INTRODUCTION

Bamboos are variety of woody grasses. There are over 1,600 species of bamboos that are most widely distributed in tropical and sub-tropical regions of the Asia, Africa and Latin America. It is perennial, fast growing, high biomass producing and a versatile material, if managed properly. There are over 10,000 utilities of bamboo ranging from sustenance use products including food, feed and fodder to high end industrial / engineered products. Bamboo’s global domestic production and consumption is valued at USD 60 billion with over USD 3 billion worth of bamboo products globally traded. Thus, it has huge potential for livelihood and income generation. In addition, bamboo provides huge intangible ecosystem benefits such as soil erosion control, increased water recharge and a habitat to number of wild life.

Based on the FAO-INBAR World bamboo assessment report (2007), six countries of Africa (Ethiopia, Kenya, Nigeria, Uganda, Tanzania and Zimbabwe) has over 2.7 million hectares. Recent INBAR-Tsinghua University regional remote sensing study (2016) of Ethiopia, Kenya and Uganda estimate a bamboo growing areas of 1.66 million hectares. Remote sensing based bamboo resource assessment report of Madagascar has shown a bamboo growing areas of over 1 million hectares. Information on quantum of bamboo resources in Africa is partial. Bamboo is also widely found in Tanzania, Nigeria, Mozambique, Angola, Benin, Burundi, Cameroon, Central African Republic, Comoros, Cote d’Ivoire, Democratic Republic of Congo, Eritrea, Gabon, the Gambia, Guinea, Guinea Bissau, Liberia, Malawi, Mozambique, Reunion, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Togo and Zambia.

Bamboo species diversity in Africa is low. Except, Madagascar which have high species diversity with over 30 bamboo species, other countries in Africa have fewer bamboo species. Two commonly found / indigenous bamboo species in mainland Africa are *Yushania alpina* K. Schumach (synonyms *Oldeania alpina*, *Arundinaria alpina*) locally known as highland bamboo commonly found in altitudes of 2300 – 4000 meters above mean sea level; and *Oxytenanthera abyssinica* A. Rich (lowland bamboo), commonly found in altitudes of 500 – 2000 meters above mean sea level. Also, two introduced bamboo species namely *Bambusa vulgaris* and *Dendrocalamus giganteus* are naturalized and found Pan-Africa. In addition, over 20 bamboo species are introduced by research agencies of many African countries and development agencies especially in Eastern and Southern Africa.

MAJOR CLASSIFICATION OF BAMBOO

Bamboo in Africa belong to “sympodial or clumping bamboo” category.

Bamboo based on their rhizome and underground structure which constitute the structural foundation of the plant can be classified into three types:

1) Pachymorph / sympodial (short-necked pachymorph) / clumping bamboo
2) Amphipodial / sympodial (long-necked pachymorph) / clumping bamboo
3) Leptomorph / monopodial / running bamboo
Sympodial (Pachymorph - short necked rhizome)

The rhizome proper is short and thick; rhizome neck is short (and diameter is smaller than either of the axis it joins together). In these bamboos, new culms emerge close to each other because of small rhizome necks, thereby forming tight clumps. Mostly found in tropical and sub-tropical climatic zones. Bamboo of genus Arundinaria, Bambusa, Cephalostachyum, Dendrocalamus, Gigantochloa, Oxytenanthera, Thyrsostachys etc. belong to this category.

Amphipodial (Pachymorph-long necked rhizome)

These are typically clump-forming bamboos with long rhizome neck. The culms within clumps are bit scattered due to long rhizome neck. Mostly found in the tropical and sub-tropical regions. Bamboos of genus Melocanna, Yushania, Fargesia, Valiha, etc. belong to this group.

Monopodial (Leptomorph or running bamboo)

Monopodial or running bamboo is usually found in temperate zones (cooler climates) and grows as “single, free-standing culms”. In these bamboos, the underground rhizome runs beneath the soil and new culms emerge from the underground rhizome nodes at long, uniform distances thereby giving the appearance of a single culm plantation. Bamboos belonging to genus Phyllostachys, Indosasa, Semiarundinaria and Acidosasa belong to this category.

