Kenya's Water Towers Protection and Climate Change Mitigation and Adaptation (WaTER) Programme

GUIDELINE ON PROPAGATION, MANAGEMENT AND UTLISATION OF BAMBOO

Component 4: Science to Inform Design of Community-Level Actions and Policy Decisions

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1.0 INTRODUCTION

Bamboo is a member of the grass family. There are over 1200 bamboo species. The most common bamboo species , preferred for bamboo product making, unlike the herbaceous and shrubby species, resemble trees in many properties. The jointed growth pattern of bamboo culms is evident throughout the culm including underground rhizomes and branches.

Different bamboo vary in size, colour, root structure, clumping forms among others. For the bamboo product making industry to prosper, there is need for readily available raw materials. Uptake of bamboo growing among farmers is of essence considering that most of those in government forests have not been well managed and this reduces their economic value. Further, the species available in government forests does not grow to big sizes and species diversification can only be attained in private lands where there is more land for planting. Having enough raw materials is important in encouraging setting up of processing industries.

Bamboo is well known for its resilience and long-lasting sturdiness. On an equivalent weight to weight basis, bamboo is stronger than wood, concrete and bricks (Roach 92). According to INBAR (2010), due to the strength of bamboo an estimated more than a billion people live in some form of bamboo housing. The flexibility of bamboo makes it an ideal material for the craft industry.

Bamboo is also promoted due to its eco-friendliness. According to McCoy (2009) bamboo has the capacity to absorb four times as much carbon dioxide from the trees as trees do. Also the energy required to produce bamboo is about half that of producing wood and one eighth energy necessary for using concrete for the same capacity. Further, bamboo can have more output in terms of biomass than timber while using less land. For example, in a year only 70 hectares of bamboo would be required to build 1,000 houses. However, it would require destruction of 600 hectares of natural forests to build similar houses (INBAR 2010).

1.1.Bamboo resource in the country

There are about 150,000 hectares of bamboo forests in Kenya, some in pure and others in mixture of trees and shrubs (Kigomo, 1998). The bamboo resource in the country consists of indigenous *Yushania alpina* and introduced species. The indigenous species is mainly found in government forests with a small percentage on private farms bordering the forests. Large indigenous bamboo sections are found at high altitudes (2000m and above) such as Aberdares, Mau ranges, Mt. Kenya and Mt. Elgon.

During the last three decades, some research on species selection and investigations on growth was done mainly by Kenya Forestry Research Institute (KEFRI) in collaboration with several Asian research and development institutions. This research work introduced more than twenty bamboo species in the country. The introduced bamboo species are more versatile in their use than the local bamboo and therefore the main interest for their introduction.

Key limiting factors to the widespread planting of bamboo in Kenya is lack of information on availability of planting materials, methods of propagation, establishment, crop management and harvesting methods. This guideline attempts to consolidate and provide such invaluable information.

1.2. Objectives of the guidelines

The main objectives of this guideline are:

1. To promote bamboo as an alternative to timber in Kenya and thus reduce the pressure on the natural timber forest.
2. To ensure sustainable management of the country's bamboo resources
3. To promote the setting up of bamboo nurseries and plantations
4. Promote research into bamboo
5. To build capacity in terms of human and other resources
6. To engage the rural communities in income generating activities with bamboo as a means of reducing poverty in the communities.

2.0 NATURE OF BAMBOO CULMS

Two main bamboo groups;

2.1.Clumping bamboos

This is composed of bamboos forming pachymorphs (sympodial system of rhizome) or clump forming rhizomes. This type of bamboo grows in clumps that can be easily identified in stands having groupings of bamboo growing as individual sets. Clumping can be either very tight or loosely growing culms in a group. The nature of clumping defines management practices as some can be very tightly clumped making management laborious.

2.2.Running bamboos

Species in this type of formation exhibit leptomorph (monopodial system of rhizome) or spreading rhizomes. This rhizomal system, involves a complex underground network expansion that results in individual bamboo culms being widely spaced. This character makes them stand out as individual trees while in the real sense they are bamboo culms. This type of clumping is closely associated with bamboos living in mixed stands where the extended rhizome systems can cover a large area that doesn't confine growth of other species in the gaps developed.

2.3.Bamboo culms

Bamboo stems or culms are the aerial parts of the bamboo plant emanating from the underground network of rhizome systems. A bamboo culm emerges from the rhizomes as a shoot that extends vertically to its maximum height. Surprisingly this growth occurs in the optimal growing season that can take a few months to a few years. No remarkable growth diametrically occurs after this growth. The diameter of the bamboo culm basically remains the same after undergoing the optimal growth season.

2.4.Nodes and internodes

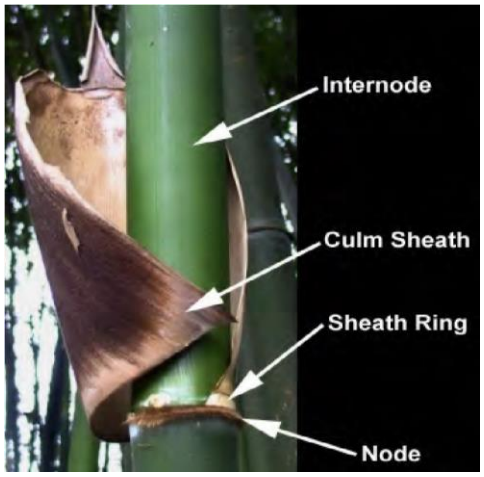

Plate 1: An illustration of different culm sections

A node is the central point joining internodes between nodes forming the main culm. Therefore, internodes form the joining parts of the bamboo culm. Nodes present one of the most viable bamboo propagation parts and can be found in branches and rhizomes of the bamboo culm. During the growing season, internodes will expand from the nodes forming the length of the culm. Internodes come to play and ensure that the culms are horizontally strong and prevent deforming and cracking voids. Similarly when new shoots emerge during the growth season, they elongate from nodes forming new culms. In most bamboo species, sheathes develop on nodes to protect them. The same will wither off, drop, and branches emerge from the culm. In some species, the branches will also wither off progressively as the culm gains height.

