

Bamboo: an alternative raw material for textiles production in Nigeria

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Abstract
The textile industry was one of the most viable prior to independence, till the 1990's. In the early 1900's the Kano textile industry and market experienced unprecedented growth. Kano was producing two million roles of cloth per year. However, in the 1990's, the fortune of the industry dipped, and the dependants level of about 17.2 million people went down to less than 250,000. Efforts by government to inject 100 billion naira lifeline for the resuscitation of the industry is yet to yield any commendable growth and development. About 10 billion naira injected into the sector through 15 manufacturing outputs has not led to any significant growth rate. Among the problems militating against sustainable development of the sector are low investments in cotton production as most of the cotton farmers are small scale rural people with little access to finance. The yields are low due to low regimes of fertilizer and pesticides application, late planting and utilization of hand tools. While cotton production generally is a high investment and a high yielding economic activity in the developed economies, it places high premium on fertilizer, pesticides and water consumption, making its impact on enviromental pollution to be very high. In comparison, bamboo produces good quality textiles. It occurs widely in Nigeria. Presently, bamboo has little or no industrial utilization locally. Other advantages of bamboo as a textile raw material its fast renewability, its biodegradability, its low water use and its organic status. Bamboo fabrics are very breathable. They have antibiotic and thermal regulating properties. The strength properties of bamboo yarn are also superior to that of viscose and cotton. The development of bamboo textile production industry in Nigeria will be a way forward for reviving the industry.
Keywords: textiles, bamboo, cotton, biodegradable, footprint

1.1 Introduction

Nigeria's march towards industrial development commenced long before independence in 1960. In 1903, Lord Lugard reunifies the territories of Borno and Sokoto Caliphate (1804 to 1900) in the British protectorate in Northern Nigeria (1900-1914) (Condotti, 2009). The economic aim of the British colonial administration was to develop existing cotton cultivation. However, the local and British cotton textile industries came increasingly into collision during the course of the late 19th century and the first half of the 20th century as a result of the inability of the colonial administration to capture the robust domestic economy of handicraft textiles production which was the main source of cotton supply to West Africa (Hogendorn, 1978). According to NAK (1911), the northern Nigeria textile industry experienced an unprecedented growth in the history of Africa. By 1911, Kano was producing more than two million rolls of cloth per year. The textile manufacturers were distributed all over the territory and export of local textiles to West African countries became intensified. During the 19th Century, Kano textile industry reaches extraordinary production levels. Kano's popularity as a market was due to a series of commercial incentives and greater regulation of market transaction (Clapperton, 1966). Likewise in southern Nigeria, the British Cotton Growers Association was operating three large ginneries at Ibadan, Lafenwa near Abeokuta and Lokoja (Condotti, 2009).

The Nigerian textile industry spread considerable in the 1900's and by 1987, the industry has grown to be the third largest in Africa, attracting investment from China and India with over 170 urban textile mills and about 600,000 skilled and unskilled labour earning their living through it (VON, 2013). The sector, in the 1980's, made annual turnover of $8.95 billion and generated 25% of the manufacturing Gross Domestic Product. It accounted for not less than 10% of the corporate income taxes (VON, 2013). With about 1.3 million cotton farmers in the country's cotton production belt and a dependency ratio of 1 farmer to 8 dependants, an estimated 17.2 million people derived their livelihood from the sector (VON, 2013). However, in the 1990's, the fortune of the textile industry dipped and the number of textile mills dropped considerably. The industry that was producing at over 63% capacity utilization dropped to a very low capacity utilization ebb. The textile mills in operation dropped to 25 with about 24,000 workers and projected dependant level of less than 250,000 people (Iroegbu, 2013). In realisation of the sector's importance in job creation, the Federal Government of Nigeria proposed a 70 billion naira lifeline that was eventually raised to 100 billion naira for the sector (Iroegbu, 2013).

The textile industrial revival scheme was also based on the believe that the cotton, textile and garment industry stands out as a potential growth area of the economy that could propel the country towards achieving vision 20:2020 and the Millennium Development Goals.

