Exploring the Neglected Potential of Bamboo Cultivation and Utilization in Nigeria for Sustainable Development: An Overview

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***Abstract*- Among the most important minor forest products, bamboo has continued to gain recognition as a multipurpose plant and as a valuable timber substitute worldwide. As such, the exploration of its potential from the present state of underutilization in Nigeria will contribute meaningfully to the realization of agricultural sector as a way of diversifying the economy that could engender national development in sustainable engineering solution, energy, industrialization, employment prospects and food security. The paper explores specifically the potential of bamboo, provides information on its cultivation and made appropriate recommendations. The understanding of the potential of bamboo would not only help a large section of stakeholders but will also prove beneficial to policy makers, funding agencies, and Non-Governmental Organizations embarking on its cultivation and utilization.**

***Keywords*: Bamboo Potential, Sustainable Engineering Solution, Energy and Industrialization.**

I. INTRODUCTION

Prior to Nigeria's political independence, agriculture was the mainstay of the economy. It account for 88% of the non-oil foreign exchange earnings, produce job for over 70% of the active labour force and contributes over 40% of the gross domestic product (GDP) (Iwala, 2007). However, with the discovery and exploitation of crude oil in the early 70's,these shift the government attention from agricultural sector to industrial sector. Agriculture's contribution to GDP started to decline rapidly from 65.7% in 1980's. The aftermath of the relegation manifest itself in raging food prices, high food import bills, hunger, malnutrition and disease among others.

Today, Nigeria with a population of over 180million is witnessing fiscal turbulence (with oil prices crashing from over $100 per barrel in first half of 2014 to $43 per barrel to $43 per barrel in 2015 and $75 as from April, 2018) and rising unemployment rates(with 1.9million economically active person within the age bracket of 15years joining the youth labour market) (Punch, 2015) despite the fact that, it is endowed with 91.1million hectare(ha) of land and 1.3million hectares of water bodies, consisting of agricultural area of 83.6million hectares(which comprises arable land (33.8%), and permanent crop (2.9%), forest or wood (13.0%), pasture (47.9%) and irrigable land orfadama(2.4%)) (Adetunji, 2006).

To reverse this trend, Nigeria leadership at present has mouthed the need to diversify the economy and to wean the nation from oil dependence with a return to agriculture. Emphasis has been made on various enterprises that encourage self-reliance, cheap input, quick return on investment and income generating activities. It has become imperative therefore to turn attention to the exploitation of underutilization of bamboo plant. Presently, bamboo production is largely uncoordinated and value added products are almost negligible as technology is either absent or at sub-optimal level and has received but a fraction of the attention it should have been accorded by civil and bio-environmental engineers, agronomist and agricultural policy makers in Nigeria. Rather, greater focus has been placed on the production of timber tree species and lately medicinal plants. Whereas, its potential has been fully annexed in countries like China, Indian, Ghana, Kenya, to mention but a few.

Bamboo is a group of perennial evergreen in the grass family *Poaceae* and includes the largest members of the grass family. It is an ancient woody grass widely distributed in tropical, sub-tropical and mid temperate zones (Hunter, 2003; Akayode *et. al*. 2016). It is in recognition of the importance of bamboo production and its potential in sustainable engineering solution, energy, industrialization, job creation, environmental development and food security that this paper was undertaken underscoring the need to boost its production.

II. OVERVIEW OF CURRENT GLOBAL BAMBOO TRADE AND PLANTATION

The world market for bamboo was valued at 10billion dollars in 2001 and grows to 29billion in 2015(Pande *et. al*, 2015). India, China and Myanmar together have 80% of the world's bamboo.

With about 22 genera and 130 species, Indian is the second largest reservoir of bamboo, next only to China. Indian share in the global bamboo market is estimated to be one billion dollar in 2012 and 5.7billion dollars in 2015 even though, it exploits only one-tenth of its bamboo producing potential. (e.g. forest area occupied by bamboo is 80.428million tonnes out of which approximately 42.27million tonnes is in Northern Eastern States only (Nimachow *et. al*., 2010) National mission on bamboo applications has been specially created to address the issue of value addition of bamboo

residues (Pande, *et. al*, 2015). In the same vein, China has estimated 4.2 million hectares of bamboo plantations, captured 50% of the world market, exploiting as much as 20 million tonnes of varied products a year. India, almost 20 years behind China in commercial production, produces only 3.5million tonnes of bamboo a year (Wageningen Food and Bio-based research, 2013)

There are 1,500 bamboo species in the world and more than 20 million hectares of bamboo plantation (Eco energy solution, 2015).Out of these 1,500 species, a number of them have been identified as priority species for research and development, for their current and potential role in industries, ecological services, and rural development. Three of these species include *Phyllostachyspubescens, Guaduaaugustifolia Oxythenanteraabyssinica*, representing the continents of Asia, South America, and Africa respectively.

Studies by Wageningen Food and Bio Based Research,(2013) revealed that, other nations in both tropical and temperate regions are lesser known for their, often considerable reserves. The internal market and trade of bamboo and bamboo products are still mostly informal and do not enter economic or trade statistics. For example Peru's Alto Purus region has approximately 2.5million hectares of tropical rain forest dominated by bamboo species and Chile has around 3.5million hectares of temperate forest with presence of bamboo species.