2.5.Lifespan of culms

Bamboo culm lifespan depends on the species which might vary between a year and ten years. Depending on year of development and growth conditions, individual culms develop independently. In optimum conditions, most bamboo culms attain maturity in 5 years where they achieve desirable wood-equivalent qualities. Henceforth, they gradually degenerate, based on species, and start off a gradual dying process that might be unnoticed to the inexperienced eye.

2.6.Lifespan of bamboo plant

The maturity and lifespan of the bamboo plant should not be equalled to other maturity and lifespan of bamboo culms of all species. The complex bamboo rhizome system is responsible for the maturity and lifespan of individual culms. This, unlike tree species, is a peculiar bamboo growth feature that improves on its longevity and sustainability. Sustainable cutting will not affect regeneration and growth of the bamboo clump as it rhizome system extends further. The natural lifespan of the bamboo pant is more than 50 years or more depending on the species.

3.0. BAMBOO PROPAGATION

Growing bamboo starts with sourcing of materials for planting. Such materials may come in the form of seed, wildings, offsets or cuttings that may be gathered in the forests. Tissue-cultured plantlets provide other forms of planting materials. Such planting materials can be raised or obtained and raised in the nursery as described below.

Out of the five methods vegetative propagation is the fastest way of multiplying this valuable resource.

3.1.Vegetative propagation

When seeds or wildings are not available, bamboos can be propagated vegetatively. This offers a better source of planting material. The approach is however limited in space due to difficulties of collecting enough of planting materials.

Use of culm cuttings is a viable alternative and has several advantages. Multiplication of several species is possible by this method. When out-planted, vegetative materials raised from cuttings develops to clumps much faster than offsets. The local species of bamboo (alpine bamboo – *Yushania alpina*) and *Oxytenanthera abyssinica* have however proved difficult, so far, to raise planting materials through cuttings.

There are two main types of vegetative propagation promoted by KEFRI namely; layering method and use of cuttings. Detailed application of these methods is outlined and illustrated below.

3.2.Layering method

The propagation methods involve several steps, mostly:

- Construct a simple green house
- Collection of healthy bamboo Culms
- Perforate culms at the middle of internodes
- Incubation of the culms
- Sprouting of the of the new shoots
- Proliferation
- Potting of proliferated seedlings
- Second -splitting of potted samplings

Step 1

Construct a polythene sheet green house where temperature and humidity are controlled. This can be constructed from polythene sheets available in local shops e. those used for covering tea seedlings. The size of the greenhouse depends on the resources available. Individuals can also construct miniature greenhouses covering for example 1 m by 5 m. These do not require the use of timber and withies can be curved to hold the polythene sheet on top.

In very warm areas, for example the lower reaches of West Pokot County; there is no need of covering the laid culms as the temperatures resemble those of the greenhouse.

Plate 2: A standard greenhouse

Plate 3: An improvised greenhouse

Step2

Healthy culms should be selected from individual culms. Care should be exercised not to collect very young culms whose tissues are too tender hence exposed to fungal attacks and rotting. Also older culms that have tough fibres should also not be selected as they might not shoot and root readily. Culms with live nodes should be obtained to ensure that they will result in subsequent shooting. As an indicator, the colour of culms can be handy during the selection process. Those exhibiting a shiny sheen should be assumed to be very young. A healthy clump can also be distinguished by the prolific shooting among individual culms.

Step3

Using a sharp panga/machete, holes should be made between the nodes (internodes). Care should be observed not to crack the culm towards the nodes to limit areas where pathogens can inhabit. The panga should be sterlised using a desirable antifungal agent.

Plate 4: A demonstration of the perforation process.

Step4

After perforating the culms, they should be taken to the green house where at least half a foot into the soil/other media (depending on culm size) has been dug. They should be laid in such a way that the nodes are facing either up or sideways. This is to ensure that the nodes will find space to shoot. The perforated side of the culm should always face upwards to facilitate watering.

Plate 5: Laying the culms in the greenhouse holes facing upward

Step5

The perforated holes will then be filled with water mixed with a fungicide.

Plate 6: Filling holes with mixture of water and fungicide

Step 6

The culms are then covered with sand or soil, and maximum care should be taken for the holes to remain uncovered with soil. The entire arrangement is then covered with polythene tube to increase temperature and humidity. Monitoring of shooting can begin after one week.

Plate 7: Polyethylene covered culms

Plate 8: Sprouting of new shoots

Plate 9: Good sprouting of shoots indicating root formation

Plate 10: Monitoring of shoot and root develop for separation purposes

3.3. First separation

After careful examination of shoot and root formation and the sprouts having attained about 1-2 feet, the culms are ready for initial separation. The sprouting culms having been confirmed that they have developed sufficient shoots and roots, are removed carefully. Using a sterilised hacksaw, splitting can commence at the nodes. At every node, only one split should be made preferably 5 cm from the node area. The resulting splitted materials are immersed in water containing a desirable fungicide.

