, walls, vessels, accessories (necklaces, bracelets, earrings, and other types of jewelry) etc.



Bamboo



Bamboo table and chairs



Bamboo bottles



Bamboo combs



Carafe

, and



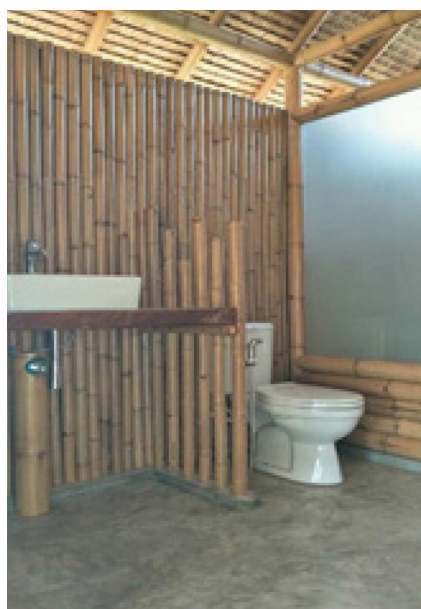
Bamboo chairs



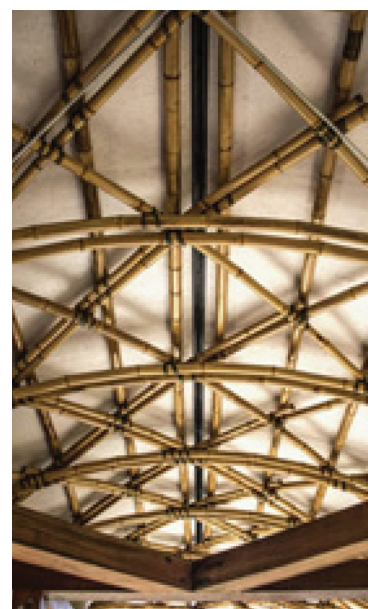
bamboo



Bamboo hanger



Bamboo use for decoration



Bamboo cooking utensils



Bamboo bag and mat



Bamboo house



Bamboo home utensils

Photo 28: Some picture of traditional bamboo utilization in world (source: INBAR, 2019 <https://www.inbar.int/>)

2. Bamboo Industrial utilization

Bamboo Industrial is mostly practiced in Asian and other foreign countries such as China, where bamboo has been used for many applications (from food source to building material). These countries produce goods like bamboo bathing products, bamboo vinegar, bamboo plybamboo, Bamboo toothbrush, bamboo scrimber, bamboo structural lumber, bamboo textiles, bamboo carbon, bamboo laminated furniture, bamboo composite board, bamboo chipboard, bamboo building panels, bamboo charcoal, Bamboo watch, bamboo Clothes, bamboo beer, bamboo paper and pulp among others.



Décoration de maison en bambou



Bamboo cooking utensils



Bamboo paper



Bamboo Conference Room



Bamboo Iron



Bamboo phone protector



Bamboo pipe



bamboo laminated



Bamboo toothbrush



Bamboo watch

Photo 29: Some picture of industrial bamboo utilization in world (source: INBAR, 2019. <https://www.inbar.int/>)

3. Bamboo utilization in Cameroon

Bamboo have multiple usage which has market potentiality for different purposes in Cameroon. These various uses range from living fences, agricultural supports, soil stabilization, forage, medical, construction materials, fuel wood, to furniture, etc. which usually depends on the bamboo species to be used.

Table 1: Some Bamboo utilization in Cameroon

NOM SCIENTIFIQUE	IMPORTANCE / UTILISATION
<i>Bambusa vulgaris</i>	Furniture (ladder, chairs, market table, rack to dry maize), Fencing and Hedges (cut poles), Construction material (poles help in house construction, house supports, electricity poles, antenna masts, traditional bridge, garner, football goals), Domestic utensils (cups, flower plots), Agriculture support (Banana, plantains, trough for chick, construct rabbit house), Water pipe, Traditional ceremonies (funerals), Fuel wood, Soil stabilization (control soil erosion and land slide), Biological drainer, Home of animals (rat, snake)
<i>Yushania alpine</i>	Construction material (poles help in house construction, house supports), Domestic utensils (cups), Fuel wood, Musical instruments (flutes) medical use (leaves), Soil stabilization (control soil erosion and land slide), Biological drainer Home of animals (rat, snake, wolf).

<i>Phyllostachys aurea</i>	Furniture (hanging screens, dress trap), fencing and hedges (live and cut poles), Construction material (house supports), Domestic utensils (working stick), Hunting implement (spears, arrows), Agriculture support (Banana, plantains, beans, yams tomatoes, protect young trees ,construct pig house and rabbit house, fishing stick) , Musical instruments (flutes and whistles), Traditional ceremonies (twins mother stick), Fuel wood, Forage (goat feed on it leaves), Soil stabilization and ornamental (control soil erosion and land slide), Biological drainer, Home of animals (snake)
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Source: *vanessa mankou, 2017*⁴⁷

Bamboo processing is non-existent in Cameroon. Generally, bamboo is used as support for agricultural crops, as ornamental plant, for construction and for craft purposes. The bamboo market and bamboo based entrepreneurship in Cameroon is not yet well developed. However, bamboo market and utilization in Cameroon can be divided into three sectors:

a. Bamboo handicraft and furniture in Cameroon

Handicraft is the most important source of employment creation for the Cameroon bamboo sector. Even though these bamboo craftsmen are few, bamboo based craft products are locally produced for sales in different part of the country. Craft objects commonly found in Cameroon markets may include: Bamboo cups, Bamboo flower stands, Bamboo chairs, Bamboo Bars, Bamboo musical instruments, Bamboo beds, bamboo picture frames, Bamboo handle tool, Etc. Bamboo culms are also used for construction (house and bridge) and decorative purposes. Bamboo craftsmen usually get their raw materials directly from the farms of bamboo farmers while some are supplied by bamboo culm collectors. Some of these craft works are represented on the pictures below;



Bamboo house



Bamboo cup and flower stand



Bamboo photo frame

54. DOMESTICATION'S CONSTRAINTS AND OPPORTUNITIES.OF BAMBOO Species (POACEAE) (KUNTH) IN THE MENOUA DIVISION, West Cameroon, July 2017.



Bamboo chairs



Bamboo cooking utensils and earrings



Bamboo musical instruments

Photo 30: Some bamboo craft products done in Cameroon

b. L'utilisation du bambou comme matériel de construction

The bamboo unprocessed culm (raw material) market is at a primitive stage in Cameroon. However, bamboo culms are usually sold in some wood depots in Douala and Yaoundé where culms are stocked alongside wood and sold as construction support. The price of a culm varies from 500 FCFA to 1000 FCFA depending on the length and size of the culm. These bamboo culms are often sold on commend.



Photo 31: Bamboo Unprocessed culm market



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