Africa too has large areas of natural bamboo stands. Ethiopia can boast of largest bamboo coverage in Africa, with over 1million hectare of savannah bamboo (*Oxythenanteraabyssinica*). The dominant bamboo in Nigeria is commonly referred to as the Indian bamboo species *Dendrocalamusgiganteus*, other lesser species are *Dendrocalamussinicus and Phyllostachysheterocycla*. They have similar morphological characteristic; though there is variation in size, suggesting influence of age and perhaps the soil condition. They are particularly adapted to the rain forest belt of Nigeria (Eastern and Western regions) where it is found in abundance along riverbank and other relatively marshy areas, and are majorly used as scaffolding material, fencing, yam stake, handcraft, as pillar to provide temporary support for the decking (Ogunwusi and Onwuahi, 2011)

Potential for Bamboo Production and Cultivation

Bamboo is considered as one of the most sustainable versatile biomass crops that find traditionally a wide application throughout the tropical and sub-tropical parts of the world as substitutes for timber products. The potential role of bamboo in engineering, industries, agronomy, job creation, food security, and rural livelihood are discussed below:

1. *Sustainable engineering solutions for energy and industrialization*

a. Alternative to steel as building material

Bamboo is an excellent sustainable building material, it is very strong with high tensile and comprehensive strength and because of its flexibility, bamboo housing can withstand high wind and even hurricanes without falling and apart from this, bamboo housing is very well ventilated which is a benefit for the tropical climate (Janssen,2011)

In Nigeria, one of the basic needs of people which have frequently remained unsatisfied is adequate shelter. With the development of bamboo as locally made building material for use in low cost residential housing, there will be increasing chances that Nigerians hoping to own houses may do so. Falade, (2009) discovered that, bamboo is a better and cheaper alternative to steel reinforcement for beams and columns in low-cost houses and as it had comparative advantages over steel reinforcement. It cannot suffer corrosion; it absorbs water and has high fiber content. It is cheaper and locally sourced. It is cost-effective while its inclusion in concrete beams increases the load-carrying capacity of the beam in low cost houses. He added that, the use of the bamboo would reduce the cost of reinforcement by 30 percent depending on design, location of site and other variables.

The design equation for the determination of the appropriate size and quantity of bamboo splits that will be required to resist applied load in any structural member has been developed with the cost analysis based on the replacement of steel with bamboo splints reduced the volume of concrete by 2.54% while reduction was 0.65% for steel production for steel reinforced beam. The cost of bamboo reinforced beam of the same section was found to be 22.82% cheaper (Falade, 2009). This is because a large proportion of the quantity of reinforcement that we use in Nigeria is imported and as such the cost of steel has been increasing consistently over the years to the extent that, the material is no longer affordable to the low and medium groups (Falada, 2009). The cost of steel per tonne in 1993 was ₦24, 000.00, it rose to ₦ 165,000 in 2008, and ₦140, 000.00 in 2015 respectively.

In Latin America, building social housing is one of the most relevant bamboo uses, e.g. in Ecuador (city of Guayaquil, with 1 million inhabitants), 50 percent of the population live in houses made of bamboo. Such houses have also been massively used in Colombia. Costa Rica has adopted a strategy to generalize social housing buildings of bamboo. In Ecuador, the Foundation- Hogar de Cristo has built over 100,000 bamboo social houses in 33 years and 75 houses are already daily delivered to families in need (FAO and INBAR, 2006). From the fore-going, Nigeria will need to embrace bamboo as a locally-made material for their housing projects.

b. Architecture

Bamboo (especially *Guaduaangustifolia)* has established itself as an interesting structural and decorating material for modern architecture (both in garden and in art). For example, architects in Colombia, Ecuador and Bolivia have been proposing innovating building based on bamboo and have achieved the acceptance of *Guaduaaugustifolia* as construction material even in countries with such strict regulations as Germany. Moreover, natural catastrophes such

as the earthquake of Armenia and Colombia have validated the anti-scismic characteristic of bamboo as a structural material (FAO and INBAR, 2006)

c. Bio-based energy resource:

Bamboo has got huge potential to bring revolution as a bio-energy/ renewable energy resource through bamboo gasification and further value addition of the residues Eco-Energy Solutions (2015) opined that, it has a number of desirable fuel characteristic such as low ash content and alkaline index. Its heating value is higher than most agriculture residues, grasses and straw. Besides, bamboo has high biomass productivity, self-regeneration, sustainable basis and environmental friendly.

Under gasification in which a solid fuel is burnt at very high temperatures between 700^{o}c and 900^{o}c in the presence of a gasification agent such as air will separate heat through exothermic reactions or indirectly transferring heat to the reaction from the outside, the energy present in the biomass is converted into a gaseous combustible or chemical energy. (Eco Energy Solutions, 2015). When whole crop bio refinery is targeted, the aim is to utilize fixed Carbon dioxide (CO_2) in the biomass at its full potential. Biorefinery is often primarily designed to extract valuable constituents such as sugars, proteins, fatty acids, while the remaining biomass residues are disposed of as renewable waste and commonly are burned Whole crop biorefinery, however, will also exploit these residues, such as pentosan, or lignin, as a source for manufacturing "green chemicals".