Plate 11: Demonstration of first separation

Plate 12: Left, Separated seedlingscuttings in fungicide and Right, potted seedling

3.4.Subsequent separations/proliferations

This process involves further multiplication of the potted seedlings from the first splitting. This takes place after the original plantlet has developed more shoots and roots and has become hardy enough to allow further splitting. The plantlet should be uprooted carefully from the potting tube and immersed in a solution of water and fungicide. A hacksaw should be used proliferate your young seedling. Pot the proliferated seedlings in desirable tubes that will be convenient during transportation if no further proliferation will be done. Proliferated seedlings are placed back into the green house where they stay for two months before they are subjected to hardening process in 60% shade. This shade level can be achieved by constructing a simple shade on top of the seedlings using locally available materials.

Plate 13: A well rooted and multiple stemmed- seedling ready for proliferation

Plate 14: Using sterilised hacksaw to proliferate

4.0. USING CULM CUTTINGS

i. Good cuttings are obtained from culms of healthy clump about 2 to 3 years old.

ii. Two-noded cuttings leaving about 5-7 cm on either side of the nodes are then prepared from the cut culms. A sharp cutting knife or machete/panga is necessary. For bamboos with thin walls, use of a saw is recommended to avoid splitting of the cut ends.

iii. Some species like *Dendrocalamus hamiltonii* and *Bambusa vulgaris var. striata* propagate very well without any further preparation or treatment. These are directly stuck, one node into the soil, in a slanting position or buried in the ground. Rooting from the buried node and sprouting from the node above the ground occur readily. Two node branches of *D. hamiltonii* also roots and produce sprout easily, but these should be stuck into the ground rather than buried.

iv. For most of the other species, except for *Y. alpina* and *O. abyssinica*, some form of treatment may be necessary to enhance the rate of rooting and sprouting of cuttings. For these, an opening (about 2cm in length and 1cm in width) is made in the centre of the internode.

v. The most recommended treatment for root induction is the use of 1-Naphthalene acetic acid (NAA). This is prepared by dissolving 10g of NAA in 250 ml of ethyl alcohol (95%) in a container and stirring the solution gently. The solution is poured into a clean container and water added to make up 100 litres. Stir thoroughly to mix. The final concentration will be 100 mg/l of water or equivalent 100 parts per million (ppm). This quantity of solution is sufficient to treat 1000 cuttings. Small volumes can be prepared by use of equivalent amount of NAA.

vi. Pour about 100 ml of the solution into the culm cavity through the opening using a wash bottle or any other convenient apparatus to avoid spillage.

vii. Then close the hole by wrapping and tying with a polythene strip, ensuring that the wrapper is tight to prevent the solution from leaking.

viii. The cuttings are placed across the nursery bed, horizontally and, with the openings facing upwards.

ix. Note that culm cuttings should be treated with NAA as soon as possible (preferably the same day). If not possible due to distance from extraction site, the cuttings may be preserved by keeping in moist sawdust, but only for up to three days.

x. The prepared culm cuttings are then transferred into a raised 1-m wide nursery bed filled with a mixture of soil and sand. One week prior to planting, the nursery bed is drenched with an effective insecticide (eg. Aldrin or any other) and a fungicide to prevent termite and fungal attack respectively.

Plate 15: Potted cuttings showing shoot development

4.1. Propagation by seed

In general, bamboo only flowers once in its lifetime and dies off. Further, bamboo flowers at long intervals, mostly from 40 years and more for the local species and when this happens, the clumps of an entire area flower simultaneously. Although the flowering is gregarious in nature and produces vast amounts of seed, the seed is only viable for days or a few months. Therefore, on a regular basis propagation of bamboo using seed is unsustainable.

However, once a bamboo stand or clump has flowered, seed can be collected within the flowering period and seedlings raised as outlined below:

i. Because of poor viability of seed, it is more desirable to collect and sow the seed without delay.
ii. Sow seeds in the nursery bed or in polyethylene containers. Cover with a thin layer of soil and water daily. Watering should be done carefully using a watering can with a fine outlet.
iii. Prick out germinated seedlings from beds into soil filled boxes, polyethylene tubes or other nursery beds when about 3 cm high.
iv. After 8-12 months from the date of pricking out, good-sized transplants can be obtained. It has however been observed with some species that seedlings over 1 year old establish better. Where rhizomes of seedlings have not developed well due to inadequate supply of water or soil nutrients, such seedlings may be maintained in the nursery for over 1 year.

4.2.Use of Wildings

Apart from raised seedlings, wildings of bamboo from indigenous forest stands can be collected and used for raising a bamboo plantation. Wildings can be found in areas where bamboo has established itself for a long time such as Mt.Elgon, Mau, Cherangany and Aberdare ranges.

Young clusters of bamboo wildings can be scooped using a spade and taken to the nursery for individual pricking into polyethylene tubes. Care should be taken to avoid disturbing intact small wildings which resemble a mass of grass in the field. Small wildings of bamboo when pricked into tubes and kept under shade establish well. This method can raise many seedlings.

Once in the nursery and under shade, watering can is done regularly using a watering can with a fine outlet. Direct planting of large bamboo wildings has not been practised in Kenya. Most likely establishment would be poor due to disturbance of the rooting system during the uprooting from the forest.