Despite the efforts of the government which has led to the disbursement of the first installment of 10 billion naira through the Bank of Industry to 15 manufacturing firms in the country, from January 2010, there has not been any significant improvement as analysts put the growth rate in the sector at less than 1% in the last two years with little or no significant impact on the nation's GDP or noticeable boost in the sector's employment ratio. In this paper, the raw material problems militating against the sector are examined. The problems confronting cotton fibre production and the prospects of sustainable utilization of bamboo as an alternative raw material to cotton for textiles production are examined.

2.1 Problems militating against the textile industry in Nigeria

Presently in Nigeria, cotton lint is the most important single apparel fibre. It is the basic raw material in the textile industry, thus, the domestic availability of the raw material is the essential factor for the establishment of the industry in the country. Cotton belongs to the family Malvaceae and the Genus *Gossypium*. It represents about 50 species which includes four widely cultivated species of *G.hirsutum* Linn. 1763, *G. barbadense* Linn. 1763, *G. herbaceum* Linn. 1963 and *G. arboretum* Linn. 1763. The growth of upland cotton comprise of three development stages namely planting and seedlings establishment, leaf and branch formation and flower and boll production. All these stages take place within 15-17 weeks, depending on temperature and other environmental variables.

The crop place a high premium on weather elements and other ecological factors such as rainfall, temperature, sunshine, etc., which significantly affects its growth and yield, thereby determining the potentiality of its production. In Nigeria, the area under cotton cultivation is between 600,000 – 700,000 hectares (Olukosi *et al*, 2007), largely in the savannah area of the country. Production depends on various factors ranging from vagaries of weather, cotton price, problems of the textile industry, etc (RMRDC, 1990). The peak period of cotton production in Nigeria was as far back as 1976/77 when about 453,126 bales (183.43kg/bale) were produced (Olukosi and Isitor, 1990). Thereafter production started to decline due to declining price flunctuation, pest infestation and other related problems (Sanda *et al*, 2010). By 1983/84 only 69,000 bales was produced while the demand was about 531,000 bales which might have been satisfied through importation (Olukosi and Isitor, 1990). Production in Nigeria is mainly from three cotton zones namely, the northern zone (60%), eastern zone (30%) and southwest zone (10%) respectively. Production is dominated by small scale farmers; with farm sizes ranging from 3-5 ha all under rain fed ecologies. Seed cotton yield range from 0.6 – 1.5 tons per ha, and about 98% of the cotton grown locally belongs to *Gossypium hirsutum* species with *G. barbadense* making uo the balance of 2%. The Institute for Agricultural Research, Ahmadu Bello University, has mandate for genetic improvement and development of varieties of cotton in Nigeria. Currently, the Institute has in circulation six recommended seed varieties for the various cotton growing areas namely; Samcot-8, Samcot -9, Samcot – 10 (medium staples) as well as Samcot – 11, Samcot – 12 and Samcot 13 (long staples) respectively. Other causes of poor crop yield in Nigeria have been attributed to late planting, adverse weather condition, finance and high cost of production (RMRDC 1990). A number of studies have also shown the physico chemical properties of the soils in which cotton is grown in a number of localities such as in Kano and in Kaduna states to be generally poor and require replenishment for proper growth and yield (Aliyu and Kutama, 2007). This type of observation was also made by Lekwa and Nto (1982). The authors demonstrated that the soils in cotton growing areas of northern Nigeria were generally of the sandy loam or loam sandy, acidic with low humus contents type with low nitrogen. Lekwa and Nto (1982), recommended the need for adherence to prescribed fertilizer regimes for the specific soil types for yield increase. Cotton is also sensitive to the time of planting. Brown *et al* (1992, 1993, 1994, 1995) reported that planting late does not only influence growth, development and yield of the crop, it also affects infestation by insect pests. Kuchinda *et al* (2002) reported that the sowing of cotton in mid June and early July resulted in higher plant height, boll numbers, percent of mature bolls and seed cotton yield than late planting . Earlier reports (Kittock et al, 1985) indicated that response of cotton to planting date is site and year specific and that lower yield obtained by planting after optimum planting date were due to short growing season.