APPLICATION OF THE GUIDELINES

• This guideline on sustainable harvesting and management of bamboo was produced with support of Dutch-Sino East Africa Bamboo Development programme being implemented in Ethiopia, Kenya and Uganda, the guidelines aimed at sustainable management and harvesting of sympodial and /or amphipodial bamboo belonging to genus Yushania, Oxytenanthera, Bambusa, Cephalostachyum, Dendrocalamus, Thyrsostachys, Valiha, and Melocanna.

• This guideline can be applied for sustainable management of bamboo forests, bamboo farms and homestead bamboo.

• In addition, different management methods for bamboo pole / timber harvesting for value-addition, and bamboo shoots are elaborated separately.

NEED FOR SUSTAINABLE MANAGEMENT AND HARVESTING GUIDELINES

• Bamboo is one of the most important Non Timber Forest Product (NTFP) in Ethiopia, Kenya and Uganda.

• Bamboo resources in state managed bamboo forest / protected areas, communal bamboo forests and private farms are degraded owing the lack of management and sustainable management and harvesting practices.

• Bamboo in state managed forests is not managed. There are both instances of “over harvesting” as well as “no harvesting”; varies according to countries, accessibility and remoteness of the location.
Communal bamboo forests are over-harvested and/or unsustainably managed. There are more number of older bamboo poles (3+ years old) standing in the bamboo clump. Most of the young bamboo poles (~1-year-old) are harvested for value-addition into basketry and other applications; thereby jeopardising the emergence of new bamboo shoots and reduction in size of bamboo poles.

Bamboo in private farms or small holder farms is comparatively better managed than bamboo in state forests and in communal lands. However, bamboo in private farms is not optimally managed: both the clump intensity (number of bamboo pole in a clump), clump composition (proportion of different aged bamboo) as well as harvesting methods is not practiced. Generally, standing bamboo poles in a clump belong to the category of Year 1 and Year 2; and the harvested bamboo poles belong to the same age category. With frequent and over harvesting, bamboo clumps are not producing optimal successive generation poles in terms of diameter as well as number of bamboo poles.

Overall, the management of the bamboo forests and bamboo in farm lands is done by traditional knowledge. There are very limited extension support services to communities’ for managing the bamboo resources.

Bamboo is a “woody grass” which produces new bamboo shoots or bamboo poles every year, and old bamboo poles in a clump dies out every year. Sustainable harvesting (harvesting of bamboo poles of 3+ years) improves the quality of bamboo forests as well as bamboo poles.

**BASIC TERMS**

**(MORPHOLOGY)**

It is important to understand the terms used throughout the document to sustainably manage bamboo plants.

Morphology refers to the outward appearance of the plant’s components. The vegetative parts of the bamboo plant consist of clump, culms, roots, rhizome, culm sheaths, branches, nodes, internodes, buds and leaves.

- **Clump:** A clump is a cluster or group of bamboo culms originated from a single mother plant.

- **Shoot:** The bamboo shoot is an emerging stem or culm. It originates from buds on the underground rhizome.

- **Culm sheath:** Culm sheaths are modified leaves, arranged alternately on opposite sides of the growing culms, providing protective cover for the young shoots / culms.

- **Branches:** When a shoot / culm reaches its full height growth and culm sheaths fall off, branches grow out from the nodes of the culm.
Leaves: Bamboo leaves grow out from the top of the newly emerged culm when height growth ceases and proceeds downwards; quite the opposite of that observed for most plants.

Nodes and internodes: Each culm segment begins and ends with a solid joint known as a node. Nodes are key growth points in rhizomes, culms and branches from where new vegetative axes develop and grow. Buds on the culms are also placed on nodes. The segment between two successive nodes is known as an internode.

Rhizomes: The underground portion of the bamboo plant is the rhizome. The rhizome system constitutes the structural foundation of the plant.

Buds: Buds are meristematic organs in bamboo located at nodal portions on culms and branches. In the underground portion, buds are placed at the nodal region in the rhizomes.

GROWTH PATTERN OF A BAMBOO CLUMP

Bamboos are monocarpic plants, which flowers and produces seeds once in its life time, after which the clump / bamboo forest dies. Broadly, the flowering cycle of bamboo ranges from 35 – 45 years. In some species it flowers once in 120 years and there are some species which don’t flower and seed. Therefore, bamboo are perennial plants that produce bamboo poles without replanting.