4.3. Use of Offsets

Offsets (rhizome with attached section of stem) are commonly used but extraction of these is laborious. During extraction, damage may also occur to the roots, buds and rhizomes of mother clumps. Offsets are bulky and also difficult to transport. Only small annual planting programmes may therefore be possible when using offsets materials.

At the onset of rains (usually in April) and just before new shoots emerge, offsets can be obtained from bamboo stands as outlined below:

i. Dig out about 30-60 cm below ground for a rhizome of 1-2 years old culm. This can be recognised by the dark green colour and smooth stems.
ii. Once a rhizome is exposed, cut back the aerial culm to 60 cm in length and cut the rhizome off from the parent clump. Avoid injuring the junction of the culm and rhizome and the underground dormant buds at the base of the culm.
iii. Extracted offsets should be transported to the planting site without any delay (preferably the same day or the next) and planted immediately.
iv. Important precaution
    a) Offsets taken in the late rainy season after a new growth has started usually fail. Therefore, acquire your planting materials early as possible but timely.
    b) The younger the rhizome, the more the vigour in the buds.
    c) Larger diameter materials are better in establishment and survival.
    d) The larger the aerial culm, the better the survival.
    e) Avoid damaging the junction and the culm and rhizome and the dormant buds.
    f) Do not delay in planting offsets after digging them out. Early planting offsets root easily.

4.4 Tissue culture

KEFRI launched a program in 2004 to investigate the possibility of producing planting materials of bamboo by means of micro propagation or tissue culture in its laboratory at Muguga, attempts to micro propagate species such as *Y.alpina, B.tulda, and D.giganteus* have had limited success. Some positive results in generating shoots have, however been obtained for *B.tulda* and *D. giganteus*. Bamboo is not an easy plant to micro propagates and different protocols are required for each species. Success in shoot development is certainly an achievement, but the real challenge is the successful development of roots in sterile media (Brias, 2006).

5.0. NURSERY MANAGEMENT OF BAMBOO SEEDLINGS

5.1.Shading

Whatever planting stock is used (seedlings, wildings, offsets or cuttings) shade must initially be provided to protect them from direct sunlight. The shade, mostly of thatch or any other material could be removed during the onsets of cool weather.

5.2.Watering

Water is needed by young seedlings and cuttings in beds or polythene tubes. During cold weather, watering may be done once per day. In the dry season, watering should be done twice a day.

5.3. Treatment

After one month, it is recommended that sprouts from cuttings are treated with one effective fungicide (eg, copper sulphate) to avoid fungal attack. If necessary, farmyard manure may be applied to increase the vigour of the sprouts.

5.4.Mass Production (Proliferation) of seedlings

Growth of bamboo is supported by the development of system rhizomes. Establishment of planting materials depends very much on how well the rhizome system of a planting material is developed. Development of the rhizome system starts early in seedlings and the buried cuttings, and at some stage in the nursery and can be separated into several individual shoot. Proliferation is the method of separating developed system of rhizome in young nursery materials into many individuals. Such individuals are transplanted into polyethylene tubes that give them 'new' vigour of growth.

Where procurement of bamboo seed is difficult, available seedlings in the nursery are maintained through proliferation (mass production) while still carrying out annual planting programmes. Cuttings are also proliferated through initial separation of sprouted and rooted nodes, done by cutting at the middle. These are transplanted into separate containers and further proliferation can then be undertaken in the same way as seedlings.

Use fresh potting medium of forest soil and humus and new containers or polyethylene tubes each time in order to rejuvenate growth in separated shoots of seedlings. Multiplication of nursery seedlings should not be carried out in intervals of less than 6 months. This is to enable adequate development of a critical mass of a rhizome system in the containers. Watering in the mornings and afternoons should be strictly followed to allow for fast recovery of the disturbed system of young roots and rhizomes.

5.5.Hardening

Before planting, it is necessary to harden seedlings especially where some shading and frequent watering had been done. This is done by gradually decreasing the shade and watering levels and rates. Hardening can take one to two months. By this process, the seedlings are expected to withstand conditions in the field after planting.

6.0. FIELD PLANTING AND ESTABLISHMENT

6.1. Selecting the Planting Site

- Site selection for various species of bamboo is important in order to enhance management, field operations and healthy growthThe planting area should be selected and demarcated early, preferably before January or early February in the year of planting.
- Bamboo prefers loamy and sandy loamy soils, but what is more critical is good drainage since the crop cannot withstand water logging. Sloping land is thus preferable.
- *D. strictus* and *O. abyssinica* can withstand areas having annual rainfall of between 500 and 800 mm. The latter grows naturally under rainfall of even below this range. For reasonably good growth of the rest of the bamboos, rainfall should preferably be more than 1000 mm. the area planted should be protected against grazing and fire.

6.2. Site and ground preparation

- Planting sites must be cleared off bush, grasses and other unwanted vegetation. Clean cultivation may also be carried out especially where intercropping of bamboo with other crops is to be done.
- After ground clearing, chaining for planting spots is done at a spacing of preferably 5 by 5m for clump forming (sympodial) bamboo. Almost all cultivated species of bamboo in Kenya are of this type.
- Usually holes of about 45 cm square and also 45 cm depth should be dug around each stake in areas of medium to higher rainfall. Wider holes of up to 1metre in diameter are preferred in areas of rainfall less than 1000mm per year. The latter allows for improved microcatchment. In both cases the holes must be refilled with soil up to 10cm below the ground surface. Where necessary mix about 2kg phosphoric fertilizer of organic manure in the top soil in each pit.
- The density of bamboo plants per hectare (2.5acres.) using the above range of spacing will be 400-500.