3.1 Environmental impact of cotton production

While cotton production is practiced as small scale activities in Nigeria, cotton production in most parts of the world is regarded as a high yielding and high investment activity. Whereas, just over 10 million tonnes of cotton were produced globally in 1960 – 1961, by 2007 production has risen to 25.7 million tonnes (Zhao and Tisdell, 2009). This was attributed in part to technical progress in the production of cotton and improvements in the management of cotton cultivation as well as attributes of cotton which sustains demand for its use in blends with chemical fibres. However, a number of authorities have reported changing economic and environmental factors to be capable of limiting future global supply. It has been widely reported that the expansion in global cotton production impacts negatively on the environment (Roy, 2006; WWF, 2003, Rathod, 2006). Cotton cultivation is a pesticide intensive activity globally. Indiscriminate use of chemical pesticides has caused a wide range of problems, among which is increase in cultivation cost, destruction of beneficial insects, development of ressistant insects and surge of pest intensity, pollution of the environment, presence of pesticide residues in cotton and value added products, thus, endangering human health etc (Roy, 2006). The quest for alternative and supplementary means to combact pest is therefore a research priority in cotton cultivation. In India for instance, although cotton production occupies only 5% of the cultivated land area, over 50% of pesticides consumed in Indian agriculture goes into cotton farms (Roy, 2006). In view of this, the Indian government has placed a ban on the use of 25 pesticides and 6 formulations (Zhao and Tisdell, 2009). The challenge of pesticide application also influence returns from cotton cultivation in China. The economic returns fluctuate because cotton prices fluctuate all the time and production costs, due to variation in the prices of pesticides and chemical fertilizers change constantly (Zang et al, 2008). Cotton accounts for 11% of all insecticides used each year worldwide (WWF, 2005). Apart from pesticides, cotton production has a poor tract record for social and environmental concerns (Waite, 2009). The major social and environmental impacts are outlined in Table 1 (Allwood *et al*, 2006). These impacts include a contribution to climate change, the release of toxic chemicals, the addition of high waste volumes of landfill, water, and space consumption, the use of non renewable resources, low wages, low labor standards, low collective bargaining power and lack of fair trade. For instance, in cotton production, large amounts of water, fertilizers and pesticides are used. The amount of irrigation can be high as 25,000 litres per kg of cotton produced (Luiken, 2013). The global water footprint due to consumption of cotton is roughly 256 Gm^3/ yr, roughly $43m^3$/yr per capital on the average, meaning that the consumption of cotton products is roughly 2.6% of the total global footprint (Chapagain et al, 2005). Cotton cultivation causes local water shortages as well as environmental catastrophes such as the shrinking of the Aral Sea in Uzbekistan in Central Asia (Anson and Brocklehurst, 2007) and the deteriorating health of the people living there. Cotton is also the most thirsty crop in several large river basins especially in Indus River in Pakistan, the Murray- Darling basin in Australia and Rio Grande in the United States and Mexico (WWF, 2003). This results in enormous environmental impact as the course of water is altered to be able to irrigate the cotton fields. This also results in salty soil as the evaporating water leaves its salt content behind.

4.1 Environment impacts of polyester, rayon and wool

Nylon and polyesters are made from petrochemicals. They are synthetic materials and non biodegradable. Nylon manufacture creates nitrous oxide, a green gas 310 times more potent than carbon dioxide. In addition, the manufacturing processes uses high level of energy input and generates large amounts of atmospheric emissions including particulate matter, carbon dioxide, nitrogen oxides and hydrocarbons, sulphur oxides and carbon monoxide (Anson and Brocklehurst, 2007). Global warming is one of the most significant ecological harzards today and the polyester industry is a major contributing factor. Although rayon (viscose) is an artificial fibre made from wood pulp, the need for forests protection in view of climate change mitigation, the high level of hazardous chemicals such as caustic soda and sulphuric acid required to treat wood pulp makes it unsustainable. In addition, the increasing exposure of both agricultural and craft workers to organophosphate sheep dip is causing increasing health concern. This is also hinting on the unsustainability of wool as a source of raw material for textile production.