Once planted, depending on the site condition and management, most sympodial bamboo clumps require about 4 – 6 years to reach maturity (bamboo culms within clump reaches its maximum height and diameter; bamboo clump reaches its girth), and thereafter it remains more or less static.

The number of culms and DBH and height gradually increase in subsequent year of planting, and it reaches maximum in about five years of planting. The expansion of the clump girth is rapid during 4-6 years of planting and then slows down. If there is no harvesting after clump maturity, culm production gradually decreases. In the case of undisturbed clumps, crowding and congestion happens (new shoots / culm emerge every year and old culms die every year). Due to congestion, yields decrease, culms are more often bent and twisted, making it unsuitable for high-end value addition.
Bamboo clumps produce new shoots / culms / poles annually and at the same time, old bamboo culms / poles (over 5 years old) start deterioration and dying. If bamboo poles (matured) are not harvested regularly, the productivity and quality of poles and shoots reduces drastically. If over harvested, the productivity drops and can lead to degradation of clumps. Therefore, sustainable and selective harvesting coupled with proper management practices is key to healthy bamboo clumps which could provide annual income opportunities for harvesters, growers and processors.
SUSTAINABLE MANAGEMENT AND HARVESTING

Sustainable Management and Harvesting of bamboo forests and farms depends on the objective. Broadly, this guidelines document illustrates the management guidelines of (a) management for timber production and (b) management for bamboo shoot production.

BASIC HARVESTING RULES

• No clear felling should be allowed.

• All older or matured bamboo culms should be harvested (3 years+)

• Current year culms should be retained.

• At least a minimum of six culms over 1-year-old, spaced uniformly over the clump should be retained. When there are large clumps, proportionately more mature culms can be retained.

• Number of harvestable culms should not exceed the number of poles emerged in the last year.

• Digging of rhizomes is not permitted, except for propagation purpose.

• Culms should be felled / cut above first node from ground (about 10 cm from ground level).

• A sharp instrument (knife or saw) should be used when felling to avoid splitting and damage of culms.

• All dead and dry bamboo, all debris as a result of harvesting and high cuts (due to lopping) should be removed from the clump.

• Bamboo forests should be protected from fires.

IMPORTANCE OF AGE COMPOSITION (BAMBOO CULMS) IN A CLUMP

Though individual bamboo poles or culms stand apart, underground portion (rhizome system) of bamboo clump is inter-connected.

Due to annual production of new shoots, different-aged culms / poles are observed in a bamboo clump. Age determination of these culms is important to sustainably manage and harvest bamboo, as bamboo culms of different age category have (a) different physical, mechanical and chemical properties and (b) different age category culms have unique functions in a clump.

Difference in properties for value-addition

• The age of the culm is an important factor for its suitability of different application. Bamboo shoots emerging from ground take about 90 – 120 days to reach its full height, diameter and wall thickness. Thereafter only maturation: mechanical and chemical property changes in bamboo poles.

• Uniformity of raw material is critical for production of high quality, standardised/industrial products. Bamboo poles of similar physical, mechanical and chemical properties (with age-grading) will ensure production of uniform and standardised products.