6.3. Field planting

- Seedlings should be transported at the onset of the rainy season to ensure good survival. The rains also keep the soil moist enough to provide them with enough water.
- Planting of container or potted transplants from the nursery should be done immediately after the rainy season has set in.
- For offsets removed from the forests, planting must be done the same day with a maximum delay of one night.
- When planting the potting material should be removed before placing the seedling in the planting hole.
- The rhizome portion of the offset should be placed 10-20cm below the ground level and covered with soil.
- After placing the plant (either seedling or offsets) in the hole, cover with soil and always lightly press the soil around the plant.
- Where necessary and if financially possible, offsets may be protected against termite attack. The soil returned into hole is mixed with an anti-termite chemical.

7.0. PLANTATION MAINTENANCE AND HARVESTING

Silvicultural management of bamboo crop is heavily reliant on its growth habits particularly the way the rhizome spreads in the ground. Proper maintenance and protection of the plantation is highly important. This involves replanting, plant protection, weeding, general tending and sustainable harvesting of culms.

7.1.Weeding and mulching

- In drier areas, with rainfall less than 800mm, it has been found that mulching around seedlings encourages growth through reduced evaporation of soil water.
- Spot-weeding rids the seedling of competing weeds. This should be done at a radius of 60cm around the seedlings after out-planting. Weeding should be as regular as necessary to avoid competition from weeds.
- The soil should be loosened at least three times during the plantation establishment year to improve aeration.

7.2.Replanting

Normally, not all transplanted seedlings and offsets will survive the new environments .Plantations should therefore be visited regularly to check on their survival and replace dead seedlings and offsets. Replanting should be done simultaneously with the first weeding schedule. This is done in the subsequent rainy season when there is enough moisture until the second year.

7.3. Plant protection

- Bamboos are palatable to animals and especially in dry grazing areas where goats are left loose. It is necessary to carry out protection against goats and cows using simple sticks. These are stuck in the ground around the seedlings and made to converge above the seedling, forming a conical shape of protection.
- Where browsing may come from large animals some fencing maybe necessary to allow establishment of the bamboo seedlings. Patrolling the area regularly can also protect the plantation from foraging animals.
- Fire is a major hazard to a bamboo plantation especially during the dry season and in drier areas. To safeguard the area, fire breaks should be established. A 10m wide fire-line is enough to stop fire from spreading into the plantation. In some species, the amount of bamboo litter on the ground is too thick. During the dry seasons this needs to be reduced by collecting it and thus improving the degree of success in fire control.

7.4. General Tending

Depending on the intensity of weed growth, weeding and hoeing may have to be repeated in the second and third year.

- Soil should be heaped around the developing clump to allow and ease shoot production, which takes place mainly in the periphery of the clump.
- The very small and thin culms, broken and over-hanging culms, should be regularly removed to leave only clean culms standing within a clump.

8.0. UTILISATION

The bamboo craft industry in Kenya is still at a rudimentary level of development. Kenya has previous experience of technical cooperation related to bamboo with the International Network for Bamboo and Rattan (INBAR), the EABP, the International Development Research Centre ((IDRC) and government employee training particularly in China and India.

The WaTER Tower project approach to bamboo sector development in the Cherangany ecosystem is being adopted but not limited to the following approaches:

- The promotion of bamboo cultivation in private lands, as a cash crop using high yielding species for income generation and supporting bamboo based enterprises and trade.
- The conservation of Cherangany and Mt. Elgon wood forests through promotion of bamboo growing and consequently reduce dependence on wood.
- The sustainable management of bamboo to provide essential bamboo materials for traditional and commercial use in bamboo based industries, enterprises and handicraft sectors.
- Training artisans (producer groups) and strengthening their management and technical skills

The Kenyan economy is primarily agrarian with majority of farmers involved in small scale agriculture and a minority in commercial agriculture. Being a multipurpose, eco-friendly crop that can grow throughout Kenya, bamboo requires to be managed and exploited for sustainable use. Bamboo, therefore, represents an untapped major resource in Kenya whose full ecological and economic potentials remain underutilised. Planned and sustainable utilisation of forests containing bamboo is feasible and could go a long way in providing self-employment and job opportunities to the rural population.

Utilisation of bamboo in the country is still localised to basic domestic use. Fencing, basketry and food storage containers are among the uses of bamboo especially in areas where the resource is available on farmlands. These products are made with minimum processing with the skills passed down to artisans by older ones. Current demand for bamboo surpasses the supply. The presidential ban on bamboo harvesting in government forests has aggravated the situation.

8.1. Promising opportunities in the bamboo sector

Bamboo is appreciated as the most economically important non-timber forest product (NTFP) for humans in terms of scale. In China it is referred to as ‘the friend of the people’, in India it’s ‘the wood of the poor’ and in Vietnam ‘the brother’.

The world’s bamboo industry is recording tremendous growth that is foreseen to expand further. The global bamboo market, led by China, is worth USD 7 billion per year. Traditional markets involved in handicraft making, traditional furniture and bamboo shoots hold almost 95% of the global market by value. Emerging industries, targeting contemporary markets provide an opportunity with potential for growth. The latter markets are projected to compete with traditional markets and claim about 45% of the total bamboo market over the medium term.