Gas products are easier to handle, they can be used in combustion engine or gas turbine and combustion is clean and less polluting. The produced gas has a colorific value of 25-30 percent of natural gas and is a valuable source of bio-energy for a variety of purposes (eco-energy solution, 2015)

However, in Nigeria today, a substantial number of villages in our country are still neither electrified nor energy secured. Even electricity in towns and cities, conventional fossil fuels like coal, oil, etc are used but they have limited storage, and their pollution activity has introduced the problem of global warming even though, power supplies are epileptic. The situation is deteriorating and bamboo has got potential to tide over this problem and ensure energy security. Thus, small scale bamboo bio-energy power plant can be developed for areas that lack electricity and with this micro enterprise, it could create job for lots of people. The test and analysis conducted by MITCON (a company in India.)have shown that 1.2 kilogramme of bamboo biomass can generate 1kWh of electricity (Eco-energy solution, 2015). Nigeria needs to take a clue from this.

d. For drip irrigation:

Ogedengbe, (2013) reported that, bamboo pipes were effective in carrying out drip irrigation just as it was utilized by Japanese during the second world war to supply water to some of their cities when there was shortage of raw materials to manufacture pipes and by Tanzanian government to supply portable water to some Rural communities because of reduced cost of procurement as compared to the manufactures pipes.

Ogedengbe, (2013) reported the use of bamboo pipe-like aerial stem (culm) as a promising substitute for irrigation pipes in agricultural land where medical infusion tubes (medi-emitters) were forced fixed on the prepared bamboo pipes irrigation unit to act as emitters or drippers with *Amaranthushybridus* as the test crop. The diaphragm at the node that causes discontinuity (as water conveyance material) is removed using drilling bit to make way for a hollow length of bamboo for water conveyance. The flow rate was 0.042-0.117 litre/hour. Emitters co-efficient of discharge and Christiansen Uniformity Co-efficient varied between 1.82-3.38 and 96.20-98.86 percent respectively, which were within acceptable limits. The maximum yield of *Amaranthushybridus* was 4.6 kilogramme per meter square (4600 kg/ha) with the medi-emitters discharging at 20 drops/minute, a high yield per hectare for an irrigated vegetable. Thus this will afford resource poor farmers who cannot afford the purchase of manufactured pipes the potentials of conveying water for irrigation practice on their small farm holding. Most of these peasant farmers lived in rural communities where bamboos are found in abundance. This is also a new dimension in affordable drip irrigation, technology and an avenue to exploit local and cheap materials whose propagation should emphasized.

2. Bamboo Potential in Industries

a. Bamboo pulp and paper:

Bamboo has a high cellulose (40 – 60%) and low hemicelluloses content, and the fibres are strong, long (2.0 – 3.0mm), have a high length to width ratio and thick walls which are beneficial for paper making while bamboo culms are excellent raw materials for processing to different kinds of paper. (INBAR, 2016).

Global dwindling forests and shortage of wood supply has made pulp and paper production for the world market increasing and requires large amounts of raw materials (FAO and INBAR, 2016). Different pulp grades can be made from bamboo pulps that find various markets for value addition. Most bamboo pulp is used in the internal Chinese markets while less than 100 tonnes per year is exported worldwide (Wageningen, Food and Biobased Research, 2013). In Brazil, the foremost industrial experience for bamboo massive utilization is found in Itapage company which has an installed capacity of 72,000 tons/year for bamboo based paper production, and a medium-term increase of 144,000 tons/year is projected. (FAO and INBAR, 2016).Only about 7% of the world's virgin cellulose pulp is made from non-wood sources (mainly straw, bagasse, and bamboo). In the EU, US and Canada paper industries practically only wood pulp is currently used (FAO and INBAR, 2016).

b. Bamboo Composites, Panels And Boards:

The current industrial bamboo composite materials, panels and boards and veneers are manufactured by utilizing synthetic resins to glue the particles. Novel developments in the bamboo composites are reported with renewable polyesters, polyesters, polyamides or bio-basedpolynylene (Wageningen, Food and Bio-based Research, 2015). The bamboo panels and flooring industry has been developed in Colombia since 2006 (FAO and INBAR, 2006)

c. Bamboo Textile

Like wood based pulp, bamboo pulp can be further purified into dissolving cellulose, which is used as feedstock for the production of cellulose textiles and cellulose derivatives. Regenerated cellulose (viscose-rayon) is by far the largest of the cellulose derived biopolymers (3.5 million tons world-wide), followed by cellulose esters (> 1 million ton) and cellulose ethers (< 1 million tonne). More than 60% of chemical grade pulp is used to produce regenerated cellulose, mostly from wood cellulose. Regenerated cellulose is used to produce both fibers and films. (FAO and INBAR, 2006) The textile fibers are economically much more important than films.