5.1 Organic cotton production

One of the environmentally friendly production methods which is gaining ground is organic agriculture. This entails production of cotton without use of chemical inputs. It relies on natural processes to increase yields, disease resistance and soil quality. It is based on a system of farming that maintains and replenishes soil fertility without the use of toxic and persistent pesticides and fertilizers and genetically modified soils (Greenbiz, 2006). The soils of organic crops must have been kept free of toxic and persistent fertilizers for at least 3 years (Coster, 2007). Presently, this is the only type of cotton that has an internationally recognized independently accessed label for its products. In 1993, total global production of organic cotton was estimated between 6000 to 8000 tonnes which represented about 0.04% of total global cotton output. Of this, about 75% was in the United States. Global retail sales of organic cotton products increased by 85% from US $583 million in 2005 to US $1.1 billion in 2006 (Marquarat, 2007). However a number of problems are militating against organic cotton production.

First, organic cotton requires farmers to make considerable investment in studying the ecosystem of the area; second, available evidence suggest that organic methods of cotton production entails reduction in yields to a variable degree which may not be fully offset by the reduction in costs; and, third, the reduction in yield may be very high as a result of natural population of pest that organic methods may not be able to compete with conventionally grown cotton (Banuri, 1998). Although, there is no record of organic cotton production in Nigeria, the concept is rapidly growing on global basis.

6.1 Development and Utilisation of Bamboo

One of the major raw materials being promoted for use in the development of the textile industry is bamboo. The history of bamboo's utilization can be traced back to 5000 to 6000 years ago (Zhaohua, 2004). Although, most of the earlier developments in bamboo utilization and processing took place in China (Zhaohua, 2004), the increasing realization of the roles of bamboo in climate change Mitigation, Adaptation and Development (MAD) has made it a bride in most countries for the development of local industries (Schellnhuber , 2009). According to Wooldridge (2012), bamboo is being hailed as a new super material with uses ranging from textiles to construction. With advancement in technology, nearly 4000 commercial products made out of bamboo or its products are available and in use daily around the world (Singh, 2008). Despite this, bamboo usage is still undergoing transformation, making experts to call the timber of the 21^{st} century (Wooldridge, 2012). In addition, bamboo fibre comes from nature and completely return to nature. Therefore, bamboo is being praised as the natural green and eco friendly new type of textile material of the 21st century. The world bamboo market stands at 10 billion dollars today and the World Bamboo Organization observed that it could double in the next five years (Wooldridge, 2012). Dayawansa (2012) estimated the world trade in bamboo resources in 2002 at 12 billion dollars. With an annual growth rate of 2 billion dollars, total bamboo resources trade will increase to about 20 billion dollars by 2015 (Dayawansa, 2012). Globally, bamboo is being targeted for livelihood development and alleviation of both environment and social problems.

In view of the increasing popularity of bamboo in the industrial sector and its role in the MAD challenge (Schellnhuber, 2009), most countries have initiated plans to invest in bamboo production and processing in order to increase its role in industrial production processes (Pandey and Shyamasunder, 2008). In Sri Lanka, approximately 24 million dollars is being invested in bamboo processing in collaboration with UNIDO, Global Environmental Facility (GEF) and the Ministry of Industry and Commerce (Dole, 2012). The aim of the Sri Lankan Project is to plant 10,000 hectares of bamboo by 2019 in order to generate 150,000 tones of dry bamboo annually (Dole, 2012). This is expected to create 10,000 direct and indirect employment opportunities. The interest in bamboo development and processing has also spread across Asia, Europe and the United States of America. In the USA, the idea of growing bamboo for profit has been at play for nearly a century with test plots of bamboo successfully established in Alabama in 1994 (Stevens, 2012). Although, the project was not optimally pursued in view of the ready supply of bamboo from Asia, the race for truly renewable resources and search for solution to climatic change problems have led to renewed interest in bamboo development in the United States (Stevens, 2012). Another major incentive for bamboo development in the USA is the spread in demand across multiple industries (Stevens, 2012).