8.2. Acceptability of products

Bamboo products are relatively new to Kenyans and much needs to be done in convincing the population to accept bamboo as a substitute to wood. Experience by KEFRI and bamboo artisans has shown that products made from bamboo, especially when value addition is done, have more appeal compared to wood products and only need a higher level of acceptability for adequate uptake to shape up and bamboo to position itself as an income generating activity. To achieve this, more people should be trained in the propagation and cultivation of bamboo as well as processing of bamboo.

8.3.WaTER Tower Utilisation Approach

The WaTER Tower Project aims to involve local communities, in the two ecosystems, especially those with low incomes and with proximity to forests, to be part of the bamboo economic network so as to increase their income. For adoption and accelerated uptake of bamboo processing and utilisation, a 'small technologies' approach would be more effective for the project objectives at the village level. This approach targets non-powered machines, treatments, colourings, setup fixtures and finishes. This approach will encourage sustainability as well as ensured continuity of the project after exit of donor. Further, considering the level of income of the target communities across the ecosystems, starting with easily to find or make tools and equipment will encourage uptake and diversification of product range.

The approach in this project will target three areas: firstly training of artisans in making basic products and introduce complex furniture as trainees gain confidence, secondly, the project will aim at increasing the overall productivity of products and lastly target sustainability of production of products by building capacity of artisans and identifying viable sources of raw materials. If properly managed, bamboo has the potential of reducing reliance on the wood forests while at the same time lead to creation of new employment and income generating activities across the project area. The project will encourage a business model that introduces the trained artisans to existing bamboo products artisans and networks which will ensure collaboration in marketing, development of a diversified product range and information sharing of raw materials sources. The networking will also allow other opportunities to artisans such as:

- Access to knowledge and local networks
- Assured sales
- Fair prices
- Technical assistance
- Technology and knowledge transfer
- Strategic positioning
- General involvement in a business environment

WaTER Tower Project will endeavour to promote formation of groups from the cohort of artisans trained; this will mainly involve artisans from the same county. The promotion of groups is informed by the need for artisans to produce a wide range of good quality products. Also the groups will facilitate linking their products with markets.

Further, the networking will allow for sustainability of the project when the donor and the implementer (KEFRI) exit the scene.

8.4. MATERIAL PROPERTIES OF BAMBOO CULMS

Material properties of individual bamboo culms develop and change every year. Knowledge of the material properties of bamboo, particularly in relation to the age and parts of the culm, is essential for selecting raw materials for bamboo products.

8.4.1New culms

Culms that are less than one year have very soft tissues containing high water content. The fibres are soft and lack sturdiness essential for bamboo products. They are susceptible to insect and fungal attack as well as rotting.

8.4.2 Lignification

As culms mature, lignification takes place; this process involves the thickening of plant cell walls through deposition of lignin, making the culms harder and woody. Lignin introduces the sturdiness required from bamboo material.

8.4.3Maturity

The age when the bamboo culm attains maturity is when it has reached the peak of its species specific biological, chemical, and mechanical properties. Small sized bamboo species attain maturity around 2 years, medium sized bamboo attain maturity around 3-4 years while some giant bamboo species mature within 4-5 years.

8.4.4 Deterioration

In the years following maturity, the bamboo culm gradually becomes old and weak. Culms that are not harvested will eventually dry out, die, and decompose. As a general rule, the vitality, quality, and strength of culms deteriorate substantially 3 years after they reach their peak of maturity.

8.4.5 Properties along the length of the culm

The properties of the culm differ in varying degrees along its length. In particular, the fibres of the lower part of the bamboo culm are generally more tender and flexible compared to fibres in the higher section or tip.

The base and middle sections of the culm are closer to the roots and rhizomes which supply food and energy to the whole plant. Moisture and nutrition follows an upward path along the cells of the culm, diverting throughout the branches and foliage, and extending towards the tip of the culm. Accordingly, there is greater moisture in the cells and fibres of the lower and middle culm sections, than in the upper sections. The upper portion and tip of the culm receives direct sunlight and more heat in comparison to the lower portion, which is shaded by the canopy of foliage. This component of solar radiation also contributes to the properties of fibres at various levels of a culm’s height.

9.0. SELECTION OF BAMBOO RAW MATERIALS

Selection of bamboo material is critical both for woven and furniture making products. Care should be exercised not to rush when selecting materials. Culm length, age, and growing environment are the main criteria for selecting bamboo material.

9.1. Properties for specific applications

The raw material required hugely depends on the final intended product. Young culms, less than one year, are appropriate for finishing strips for weaving. The base and middle portions of the culms are ideal since they are tenderer than the upper part of the culm. Bamboo culms for furniture products should be older than three years.

9.2.Determining the age of bamboo culms

This is an essential skill for artisans in bamboo trade. There are three methods used:

9.3Colour of the culm

This can be relatively easy for new and young culms and become increasingly difficult as culms get older. One year old culms have a distinctive sheen, irrespective of the colour of that bamboo species. Bamboo species with green culms exhibit a dark green colour at age one, and this colour fades as they age. It becomes difficult to distinguish culms aged between 2 and 3 years. Soil characteristics and climatic conditions become major influencers of colour at these ages. Therefore, giving definite years of bamboo culms using age becomes difficult and can only be done by someone who has observed the pattern of colour change of a given species, annually, in a given location. Use of culm colour can only be used at best to determine if a culm is young, mature or old. However, the estimate can be off the mark with several years. As a rule of thumb, culms to be used in furniture making should not be shiny and should be less attractive to look at.