FAO and INBAR(2006) reported that, Bamboo viscose fiber is marketed in China as a very versatile textile raw material that competes with synthetic textile yarns and natural fibers like cotton, wool, linen and silk. Exceptional qualities have been claimed for bamboo fabrics. In apparel, it offers a high wearing comfort by being soft, cool and highly moisture absorbent. Bamboo fiber fabrics have a silk like feel and appearance. The fabrics are advertised to be extremely cool and moisture absorbing due to the micro-structure in the fiber, and combined with anti-ultraviolet properties it is especially suitable for comfortable and safe clothing in warm climates. The anti-bacterial and bacteriostatic properties of bamboo textiles are ascribed to a biological active non-allergenic component called “bamboo kun” that is reported to be present in the bamboo stems. This substance that is believed to protect bamboo plants from diseases and pests is (re)combined with the bamboo cellulose for obtaining these antimicrobial properties.

Because of the relative short fiber cells of bamboo the fission process of bamboo into small and even fiber bundles like in bastfiber crops (flax, hemp) is difficult to achieve. However, in China some bamboos have been shown suitable for bamboo linen production. The use of retting procedures and enzymes in the degumming process provides tools for controlled fiber bundle production (FAO and INBAR, 2006).

d. Bamboo Chemical

So far, the enhanced use of extractives from the process for cellulose production has been investigated for different related resources such as sugar cane bagasse, *Miscanthus* or sarkanda grass. The black liquor from bamboo pulping or digested fermentation feedstock from bio-refinery has potential use as feedstock for ‘green chemicals’ and resin production (FAO and INBAR, 2006).

Bamboo non-cellulosic polysaccharides or hemicellulose is mostly composed of xylan. Xylan is a C5 sugar (pentosan) that has been studied for conversion into many food and non-food applications, sweeteners (xylitol) or liquid fuel solvents or chemicals. For example, furfural is produced in acid catalysed processes from pentosan and may be converted into furan resins by hydrogenation and controlled polymerization of the furfury alcohol. New catalysts for the hydrogenation process are patented. Another approach for the production of ‘green’ chemicals from biomass are the hydrothermal cracking processes, similar as is common in petrochemical industries (FAO and INBAR, 2006).

e. Bamboo for energy application

Bamboo charcoal and briquette production is a simple technology that is used in China and promoted in African countries such as Ethiopia, Kenya and Ghana (INBAR, 2006). Nigeria too would need to adopt this technology in views of the fact that high cost of energy (conventional electricity and kerosene) and furnish/ furnishings increases inflation rate (e.g. inflation rate moved to 16.5% in June 2016 from 15.6% recorded in May 2016. The implication of little above 1 percent increase inflation rate is the loss of value of the Naira by the same percentage or increase in prices of goods by the same margin, (Guardian, 2016).

3. Agronomic Potential

a. Control of soil erosion, water conservation and land rehabilitation: Bamboo cultivation appears to be highly promising for the reclamation of small and medium gullies instead of putting them under permanent vegetation of grasses and trees, since the country cannot afford to retire much of these degraded lands from economic production. In Indian for instance, bamboos are grown in steep hillsides and along the bank of river. Its interlocking root system and leaf deposit inhibit soil erosion (Pande*et. al*. 2015)

b. Easy harvesting and short life span: Production of bamboo is reputed to improve with the age of plantation, though the percentage of new to old culms decline with age. Harvesting of bamboo is started after 4 years with 10 old and 3 new culms available per clump in the ravine land (Dhruva-Narayana, 1993).

c. Benefit for living biomass and soil organic matter content: A bamboo grove releases some 35 percent more oxygen into the air than a similar sized stand of trees and it matures (and can be replanted) within 7years (compared to 30-50years for a stand of trees), helping to improve soil health and prevent erosion along the way (Pande *et al.*, 2015).

d. Fast growth and yield: Bamboo is so fast-growing, that it can yield 20tonnes more timber than trees on the same area. (Pande *et. al*., 2015).

e. As fenced and stake material: Bamboo are hard and durable but light weight, making them suitable for a number of on- farm uses(trellises, fences, stakes etc.) and residential fencing, also growers willing to install appropriate barrier to prevent unwanted spread or who produce containerized plants should consider pursuing any enterprise involving bamboo. (Tim, 2013).

f. Ornamental plants: Bamboo is also suited for production as an ornamental nursery crop for wholesale and retail sale. In landscaping Potted or balled- and bur lapped bamboo can be marketed wholesale to garden centres, nurseries and landscape contractors. Bamboo plants are also sold for retail prices at local farmers markets.(Tim, 2013).

g. Inter cropping system: Bamboo may be easily intercropped with shallow-rooted crops, and as bio-fertilizer and bio-insecticide.

h. Environmental friendly: Bamboo draws on very minimal natural resources for its growth, with water being the only significant environmental cost. It create more oxygen or carbon sequestration capacities (by sequestrate carbon dioxide in the form of 12 tonnes per hectare of plantation than a similarly sized timber plantation. Thus, playing significant role in linking climate change mitigation to sustainable economic development in the developing world.