Different function of age classes, functions and application

Bamboo culms or poles of different age group in a bamboo clump, performs different functions to ensure the suitability of bamboo clump.
<table>
<thead>
<tr>
<th>Age</th>
<th>Properties</th>
<th>Function</th>
<th>Usage Application</th>
<th>Visible Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 30 days</td>
<td>Bamboo shoots: Soft like vegetable, more than 90 percent water.</td>
<td>Future generation.</td>
<td>Food for humans and animals.</td>
<td></td>
</tr>
<tr>
<td>Current year:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 1 year</td>
<td>Internal tissues are slender, branches, roots and leaves are not fully</td>
<td>Future generation.</td>
<td>Production of ropes and baketry (8 –</td>
<td></td>
</tr>
<tr>
<td>(Juvenile)</td>
<td>developed. Cell wall of fiber with lamellae is very small and culms are</td>
<td></td>
<td>12 months old).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>immature. Starch and moisture content is highest.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 – 2 years</td>
<td>Root system, branching and leaves are well developed; thereby has higher</td>
<td>Highest shooting</td>
<td>Basketry, mats.</td>
<td></td>
</tr>
<tr>
<td>(Adult)</td>
<td>capacity for photosynthesis and nutrient absorption.</td>
<td>capacity.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Culm is at its peak of metabolism and shoot production. Cell wall of fiber</td>
<td>Supply of food and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>is small deposited with additional lamellae – high lumen left.</td>
<td>nutrients for rapid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Starch content is high, susceptible to decay and insect attack.</td>
<td>growth of shoot.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moisture content high.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-3 years</td>
<td>Abundance of nutrition, and physiologically active. Lower shooting</td>
<td>Production and supply of</td>
<td>Furniture products and non-structural</td>
<td></td>
</tr>
<tr>
<td>(Late Adult)</td>
<td>capacity compared to year 1 -2 poles. Strength and density of timber is</td>
<td>food for growing shoots;</td>
<td>applications; Paper and Pulping.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>augmented (cell wall of fiber is slight bigger deposited with additional</td>
<td>With established root and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>lamellae). Starch content is comparatively lower than bamboo of Year 1-2,</td>
<td>rhizome system provide</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>susceptible to decay and insect attack. Moisture content comparatively</td>
<td>protection from winds and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>lower.</td>
<td>shade.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-4 years</td>
<td>Cell wall of fiber is optimal with high structural stability with only a</td>
<td>No shooting capacity.</td>
<td>Structural applications, Industrial</td>
<td></td>
</tr>
<tr>
<td>(Old Age)</td>
<td>small lumen left. Leaf production start to decline. Starch content is</td>
<td>Right age for harvesting</td>
<td>products.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>lower Moisture content is lower.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 years +</td>
<td>Cell wall highly lignified, fragile due to lack of elasticity. Starch</td>
<td>No shooting capacity.</td>
<td>Too brittle (lack of elasticity)</td>
<td></td>
</tr>
<tr>
<td>(Advanced</td>
<td>content lowest. Moisture content lowest. Leaf volume reduces, physiological</td>
<td>Quality of timber start to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>old age)</td>
<td>activity decline, timber quality diminished.</td>
<td>decline.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decline in weight.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Culms starts to die</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>and deteriorate as age</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>progresses.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Bamboos lack the vascular cambium layer and thus lack secondary growth in diameter as in trees. Under field conditions, it is not always easy to distinguish the age of a bamboo culm, since culms in a mature clump tend to have the same girth, length and nodal structure.

The culm age can be identified based on certain features of the culm sheath, development of branches and leaves, external colour of the culm, position of new culms, etc. For example, in sympodial bamboos, younger/current year culms are usually on the outer side, while older culms are toward the inner side. Culm sheaths are usually absent on older culms. The accuracy of such a distinction is, however, dependent on the skill and experience of the person and is not always reliable.

Therefore, other guaranteed methods have to be adopted to determine the age of bamboo. Age can also be determined by marking the culms (a) with different colour paints, (b) writing year and month of shoot emergence using colour/paint and (c) inscribing the year of shoot emergence. Alternately, other innovative approaches can be adopted too.

Different colour paints: Three different colour paints are required, one for each year of a three-year cycle. Culms that are older than 3-4 years should be logged, as they become weak and brittle and can be expected to die. After the culms attain full height during the first year, they are marked with paint. A scheme for identifying culm age are shown in the below table. Please note, this is mostly suitable for on-farm bamboo plantation as well as intensely managed forest plantation.

<table>
<thead>
<tr>
<th>Colour</th>
<th>Age (Year)</th>
<th>Rotation-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Current: 0-1 years</td>
<td>Current: 0-1 years</td>
</tr>
<tr>
<td>Yellow</td>
<td>1-2 years (2019)</td>
<td>1 – 2 years (2022)</td>
</tr>
<tr>
<td>Blue</td>
<td>2-3 years (2020)</td>
<td>2 – 3 years (2023)</td>
</tr>
</tbody>
</table>
Writing year and month of shoot emergence: Using single colour paint (black), write the year and month of shoot emergence. This method is widely adopted in China.