7.1 Environmental aspects of bamboo

The rate of carbon sequestration by bamboo is one of the highest in the world. Bamboo grows very fast and establishes rapidly (RMRDC, 2004; Alfonso, 1987). It grows both in the forest and plantations (INBAR, 2009). In plantations where selective annual harvesting of mature culms takes place, bamboo can sequester more carbon, especially if the harvested carbons are turned into durable products (Karmakur et al, 2008). Bamboo sequester more carbon when managed intensively (INBAR, 2009; EBF, 2001). Consequently, development of bamboo plantations is one of the major ways of reducing environmental impacts of climate change. According to Environmental Bamboo Foundation (EBF 2001), bamboo growth habits allow it to produce more oxygen than equivalent stand of trees. This aspect holds significant implication for reduction of atmospheric carbon dioxide. As the fastest growing canopy (Alfonso, 1987), bamboo stands release 35% more oxygen than equivalent stands of trees and sequester up to 12 tonnes of carbon dioxide from the air per hectare per year (E.B.F 2001). The carbon sequestration potentials of managed forest ecosystem also depend on the use of harvested materials. As long as the volume of the bamboo products produced keep increasing, then the bamboo system is a sink, as the rate of extraction is higher than the rate of carbon release (INBAR, 2009). Bamboo is used for new applications and new ones are being developed regularly. The improvements in processing technology and equipment have enabled more durable products to enter the market (ABS, 2002).

Bamboo grows very fast with speeds of up to 1 meter in 24 hours (Alfonso, 1987). Productive grooves can be established from scratch in 10 years and individual culms harvested after 3 to 6 years (depending on species) (Alfonso, 1987). The benefits of this short rotation include lower levels of exposure to outside risks such as fire, and flexibility to change management and harvesting practices relatively quickly when facing climatic changes. The fast growth and early maturation of bamboo culms means that a bamboo stand can be selectively harvested by extracting older culms and leaving younger ones to grow without decreasing total stand biomass (INBAR, 2009). Annual harvesting of bamboo generates regular income stream that gives bamboo farmers a quick return on investment and an important annual safety net (INBAR, 2009). Another major advantage of bamboo is that it grows on marginal lands, such as degraded land and steep slopes, thereby leaving better lands for more demanding crops (ABS, 2002). Consequently, bamboo can be planted in nearly all the degraded areas, most especially in the Eastern part of the country where gully and sheet erosion are ravaging (Ogunwusi and Jolaoso 2012) and in soil damaged by overgrazing and poor agricultural techniques (Pandey and Shyamasundar, 2008).

8.0 Industrial properties of bamboo

The industrial properties of bamboo are the major factors facilitating its use across multiple industries. The physical and mechanical properties of some important bamboo species have been evaluated. The density of bamboo is reported to vary from 500 to 800kg/m^3 depending on anatomical structures such as quantity and distribution of fibres around vascular bundles (Sattar, 2005). Density increase from the centre to the periphery of the Culm (Sekhar and Bhartari, 1960; Sharma and Mehra, 1970). It also increase from the base to the top of the culm. The maximum density is from about 3 years old culms (Liese 1986; Sattar et al 1990; Kabir, et al 1993; Espisloy, 1994). Also the physico – mechanical properties are extremely unstable. In certain respects, it is more unstable than wood. The complexity is due to uneven distribution of vascular bundles, variation in moisture content, differences in the physico – mechanical properties of the node and internode parts, most specially with age. The physico -mechanical properties of bamboo material in all the three directions are also different. Nevertheless, the development of improved processing techniques including the newly developed Ecology Diversity Synergy (EDS) technique invented in Japan (UNIDO, 2009) greatly limits the obvious weaknesses associated with bamboo as an industrial raw material.