4. Food security:

Fresh bamboo shoots (culms), the soft tender young juvenile shoot from the rhizome system are delicious vegetable and some grains of some species are also utilized for food. The edible part of shoot is covered with thick sheath of leaves which need to be removed to obtain edible portion. Apart from the Asian countries such as China, Japan, Korea, Taiwan, Thailand and Phillipines where it is already established as an ethnic traditional food, bamboo shoot as become popular in other countries. For instance, they are considered a tasty alternative to the more readily available canned import particularly in United States of America (Tim, 2013). They are available in dried, canned, boiled, of fermented form and are in incorporated in daily use products like breakfast cereals, beverages, bakery products pasta, yoghurt etc. (Nirmala *et. al*., 2007), shoots are normally harvested 7-14 days after emergence from the ground, and when the shoot height is about 15-30cm depending upon the species. The products were good In taste, texture, and quality for 6 months from the date processing at ambient conditions (25^0-40^0C) in poly propylene, and glass containers when their organoleptic sensory and chemical evaluations are done at monthly intervals (Pandey *et. al*., 2012).

When compared to common vegetables like cauliflowers, potato and ladies finger, some bamboo species like *Bamboo vulgaris and Dendrocalamnshamiltonii* are not only rich in protein and carbohydrate but also have concentration of vitamins (A,B,3,6,C and, E) and flavonoids, phenols and phenolic acids which possess antioxidant activity. Bamboo shoots are low in calories and fat high in dietary fiber and rich in various nutrient like protein, carbohydrate, mineral (K, Ca, Mn, Ze, Cl, Fe, Se) and phytosterols (which make it a potential new age health food with numerous benefit like antimicrobial, anticancerous, anti-inflammatory etc) (Nirmala *et. el*. 2011). They also contain lethal concentration of the anti-nutrient (cyanigen) (EFSA, 2004). Additionally, bamboo shoot juice possesses protease activity which helps in digestion of proteins (Choudhury *et. al.*, 2010). They are used as an extender as they take on the flavor of the ingredient they are cooked with (and as medicine for stomach disorders (Pande *et.al.*, 2012). Apart from meeting the metabolic requirements, it may also modulate various physiological functions that could play detrimental or beneficial roles in some disease (Pandey *et. al*., 2011)

Thus, bamboo shoots, with their high nutritive value and bioactive compounds, perfectly fit the bill for utilization as a health food. Unlike most agricultural crops, bamboo develop naturally with the very little artificial selection, are fairly resistant to diseases, insect, and climate changes, are free from residual toxicity as they grow well without the high usage of fertilizers and pesticides and are protected from the surrounding pollution by several layers of tightly clasped sheaths.

5. Employment:

Bamboo is an easily manageable plant that provide high yield, has multiple uses and has the potential to provide high range of employment opportunities in the area of farming, management, manufacturing and treatment (furniture, utensils, fibre, and paper, tooth picks, fabric, bio- energy resource, handicraft, bucket, ladder, mats, container, tool handles, musical instruments, boats, fishing poles and other articles by local artisans), and low cost housing construction. All these will in turn lead to an increase In the per capital income of the people, unlike forest tree crop plantation which are facing criticism regarding an unclear pro-poor focus, bamboo is highly suitable for cultivation specifically for pro-poor development.

6. Rural livelihood:

All other parts of the bamboo plant can be used in rural livelihood – shoots for food, leaves for fodder and branches for items such as brooms and for firewood.

Technology of Bamboo Production and Cultivation

Experts (TIm (2013), Mehra and Mehra(2007), Jesse *et. al*., (2011) and Eco-Energy Solution(2015) have given various technology of bamboo production and cultivation and these are discussed below:

a. *Botany:* Bamboo belong to the plant family *Poacea* (grass family) and sub-family *Bambusoideae*. A monocotyledon perennial, herbaceous, giant, woody stem plant made up of an above ground element consisting of culms, branches, and leaves, and a

below ground element of rhizomes, and roots. The most visible part of bamboo plant are the tall vertical poles, called culms which are largely hollow but are divided into sections by a solid rib or node. The area between two nodes is called inter-node. Most species of bamboo also have branches, and this grew on the node. In the root, rhizomes grow horizontally underground. Each plant have many rhizomes which branch out underground, and produce new shoot and root, forming at the node. Bamboo can reach 30meter high, and 30centimeter in diameter.

There are two main types of bamboo. Running and clumping. They are classified according to their growth habits, and root system. Running bamboo has rhizomes that grow horizontally underground with new shoot, forming as much as 3meters away from the mother plant, this type is mostly found in bamboo forest as it is, notably and invasive plant and can spread quickly. On the other hand, clumping bamboo has rhizome that grow out and up from the base of a plant with new shoot forming close to the older ones. They expand slowly out from the mother plant and are particularly useful in plantation because of the dense proliferation of culms, and easy management.

b. *Site Selection:* Bamboo does best in well drained, mostly fertile soil. It grows on marginal, and degraded land. Under very heavy soil, the organic matter can be added. It cannot withstand alkaline/saline soil. As a forest plant, it performs well if a much is kept over the roots and rhizomes. It is best not to rake or sweep-up the bamboo leaves from under the plant as they keep the soil soft, moist and recycle silica and other natural chemicals necessary for the bamboo growth and development. However, it will not tolerate continuously swampy or water logged site. Land unsuitable for row crops, such as hill-sides marginal and degraded soil along field bunds and river banks from coastal regions to maintain slopes are potential sites for bamboo production, it also a very hardy plant surviving under harsh condition.

Site Preparation: There are four key stages in preparing a site for bamboo.