Please note: Marking should be done after the culm attains its full height, that is, after it has stopped growing. The indication of the stoppage of further dimensional growth (length) is when branches begin to appear, normally first in the upper portion of the culm.

- Detach the culm sheath from the culm before beginning to paint.
- Mark the different-aged culms with the thick paint by making a two to three-inch band at breast height in the internodal portion of the culm, taking care that paint should not drip down the culm.
- Use different colours (as given in Table /Figure) for marking different ages.
SUSTAINABLE MANAGEMENT AND HARVESTING PRACTICES (TIMBER STANDS)

Sustainable management and harvesting of clumping bamboos are focused on measures to (a) regulate the population structure of bamboo clumps and culms and (b) improve the growing conditions.

BAMBOO FOREST/ FARM STRUCTURE MANAGEMENT

Maintaining (a) inter-clump density (number of clumps in a hectare), and (b) intra-clump density (number of poles in a clump) and age composition (composition of different age-class bamboo culms / poles in a clump) is critical for optimal growth and regeneration.

1. Inter-Clump Density / Structure of bamboo stands

Plantations with low clump density will suffer from canopy exposure, low soil moisture and strong competition from weeds. This may result in poor productivity and necessitate a lot of labor during tending. Plantation with high clump density / overstocking at planting will also result in low productivity from smaller plants due to the intense competition among the plantlets for light, space, soil moisture and nutrients. Maintaining an optimal density of clump is crucial for optimal yields.

Optimal Inter-Clump Density: Stocking or density of clumps or spacing between clumps varies across sympodial bamboo species.

Small diameter bamboo species (< 6 cm diameter DBH): At least 4 X 4 M spacing: 625 clumps per hectare: Bamboo species such as Oxytenanthera abyssinica, Dendrocalamus strictus, Bambusa multiplex, etc belong to this category.

Medium diameter bamboo species (6-10 cm diameter DBH): At least 5 X 5 M spacing: 400 clumps per hectare: Bamboo species such as Yushania alpina, Bambusa vulgaris, Bambusa polymorpha, Cephalostachyum pergracile, Dendrocalamus hamiltonii, Dendrocalamus membranaceus and other belong to this category.

Large diameter bamboo species (> 10 cm diameter at DBH): 7 X 7 M spacing: 200 clumps per hectare: Bamboo species such as Dendrocalamus giganteus, Dendrocalamus asper, etc, belong to this category.

2. Intra-Clump density

Reasonable number of standing bamboo poles in a clump is necessary for bamboo shoot / culm production (optimizing quantity and quality). Depending on the species, it is recommended to retain 12 – 20 culms per each clump. In the case of larger diameter, medium diameter, and small diameter bamboo species, about 12, 16 and 20 bamboo culms can be retained. However, the most critical factor is the age-composition.
3. Age Composition

Year 1: Year 2: Year 3 = 1: 1: 1

Why maintaining clump composition or age structure is necessary?

One to two-year-old sympodial bamboos usually have well developed rhizome buds which will be transformed into shoots / culms. Three years and older bamboo culms are in mature phases and most of rhizomes buds are already transformed into bamboo culms or poles and the remaining buds have no shooting capacity. The main function of three-year-old and older poles are to provide shelter and protect the young culms and shoots from strong winds.

Broadly, equal number of bamboo poles / culms of different age classes can be retained, as the number of bamboo poles harvested and shoot recruited for growth into a bamboo culm could be balanced.

The composition of the Current Year 1 (0-1 years), Year 2 (1-2 years), year 3 (2-3 years) can be in the proposition of 1: 1:1.

To illustrate this, if the number of culms in a clump is 12 bamboo poles and the number of bamboo poles of Year 1 = 4; year 2 = 4 and year 3 = 4. Allow four strong shoots to grow into a bamboo culm / pole; and harvest 4 mature bamboo poles which crossed year 3.

In addition, one of two old bamboo poles (4 year) poles could also be retained.

1. Culm / shoot retaining

Why select strong bamboo shoots to grow: Diameter of future culm is established when shoot activation and partial elongation of new shoots are underway. For the growth of rhizome buds into shoots and to bamboo culms, all nutrients are supplied by connected mother culm. If more shoots are produced from a single mother culm, more difficult for the mother to supply nutrients and food, resulting in stunted growth and death of some shoots / culms. It is recommended to allow 1 or maximum two shoots to grow from a single mother culm and cull the rest.