Bamboo possesses high moisture content which is influenced by age, season of felling and species. Although unlike wood, bamboo starts shrinking above the fibre saturation point, the Ecology Diversity Synergy technology has however removed those weaknesses as EDS treated bamboo is as strong as solid wood (UNIDO, 2009). Bamboo possesses excellent strength properties, especially, tensile strength. Most of the properties depend on species and on the climate condition where they grow (Sekhar and Gulati 1973). Strength varies along the along culm height. Compressive strength increases with height, while bending strength has inverse trend (Liese 1986; Espiloy, 1987; Kabir et al, 1991, 1993). An increase in strength is reported to occur at 3-4 years and thereafter decreases (Espiloy, 1994). Thus, the maturity period of bamboo may be considered at 3-4 years with respect to density and strength. Maturity of culm is a prerequisite for the optimum utilisation of bamboo in construction and other structural uses. Janssen (1981) reported that the ratio between the ultimate compression and the mass per unit volume for dry bamboo is higher than that of dry wood. The reason is attributed to the higher cellulose content of about 55% in bamboo compared with about 50% in wood (Sattar, 1990). Some studies have been conducted on the relationship between anatomical structure physical and mechanical properties on one hand, and the technological characteristics, behaviour in processing and product quality on the other (Janssen 1981; Liese, 1992). Density of bamboo is closely related to the relative proportion of vascular bundle and ground tissue, and plays an important role in influencing the mechanical properties. This explains the variation of strength along the culm height. Permeability which is affected by anatomical characteristics, influences moisture movement and thereby treatability (Sattar, 1990). In wood, the chemical by products such as polyphenol, resin and wax influence properties such as shrinkage, durability and gluability. Nothing in this regards is known for bamboo. The propeties of bamboo have made it possible for production of textile products of unique properties compared to other sources of fibres used in textile production.

9.1 Bamboo utilisation in the textile industry

Textiles from bamboo address the aim of sustainable development by utilising a renewable resource to make cloths and other textile applications. Bamboo fibre is a biodegradable textile material. As a natural cellulose fibre, it is 100% biodegradable in soil by micro organisms and sunshine and the decomposition does not cause any pollution to the environment. Bamboo fabric is widely available in the US, UK, China, India and Japan. A Philadelphia-based footwear outfits provide socks made from 95% bamboo to offer anti-bacteria and moisture-wicking properties (Textile World, 2008). London-based bamboo clothing industry supplies a range of bamboo clothes for men and women that stay naturally cooler in the summer and hotter in the winter like murino wool

(Bamboo Clothing, 2008). In 2006, roughly 10 million US dollar-worth of bamboo textile was sold in the US, while 50million US dollar-worth of cotton was sold worldwide (Durst, 2006). There are over 200 retail stores selling bamboo textile products in the U. S. alone. The advantages of bamboo textiles can be divided into two main categories. These are:

1. Advantages derived from the use of the plant itself and

2. Those derived from fabric properties given by the plant

The advantages of using bamboo as a raw material are mainly from its renewability, biodegradability, efficient space consumption, low water use, its organic status and its carbon sequestration abilities. The second advantage is predicated on many properties of bamboo textile. The cross section of the fibres is filled with various microgaps and micro holes which does the function of moisture absorption and ventillation. The microgaps and holes also enables it to absorb more dyes as compared to other cellulosic fibres and appears luxurious and shinning. These gaps can absorb and evaporate skin moisture just as bamboo plant absorbs moisture in the ecosystem (INBAR, 2004). Also, bamboo does not require pesticide as a result of its natural antifungal and antibacterial agent known as Kun (or Kunh). The same natural substance that protects bamboo growing in the field, functions in spun bamboo fibre (FAO, 2007). The kun in bamboo stops odour-producing bacteria from growing and spreading in the textile. A quantitative antibacterial test as performed in China by the China Industrial Testing Centre in 2003 in which 100 per cent bamboo fabric was tested in bacteria strain type *Staphylococcus aureus*. After 24 hours' incubation period, the bamboo fabric showed a 99.8 per cent antibacterial destroy rate (FAO, 2007). A comparism of the physical properties of bamboo, cotton and viscose is shown in Table 2. From the table it can be observed that bamboo is superior in strength properties than viscose and cotton. The strength of bamboo at 45.6gm/tex is higher than that of cotton and viscose at 30gm/tex and 44.1gm/tex respectively. Table 3 show the strength properties of bamboo yarn to be superior to that of cotton yarn. The average breaking force, breaking work and time to break of bamboo at 2.47N, 10.06N.cm and 2.0 sec is superior to that of cotton yarn at 2.31N, 4.22Ncm and 0.96 sec respectively (Table 3).