Plate 16 Numbers on the culms indicate age. Notice how sheen is reduced as culms age

10.0. HARVESTING

10.1 Selection of culms

Culms should be selected based on the product intended. For weaving, one year old culms should be used. The thickness of the culms is important as it will influence the number of strips to be made from the culm. Older culms, between 3 and 5 years should be selected for furniture making. As a guide, a minimum diameter of 3cm and culm walls of more than 5mm should be used. In the country, *Yushania alpina* is used in making furniture, but sourcing raw materials of introduced species which have larger diameters is encouraged.

11.0. PREPARATION OF CULMS

Every stem should be washed using scourers in order to remove lichens and fungus on the outer skin of culms.

Plate 17 Left, bamboo that has not been scoured and right bamboo that has been scoured

11.1Primary preparation

Basically this involves cutting of culms to required sizes. Hacksaws are preferred in order to have even edges and reduce wastage occasioned by using machetes. Protruding areas especially around the nodes can be removed using sharp knives while taking care not to puncture the culm.

11.2 Secondary preparation

This is intended to remove gums and reduce the starch content. Gums are removed to provide the culm with an even colour while starch is reduced to minimise attacks by fungi and insects. Traditional methods used to remove gums can be classified into dry and wet processes. In the dry process, fresh bamboo culms are heated at 120^0c. Gums and water then exudes from the culms and is wiped off the culms. In the wet process, culms are immersed in boiling water for 1-2 hours or immersed in caustic soda solution (0.2-0.8% concentration) or sodium carbonate solution (0.2-1.2% concentration) for 10-15 minutes. Exudates from the culms are then wiped off dry.

A common traditional method to remove starch from the culms involves immersing the culms in water for 90 days (Sulthoni 1987). Another method practised in parts of India involves felling culms and leaving them upright in the sun with branches still attached for two weeks. Branches are then removed and the culms left upright in the shade for two months (Kaley et al. 1993).

The conventional method of treatment using chemicals involves use of borax. Here, borax and boric acid solution at 4% concentration (Liese 1990): 2 kg of borax and 2 kg/Litres of boric acid

for every 1,000 litres of water. After one week of the culms being submerged in a tank, culms are removed and put upright in sunlight. They should be turned constantly to avoid cracking as moisture is lost.

11.3. Chemical treatment

Borax has been used in Europe for generations and has proved to be cleaner and cheaper. Borax is an important boron compound that occurs naturally due to evaporation of seasonal lakes. It consists of colourless crystals that dissolve easily in water. Borax is available in granulated or powder form as boric acid and borax oxide. In Kenya, a 25 kg sack of boric acid powder goes for kshs 23,000. Smaller quantities that are affordable and practical for artisans with small quantities are available.

Preservation of bamboo is achieved using a 5 % borax solution, which is pH neutral. To attain the pH solution equal amounts 2.5% of boric acid and 2.5% of borax oxide, both in powder form, are mixed in water. This mixture can remain active for up to 2 months. Always avoid concentrations of borax that are more than 5%.

1000 litres of borax solution will require one 25kg sack of boric acid and one 25kg sack of boric oxide. Depending on size, this solution can be used to treat more than a hundred culms.

This treatment involves immersing bamboo in the borax solution. To allow the solution to enter the whole length of the culm, areas around the node should be perforated. The borax solution slowly permeates in to the culm tissues through osmosis. It is advisable to perform treatment when culms are wet to allow penetration of the preservative. Boron molecules will not penetrate dry culms and it's a total waste of preservative trying to treat dry culms.

High levels of borax in the treatment solution can be checked by looking out for white powder forming on culms surfaces. This is due to the fact that water molecules are the first to be absorbed followed by born molecules. To mitigate this, water should be added to the solution and hence reduce wastage of chemical that will not be used in the treatment.

12.0. BAMBOO PRESERVATION AND TREATMENT

Bamboo culms are rich in starch and sugars which makes them highly susceptible to fungal and insect attacks. This has been a major hindrance to its value and wider application. The lifespan of bamboo that has not been preserved is about 2 years. However, preserved bamboo can last up to 20 years.

Plate 18: Bamboo drying shed

Local communities and artisans have long used traditional methods for bamboo preservation. Although these methods provide some form of protection, long-term durability is not guaranteed and these methods should not be recommended for commercial products.

12.1. Bamboo Preservation Methods

For local communities, without adequate resources, there exists simple and efficient ways of preserving bamboo. Two of these methods include follow almost similar processes are; vertical soak and horizontal dip diffusion.

12.2. Preparation of Bamboo Culms for Treatment

12.3.Sizing culms

The length sizes to be cut depend on the end product proposedFor construction purposes, 6 metre culms are cut. Therefore the end application will determine the length.

12.4.Perforation of the culms

This is mainly done to facilitate the treating formulation to move throughput the culm. A long rod can be used to puncture the node areas or if available a drilling machine connected to a long metal rod can be used.

Plate 19: Perforating bamboo culmns

It is important to note that the punching method is dependent on the treatment method. In the case of vertical soak diffusion, punch all nodes except the bottom node. In case of horizontal dip diffusion, all nodes should be perforated.

Three methods are applicable in this treatment type but they yield different productivity levels of equal efficiency.

Option 1: fast method (Hot)

Up to four full loads of bamboo can be treated in a day. 5% borax concentration is prepared and mixed with water in a heated trough. Adequate fire should be maintained to ensure the temperature of the solution ranges between $70^0 – 80^0$C. Culms should be immersed in the heated solution and weight placed on top, preferably concrete, to ensure all culms are fully immersed. Boiling time is dependent on the size of culm walls, thin culms take between 1-2 hours while thick walled culms take 2-3 hours. Monitor the borax levels constantly and add as required.