It is also advised to thin out weak shoots and shoots emerge in late shooting period as the shoots will be less vigorous and generally will develop into a poor bamboo culm.

2. De-budding

In the case of some sympodial or clumping bamboo species such as *Bambusa bambos*, *Bambusa blumeana*, *Oxytenanthera abyssinica*, *Dendrocalamus hamiltonii*, *Bambusa vulgaris*, *Guadua spp.* and others, there are profuse and prominent branching in the bottom potion of the bamboo clump creating congestion and difficulty in harvesting and management. In those species with prominent branching at bottom portions, de-budding can be done to stop proliferation or growth of branches in the bottom 1 / 3rd height of bamboo poles. De-budding can be done when the bamboo culms reaches its entire height and culm buds start to sprout. This will improve the clump accessibility, management and harvesting.
In the case of *Yushania alpina*, *Dendrocalamus giganteus* and other bamboo species, no branching is found till half height of bamboo culms and therefore no de-budding is necessary.

3. Weeding, soil loosening and mounding

In the case of sparse bamboo forests or plantation, weeds and shrubs tend to grow which competes for water and nutrients. It is also host and habitat for insect and pests. Cut / cleaned weeds and shrubs will decompose and helps in improving soil fertility.

**Soil-loosening** in bamboo plantations is important, as maintaining a good soil structure in the stand will be beneficial to the growth of shoots and root system, as well as water conservation. Inside the bamboo clump do shallow digging and soil loosening (<10 cm deep), and surrounding bamboo clumps deeper digging of approx. 20 cm is recommended. At the same time, old and decayed cut bamboo handles and rhizomes can also be removed. Please note, soil loosening is not recommended for bamboo clumps in steep slopes to avoid soil erosion.

**Fertilization:** With the extraction of bamboo poles for value addition, soil minerals and nutrients are also extracted. Two to three baskets (15 – 20 Kg) of manure or compost can be added to the clump.

Alternatively, in the case of on-farm or high intensely managed matured bamboo plantations, 0.5 – 1 kg of NPK fertilizer can be added per well grown clump.

**Soil mounding:** After mixing the manure or fertilizer with soil, mound the bamboo clumps with excavated soil, and create a small trench surrounding the clump to hold water.

Weed cutting, soil loosening and mounding can be done once a year – just before the rainy season. Alternatively, this could also be done twice – Once before the beginning of rainy season; and another before the end of rainy season.
Best time to harvest: Timber Production

Post rainy season or early dry season is the best time to harvest bamboo poles. During the post rainy season, starch content is comparatively lower (since new shoots consumed most of the nutrient in the clump). With low starch content and relatively less moisture content, the bamboo poles are least susceptible to attacks by fungi, borers, termites and other pests.

Harvesting or felling should not be done during shoot emergence and growing periods as harvesting operation will damage the tender growing shoots.

Harvesting should not be done in end of dry season and early rainy season as the bamboo plant body have lot of accumulated starch and nutrients to feed the emerging shoots. Bamboo poles harvesting during this period will be susceptible to borer and insect attacks due to high starch concentration.

HARVESTING METHODS

New culms are commonly produced on the periphery of the clump (young culms / rhizomes are the ones which produce new shoots (1-2 years old)). So, the tendency of the bamboo collectors, harvesters to harvest the bamboo

Dendrocalamus membranaceus clump showing younger bamboo poles on outside of clump

Bambusa vulgaris unmanaged clump with dead bamboo poles on the inside of clump and young culms on outside
poles on the outside periphery of bamboo clump, which is young and immature affecting the sustainability of the clump as well as the durability of the bamboo products / poles used are low.

Mature bamboo poles in sympodial bamboo clumps are commonly found on the inner core of the bamboo clump.

In the case of sympodial bamboo with long rhizome neck such as *Yushania alpina*, penetrating inside the clump and harvesting mature bamboo poles are relatively easier due to its sparse nature of growth.