- Firstly, land must be cleared of all trees, shrubs, and weeds, this can either be done by hand or during the dry season, it may be possible to do a controlled burn-off of an area.
- Bamboo plant, particularly the shoots, is quite fragile in their first years of growth and fencing may be necessary to prevent grazing animals and pest from damaging young plants.
- The layout of the plantation must also be considered and this is particularly important when it comes to harvest time. Plant should ideally be positioned in a North- South orientation to increase the amount of sunlight caught and should be spaced sufficiently so that they do not become overcrowded.

c. *Propagation:* Choosing the right specie for a plantation depends on the soil condition, access to water and intended use of bamboo. There are various methods of propagating bamboo- through seed and vegetative method. The vegetative method is mainly through rhizomes, and for early realization of income generation, rhizome as planting material is desirable.

The planting stock is a significant piece of the start-up cost for a plantation, so it is important to ensure plants are healthy and well established. Most importantly plants should:

a. Be harden for at least 2-3weeks at the nursery prior to being transported to the site.
b. Be small but well developed roots and rhizomes.
c. Have a good amount of healthy foliage.
d. Be watered thoroughly before being transported from the nursery.

It is Important to note that, when securing planting stock, an additional 20 percent will be required to cover any plants that may die in the first few years of growing.

Wet season is the best time for planting. Bamboo planted outside this time will have a much lower survival rate, as they require a significant amount of water in their first years to take root. At this time, the pre-dug hole are filled to a depth of 10centimeter below the ground surface, up to 2kilogrammesof organic fertilizer or manure are mixed with top soil and this is used to fill the holes.

Seedlings should be transported from the nursery at the beginning of the wet season and planted immediately upon arrival. On the day of planting, it is good practice to loosen the soil in and around the hole with a pitch fork to improve drainage. The seedling is then planted vertically so that the roots are 10centimeter below the ground level. The hole is then filled completely with soil and mulched with a thick layer of surface or similar mulch.

d. Planting Techniques: Usually, the planting will be taken up with the onset of rain. Pits of 60centimeter by 60centimeter will be dug and the seedlings will be planted at a spacing of 5meter by 4meter or 6meter by 6meter. The number of plant per acre is 200. However, for economic viability of the commercial project to obtained the maximum biomass, it is advisable to have the planting density of 1000 plants per acre by following the distance of 2meter by 2meter or 2.5 by 1.5.

e. Nutritional Management: The application of fertilizer is most important during transplantation

from nursery to main field. Bamboo is a heavy feeder and therefore, even a rich soil might become depleted after a few years if not fertilizer is added. The fertilizers although may be applied at any time in a year, it is preferred to apply after harvest and before irrigations. It should be noted that rhizomes continue to be active (growing) except in the coolest part of the year. It is therefore advisable to apply small quantities of fertilizer round the year than one/two large doses. Bamboo responds well to nitrogen and potassium which are found in compost, green manure, wood ash, and chemical fertilizer. Lime is often applied to neutralize soil acidity.

f. *Irrigation Management:* Although, bamboo tolerates extremes of precipitation, from 30-250 inches of annual rainfall. For successful commercial plantation, it could be beneficial if irrigation is provided at least twice or thrice in a month after rain.

g. *Plant Protection:* Bamboo is generally free from pest and diseases however, diseases such as rhizomes rot, bamboo blister, shoot and clump borer, as well as insect pests such as scale insect, spider, and mite are observed sporadically. Timely application of systemic fungicides and pesticides will control the problem. The spray and drenching of carbendazim found to be in controlling rhizome rot

h. *Weed Management:* Bamboo plantation receive more sun because of the relatively wide separation of the culms. Sunlight encourage the growth of weeds which consume nutrients intended for bamboo and shade the ground, lower the soil temperature and thus retarded shoot emergence. Regular weeding during the first three years is necessary for vigorous growth of bamboo.

i. *Pruning & supplying:* Bamboo grows vigorously and many branches develop on the culm along with thorns. It is therefore necessary to prune undesirable branches to maintain healthy growth of the harvestable culmsand maximize yields. Any dead or significantly rooted plants should be improved and replanted with the remaining planting stock. This should only occur during the wet season and when new plants will have the best chance of surviving.

j. *Intercropping Pattern:* The gestation period in bamboo plantation is four to five years. During the first 2-3years,it is possible to take-up intercrops such as turmeric, ginger, chilli, groundnut, garlic and vegetables. This can be an incentive to the farmer to keep the weed and pest population down as long as crops are adequately managed, there is no detrimental effect to the growth of the bamboo.

k. *Harvesting and Output:* The annual yield of a bamboo clump depends on the number of new culms produced each year. This in turn is related to the production of young leaves. Culms become mature after 4-5years. To maximize shoot output, some shoots must be left each year to develop into leafy young culms. A bamboo clump on average produce 10 culms in a year under good growing conditions. Considering a 30years life cycle, one clump may produce 300 culms on the whole. It is important to harvest culms during the dry season when the starch content is lowest, because new shoots tend to grow around the outer edges of clumps. Bamboo should be harvested from the inside out. The best way to do this, and indeed to manage a clump, is by creating and shaping it in the form of a horseshoe. Considering the average weight of culms as 10kg, the yield in the first year of harvest would be 12 tonnes per acre which will stabilize at 20 tonnes by ninth year with 200 plants population per acre. However, up to 30-40 tonnes biomass could be obtained under intensive cultivation by managing 1000 plants per acre given the large amount of biomass that bamboo can produce. It provides a very interesting source of bio-energy in the tropics. When grown as a commercial crop the biomass produced by bamboo can be considered as a renewable source of energy.

l. *Labour Requirement:* The first 2years after planting are the most crucial for bamboo and maintenance tasks can be labour intensive. Manual labour is required for all aspects of production and harvest such as clearing shrubs, weed control, fertilizer application e.t.c. The level of management for container grown nursery plants can be significantly higher than field production.