Plate 20: Treatment of bamboo culmns

Option 2: Slow method: (Hot and Cooling down)

Two full loads can be done per day and the temperature should be maintained at 80^0C. Repeat the process of adding 5% borax while heating the solution. Allow the fire to die off gradually allowing the culms to be soaked in the warm solution for about 4 hours. The treatment of one load full might take about 6 hours.

Option 3: Cold Method

A metal or concrete trough is ideal in this method.The perforated culms should remain in the borax solution for 7 days. Using this method one load of bamboo can be treated every 7 days (one week).

Plate 21A metal /concentrate trough

13.0 DRYING

The culms should be dried away from direct sunlight to avoid cracking and deformations. An A-frame should be built to support culms during drying. The base of the A-frame should be supported by diagonal bamboo culms to hold weight.

Plate 22: Drying bamboo culmns away from direct sunlight

Poor quality culms can be used at the base of the frame to provide some elevation. In case of direct sunlight, the culms should be changed positions as many times as possible. After drying under the right conditions, the culms can be moved to the storage area after 1 month.

14.0. Pests and products

One of the major challenges to bamboo products is insect and fungal attack. This can occur in a relatively short period. It mostly results from poor treatment and preservation methods but can also be occasioned by prevailing elements the product is exposed to. The most common insect is the 'powderpost beetle'. Its damage is manifested by a talcium-like yellowish powder accompanied by small holes on the nodes and along the internodes.

Whereas it might not significantly affect the structural integrity of the product, the holes and emanating powder makes products unattractive. Consequently, these blemishes reduce sales and reduce consumer confidence. Use of natural salts especially borax and boric acid during treatment will prevent attacks.

15.0. BAMBOO POLICY STATUS

Considering the ecological significance and vast economies potential of bamboo in Kenya, the suggested aims and objectives of a new bamboo policy should include the following:

- Protection and preservation of mountain ecology and bio-diversity; protecting the mountain slopes by affording protection to bamboo forests and bamboo regeneration areas for sustained productivity and environmental security for the people.
- Promotion of private bamboo plantation (individual and community owned) as the key thrust area for future economy of the adjacent economies.
- Sustainable development and improvement of bamboo productivity on farms and forest reserves through improved silvicultural practices thus making bamboo plantation a profitable and attractive economic enterprise for securing adequate return on investment.
- Promotion of bamboo based industries at small, medium and large scale levels with improved technology for utilizing the available resources in a sustainable way.
- Promotion of bamboo sector development as an essential component of rural development strategy linked with forestry and agribusiness sector promoting rural employment and enhancing household incomes.
- Promotion of enterprises manufacturing bamboo based products and wood substitutes thereby reducing pressure on forests and reducing the already high wood deficiency in the country.

12.0. APPENDIX 1

12.1. BAMBOO SPECIES INTRODUCED TO KENYA

Botanical Name	Form of Introduction	Origin
Arundinaria alpine	Offsets and wildings	Kenya
Bambusa vulgaris	Offsets	India
B. vulgaris var. striata	Cuttings	Asia
B. bamboos (B. arundinacea)	Seed	Thailand and India
B. nutans	Offsets	India
B. thornicornis	Offsets	Asia
B.tulda	Seed	Thailand and India
Cephalostachyum pergracile	Seed	Thailand
Dendrocalamus brandisii	Seed	Thailand
D.hamiltonii	Seed	India
D.membranaceus	Cuttings	India
D.strictus	Seed	Thailand
D.aspera	Seed	Thailand and India
Oxytenanthera abyssinica	Offsets	India
Phyllostachys pubescens	Seed	Zimbabwe
P. nigra var. henonis	Offsets	Zimbabwe
Shibataea ruscifolia	Seed	Japan
(syn. S. kumasasa)	Offsets	Asia
Thyrsostachys siamensis	Offsets	Asia
	Seed	Thailand

13.0.APPENDIX 2

13.1.A GROSSARY OF SOME TERMS USED IN TEXT

Clumps-A cluster or group of bamboo growing from a common underground rhizome system

Culm-A stem of bamboo plant

Cutting cycle-period between stem cutting or harvesting from a clump and the next time cutting is done in the same clump or bamboo stand. Cutting cycles are series of cuttings or harvest taking place in a regularly repeated order.

Monopodial Bamboo-Type of bamboo formation that spreads by underground rhizomes or stolons. Most of monopodial type of bamboos are found in the temperate climatic conditions.

Offsets-A dug out rhizome with a short portion of a culm (about 50cm long) attached.

Sympodial Bamboo- Type of bamboo formation that displays distinct clumping in their development and growth. Sympodial bamboos grow mainly in the tropical climatic conditions.

Plantlets- Smalls plants that develop from mass of cells (callus) of plant parts being used in mass propagation of bamboo through culture technique.

Rhizome-Thick, horizontal stem bamboo just below the ground, from which new shoots and roots grow.

Plant Tissue culture-Several techniques that together enable the nurturing of a plant organ, tissue, cells or even cells without walls in a controlled nutrient medium. The technique is useful in mass propagation of plants.

Wildings-Seedlings germinated in the wild under natural conditions after bamboo plant has flowered and produced seed.

14.0APPENDIX 3

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