In the case of unmanaged sympodial bamboo with short neck rhizome (genus such as *Bambusa*, *Oxytenanthera*, *Dendrocalamus*, *Cephalostachyum* and others) bamboo clump is congested prohibiting the entry into the clump.

Two techniques for managing congested or clustered bamboo are **(a) Tunnel technique and (b) Horse-shoe technique.**

**Tunnel Technique**

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

**Horse-Shoe Technique**

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

*Year after year, the size of the tunnel and horse-shoe will expand and with right culm density, harvesting operation will be easier and cost effective. Please note: Harvesting should be selective, only mature culms should be harvested using very sharp tools. It is advised to disinfect the harvesting tools to lower the risk of infection in plants.*
Felling / Cutting Method

Cut the culms in a slanting manner (45 degree) just above the lower most node (~ 10 -15 cm) to minimise wastage, avoid sprouting and at the same time rainwater will not stagnate in cavity of stump portion.

When felling is done far above the ground, buds on the nodes of cut stump will get activated and produce branches and create bushy clumps hindering future harvesting and management operations.

Care during felling / harvesting

- Branches and twigs from harvested poles needs to cleaned from the mother culms.
- Dead, rotten and deformed culms and stumps should be cleaned.
- Harvesting and felling operations should not be undertaken in culm emergence period.

Rotational Harvesting in case of Bamboo Forest Management

- Clear cutting should not be allowed.
- Three-year rotation cycle can be followed. Three blocks or compartments can be created in a bamboo forest, and cutting is permitted in only one block per year.
- Leave all the one-year-old culms and leave equal number of mature culms (2 & 3 years combine) and harvest the rest.
- In managed bamboo forests, regeneration (quantity) and quality of bamboo poles will be better.
- In locations of unregulated or over harvested bamboo forests for years, stopping harvesting for few years allows the bamboo forests to recoup.
SUSTAINABLE MANAGEMENT AND HARVESTING PRACTICES (BAMBOO SHOOTS/ BAMBOO JUICE)

The primary objective of bamboo shoot clump management is to maximize sustainable bamboo shoot production. This technique can also be applied to bamboo juice production (especially in Tanzania), as the bamboo juice is tapped from bamboo shoots.

Depending on the species, there are about 6 – 12 buds or more in each rhizome, among them 1-2 will get activated and elongated into shoots or culms. If they are harvested, the remaining ones will get activated and grow as new shoots, enabling harvesting of bamboo shoots and sustenance of bamboo stands.

The shooting period lasts for about 2-6 months (varies according to species and site conditions). It occurs in three distinct phases namely: (a) the early phase, (b) peak phase and (c) final phase. Nearly one fourth of shoots are produced in early phase; one half during peak phase and one fourth during final phase. Select the best shoot during peak stage which are strong and leave it to grow into a new mother bamboo.

Sustainable management and harvesting of clumping bamboo shoots are focused on measures to (a) regulate the population structure of bamboo clumps and culms and (b) improve the growing conditions.

BAMBOO FOREST/ FARM STRUCTURE MANAGEMENT

Bamboo Stand Structure: Bamboo shoot clumps needs to be diffuse or open compared to timber stands due to need for better site conditions such as heat, light, nutrient and moisture.

Bamboo stand structure comprises of (a) Inter-clump Density and (b) Intra-clump density and (c) age structure in a clump (clump composition – different aged bamboo poles), which are similar to timber stands.

1. Inter-clump Density

Clump Density: Distance depends on species and growing conditions.

- Small diameter bamboo (< 6 cm diameter at DBH): Atleast 4 X 4 M spacing: 625 clumps per hectare: bamboo species such as Oxytenanthera abyssinica, Dendrocalamus strictus, etc.
- Medium diameter (6-10 cm): Atleast 5 X 5 M: 400 clumps per hectare: bamboo such as Yushania alpina, Bambusa vulgaris, Dendrocalamus hamiltonii, Dendrocalamus membranaceus and other.
- Large diameter (> 10 cm): Atleast 7 X 7 M: 200 clumps per hectare: bamboo species such as Dendrocalamus giganteus, Dendrocalamus asper, Dendrocalamus latiflorus, etc.

2. Intra-clump density

For large diameter bamboo (> 10 cm diameter), usually 4 – 6 mother culm are retained.