Constraints of Bamboo Cultivation

While bamboo as become the focus of increased attention as a potential alternative crop, it has not gained desired momentum in the country due to a number of limitations:

i) *Reputation for being invasive and difficult to eliminate:* There may be cases of bamboo species escaping from plantation and spreading into nearby woods and fields. (Tim, 2013)

ii) *Lack of awareness:* Bamboos are found growing in the wild in Nigeria. It still remains a forest species in respect of industrial use and commercial plantations. There is a need for changing the forestry mindset to the farming mind set and creating awareness on the commercial viability and profitability of the species. Many cabinet makers and carpenters do not know that bamboo is used for roof structural members and in nutrient buildings.

iii) *Harvesting and transport restriction:* Bamboo is a forest product which attracts the felling and transit levy of States' Ministry of Agriculture. Levies are high and procedure for taking permit is cumbersome. This may deter farmers or entrepreneurs from raising bamboo on commercial basis. Thus,the need for exception of bamboo from the restrictive harvesting and transport rules.

III. CONCLUSION AND RECOMMENDATIONS

Nigeria has great potentials required to achieve rapid economic development and growth. The country is endowed with rich natural resources and human capital and therefore has the capacity to acquire the right technology, physical and human capital to fast track the pace of agricultural production growth as a way of diversifying the economy. There appears to be much greater potential on the production and cultivation of bamboo for sustainable engineering solution (alternative to steel, architecture, bio-based energy), industries (pulp and paper making, panels, and boards) agronomy uses (control of soil erosion, living biomass, and environmentally friendly) as food security, employment generation, and rural development. It grows more rapidly than trees and starts to yield within 4-5years of planting, requires minimal capital investment and can be harvested annually and non-destructively. Market for bamboo is growing and offer new opportunities for promotion of bamboo as alternative to wood, steel and other products. This is a golden opportunities for the farmers, entrepreneurs, industries, bank, and government relevant agencies to tap the potential under the sector for economic, ecological and social gains.

However, policy and operational constraints such as lack of awareness, harvesting and treatment restriction etc. need to be addressed to give the desired momentum to the sector. Among the issues that will have to be sorted out for the sustainability of bamboo sector in Nigeria to take place are:

1. *Strong Political Will:* The present government must back its words with the requisite vision and firm political will of diversifying the economy through agriculture by declaring an emergency in the sector. There should be bamboo development policy to give focused thrust to develop the sector with an integrated approach for commercialization of bamboo. This may necessitate the establishment of a government agency on bamboo cultivation and applications (as in India) and encourage the bamboo products at the government offices, agencies and public sector undertakings to pave way for large scale demand, supply, production of bamboo based utility items and regeneration of bamboo by strengthening the supply chain. The agency will also require financial and service supports in order to operate properly.
2. *Financial Incentives to Intending Farmers:* Large scale bamboo plantation could be undertaken and the cost of establishment may be through financial incentives (e.g. capital/interest subsidy) to intending bamboo farmers/entrepreneurs on a collective basis and such policy instruments can be converged with land based schemes (e.g. leasing of land) while the remaining cost of plantation could be met from the group towards environmental services provided by the locational bamboo ecosystem.
3. *Need for Organized Supply Chain*: Though, vast market exists for the bamboo sector. Potential growers should thoroughly investigate all aspect of growing and market this crop before considering production. Thus, an organized market with assured price regime to encourage the small farmers to take up bamboo plantation on their private waste land is hereby suggested. Also contract farming by user industries needs to be encouraged.
4. *Research and Development:* Forest Research Institute of Nigeria (FRIN) will need to step up research in bamboo production and utilization. Public investment in research and development (R and D)is also an effective lever for government to promote agricultural productivity growth. Many technologies and management practice that have driven agricultural productivity growth are the output of public investment in R and D. more so, R and D under the sector needs to be complimented with awareness creation, demonstration and extension support as well as capacity building programmes for multipurpose effect. FRIN could collaborate with international Network For Bamboo & Rattan (INBAR), China in this regard as done in other countries such as Ghana and Kenya.
5. The plantation of bamboo species needs to be established at a different locations, so as a to gain the economic and ecological importance of bamboo. This could be of great help to mitigate land degradation problem besides improving the livelihood of the farmer and carbon dioxide emission problem, INBAR also shared this view.