For mid-size and small diameter bamboo (< 10 cm diameter), usually 6 – 12 culms are retained.
3. Age Composition

Year 1: Year 2 = 2: 1

Only one to two-year-old sympodial bamboos have the potential to produce bamboo shoots (well-developed rhizome buds / eyes which has intensive germinating capacity). Older bamboo culms / poles (3 years and older) are in mature phases and most of rhizomes buds are already transformed into bamboo culms or poles and the remaining buds have no shooting capacity.

The clump or age composition of culms can be in the ratio of 2: 1 (Year 1: 2; Year 2: 1).

For example, if an intra-clump density is 9 culms: Year 1 culms = 6; Year 2 culms = 3.

SHOOT HARVESTING AND CULM RETAINING

- Depending on bamboo species - Bamboo shoots are harvested when it reaches height of 15 – 50 cm. In the case of *Dendrocalamus* species it is about 15 – 30 cm; In case of *Yushania alpina* it will be about 40 – 50 cm.
- Soil surrounding the shoots are removed till shoot buds. Then, shoots are cut with sharp and clean knife without damaging the mother rhizome.
- Select the best / strong shoot during peak stage and allow it to grow into a new mother bamboo. For example, if we are maintaining an intra-clump density of 6 culms, 4 bamboo shoots should be allowed to grow into a full culm / pole. This culm will produce bamboo shoots for coming year. Allow shoots from different locations of clump to grow rather than allowing all shoots from one location to grown to avoid congestion.

MANAGEMENT TECHNIQUES

1. Weeding

Weeding of other vegetative growth including weeds, climbers and shrubs should be done one to two months before the active rains.

2. Soil loosening and sun basking

1-2 months before active rainfall season, remove the soil cover (dig up soil cover starting from outside to clump center). Expose the bamboo rhizome and shoot buds to sunlight. Remove messy roots around shoot buds and expose the shoot buds / eyes to direct sunlight and wind. This promotes burgeoning of shoot buds resulting in early sprouting and increase in number of shoots.

Soil loosening is done loosening up to top 20 cm of soil to improve soil ventilation.

3. Manure and Fertiliser

Bamboo shoot clump generally needs more nutrients as large number of bamboo shoots are extracted.
**Small holder Farmer:** Two to three baskets or manure or compost can be applied mixed with soil during soil mounding.

### 4. Soil Mounding

At least expose the rhizome to sun and wind for about 2 weeks. Some rhizome buds / eyes after sun basking start to expand and turn blue to form little shoots. It is the right time to earth up to cover the shoot buds to enable sprouting shoots to grown in inside dark soil. Soil mounding of bamboo clumps is done by adding soil on the entire bamboo clumps to cover the root and rhizomes and 20 cm above the surface. Surrounding leaf litter can also be added.

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**COMMERCIAL CULTIVATION OF BAMBOO SHOOTS**

In the case of high intensity commercial farms, fertilizer application can be applied in addition to manure / compost along with soil mounding, as the fertiliser instantly release nutrients compared to manure or compost. NPK is the most ideal combination, ratio required by bamboo stands are in ratio of 5:4:3. Three times disbursal of fertilizer instead of one time is better.

**Fertilization Schedule**

<table>
<thead>
<tr>
<th>1st</th>
<th>2 weeks after sun basking</th>
<th>1kg per clump (NPK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>Early period of rain (Just before shoot harvesting – during bud differentiation and expansion)</td>
<td>1kg per clump (NPK)</td>
</tr>
<tr>
<td>3rd</td>
<td>Before end of rainy period (after shoot harvesting period)</td>
<td>1.5 kg per clump (NPK)</td>
</tr>
</tbody>
</table>

**Irrigation**

For increasing shoot yield, during dry season irrigate bamboo clumps once in two weeks to induce early shooting and increased production of shoots.

In case of no rain during active shoot period, clumps should be regularly irrigated to ensure maintenance of high soil moisture.

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**FOUR BASIC THUMB RULE TO REMEMBER**

- **Cut the small, keep the big.**
- **Cut the old, keep the young.**
- **Cut the crowded, keep the scattered.**
- **Cut the sick, keep the strong.**

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