REFERENCES

[1]. Adetunji, O (2006): Creating Appropriate Technology Asa Means of Waste Minimization in Cassavaend Products. www.nifst.org./?nifst:articles

[2]. Ademiluyi, F.T. and Braide, O(2012): effectiveness of Nigerian bamboo with different activating agent on the absorption of BTX. Journal of science and environmental management, 16(3): 267-273

[3]. Akayode, S.B., Nimasaun, J.O., Lowogbon, T.S. and Olumide, O.D (2016): Evaluation of the Socoi-economic potentials of bamboo processing in Ekiti State, Nigeria. Proceedings of 50th Annual Conference of Agricultural Society of Nigeria (ASN) held at NRCRI Umudikebetween 3rd -7th October, 2016.

[4]. Chouldhury, D. Sahu, J.K and Sharma, G.D(2010): Biochemistry of bitterness in bamboo shoots. Assam University Journal of Science and Technology (6): 105-111).

[5]. Dhuruva- Narayana, V.V(1993): Soil water Research in India, In: Pande et. al. (2015): Economic Analysis of Bamboo Plantation in three major ravine system of India. AgriculturalEconomics Research Review(25:1) PP 49-59.

[6]. EFSA(2004): Opinion of the scientific panel on food additives flavourings, processing aids and materials in contact with food(AFC) on hydrocyanic acids in flavourings and other food ingredient with flavouring properties. EFSA Journal 105:1-2

[7]. Eco- Energy Solutions (2015): Cultivation of Bamboo and its Bio-Energy Solution. Available on www.ecoenergysolution.co.in/pdf/bioenergybambooproject

[8]. Falade, F. (2009): Low-Cost Houses: Research Favours Bamboo as Alternative to Steel. In: The Punch, 12th May, 2009.

[9]. Jesse, G,. Alexander, B., Robert, M,. Amelia, I,. Nina, V,.and An, T(2011): Javana Bamboo Plantation. Available on www.ewb.org.au/resources/download/2150P2011-10-31_16:25:03
[10]. Food and Agriculture Organization (FAO) Forest Department and INBAR (2005): Global Forestry Resources Assessment Update 2005. Nigeria Country Report on Bamboo Resources. FAO working paper 127
[11]. Food and Agriculture Organization [FAO] Forest Department and International Network for Bamboo and Rattan (INBAR) (2006): Global Forest Resources Assessment for Latin America. FAO working paper 123. Available on ftp://ftp.fao.org/docrep/fao/010/ah782e/AH782e00.pdf
[12]. Hunter, I.R (2003). Bamboo Resources, uses and trade: the future? Journal of Bamboo and Rattan 2(4): 319-326.
[13]. Iwala O.S (2007). The Role of Development Organization in Rural and Agriculture, Transformulation of Nigeria.The Case Study of EU mpp6 in Ondo State. Published in the proceeding of the 16th Annual
[14]. Congress of the Nigeria Rural Sociological Association held in Bowen University, Iwo, Osun State on 13th – 17th August 2007.
[15]. International Network for Bamboo and Rattan {INBAR) (2006): Improved Cultivation Technique forHigh Yielding Bamboo Stand for Industrial Pulp and Paper Production. Available on http://www.inbar.int/sites/default/files/bamboo%20plantation%20-%20highyield%20stands.pdf
[16]. Nirmala, C., David, E and Sharma, M. L (2007): changes in nutrient components during ageing of emerging Juvenile bamboo shoots. International Journal of Science and Nutrient 58: 612-618.
[17]. Ogendegbe, K (2013): Evaluation of Bamboo (*Bambusa vulgaris*Sch rad) Culm for Drip Irrigation. International Science and Technology Journal 2(1) 33-43.
[18]. Ogunwusi, A. A and Onwualu, A. P(2011): indicative inventory of bamboo available and utilization in Nigeria. JORIND 9(2): Available on www.transcampus.org, www.ajol.info/journal/jorind
[19]. Pande, V.C., Kurothe, R.S., Rao, B.K.,Gopal K., Pakandiyal A.K., Singh, A.K., and Ashok, K (2015): Economic Analysis of Bamboo Plantation in three Major Ravine Systems of India. AgriculturalEconomics Research Review(25:1) pg 49-59
[20]. Pandey, A. K. Ojha, V., Yadar, S and Sahu, S.K(2011) Phytochemical Evaluation and Radical Scavenging activity of Bauhinia Variegate Saraca Asoka And TerminaliaArjuna barks. Research journal of phytochemistry 2:89-97
[21]. Tim, Phillips(2013). UK Co-operation Extension Service, University of Kentucky- Bamboo Centre for Crop Diversification.Bamboo Production.Available on https://www.uky.edu/Ag/CCD/introsheets/bamboo.pdf
[22]. The Guardian (2015): Saudi Arabia's Plans, Lesson for Nigeria. 24th November, 2015 pg 45
[23]. The Guardian (2016): Energy, Furnish Cost Push Inflation Rate to 16.5%- NBS. 19th July, 2016, page 1
[24]. The Punch(2015): 1.9million Nigerians join Labour Market as Nigeria Bureau of Statistics Released Unemployment Watch Report for the 3rdQuarter of 2015. November 23, 2015 pg 47
[25]. WageningenFood And BiobasedResearch(2013): Analyzing the Potential of Bamboo Feedstock for the Biobased Economy. NL Agency Ministry of Economic Affairs, Colophon. Available on english.rvo.nl/sites/.../Bamboo%20report%20AgNL%20format%20June%202013.pdfA