9.2 Prospects for Bamboo Textiles Industry in Nigeria

Bamboo presents a veritable opportunity for the development of the textile industry in Nigeria. One of the major factors that would propel bamboo utlisation in the textile industry in Nigeria is its wide occurence, availability and distribution. RMRDC (2004) reported that bamboo is widely distributed in the south and middle belt regions of Nigeria. According to the report, distribution of bamboo is related to ecological conditions with the rainforest areas having the most abundant. Bamboo is found in abundance in all the States of Southern Nigeria, except Lagos and Bayelsa where the distribution is considered relatively less. The most endowed states in terms of bamboo occurrence are observed to be Ogun, Oyo, Osun, Ondo, Edo, Delta, Rivers, Akwa Ibom, Cross River, Abia, Ebonyi, Enugu, Anambra and Imo States. The report indicated that at least 10% of the natural vegetation in these states is dominated by bamboo, with existing bamboo clumps showing appreciable gregarious growth that is contiguous over large areas. In Lagos, Ekiti, Bayelsa, Kogi, Kwara, Benue and Nasarawa States bamboo distribution was observed to be frequent, indicating that between 6.0 to 9.0% of the natural vegetation is occupied by bamboo. Pockets of bamboo clumps were also reported in Niger, Taraba and Plateau States as well as within the Federal Capital Territory. There are 12 states where bamboo occurrence is rare. These are Adamawa, Bauchi, Borno, Gombe, Kano, Kaduna, Katsina, Kebbi, Sokoto, Jigawa, Yobe and Zamfara. According to RMRDC (2004), the major uses in all the states are as scaffolding materials. Other uses include fencing, yam stakes, environmental amelioration, handicrafts and fuel wood. In the construction of story buildings, bamboo culms are used as pillars to provide temporary support for the decking. In view of this, there is ample quantity of bamboo that can be used in the textiles industry.

Closely allied with the above is the less cumbersome process technology for bamboo textile production. There are two main methods employed in the manufacturing of textiles from bamboo. These are chemical and mechanical methods. In the mechanical process, the woody parts of the bamboo plant are crushed and natural enzymes used to break the bamboo walls so that the fibres can be mechanically combed out and spun into yarn. This is as an eco-friendly manufacturing process. Bamboo fibre product made from this process is sometimes called bamboo linen. The bamboo manufactured by the chemical process is sometimes called bamboo rayon. The chemical process consists of cooking the bamboo leaves and woody shoots in strong chemical solvents such as sodium hydroxide and carbon disulphide in a process known as hydrolysis alkalization combined with multi-phase bleaching. This is basically the same process used to make rayon viscose from wood or cotton waste by-products. According to Waite (2009), the process for producing regenerated bamboo fibre using hydrolysis alkalization and multi-phase bleaching technology consists of the following steps:

1. Leaves and inner fiber are removed from bamboo
2. Leaves (in some cases) and inner fibers are crushed together to make bamboo cellulose
3. Bamboo cellulose is soaked in a solution of 18% sodium hydroxide, NaOH, (also known as lye or caustic soda) at 20 to 25°C for 1 to 3 hours.
4. Bamboo cellulose and NaOH mixture is pressed to remove excess NaOH, crushed by a grinder, and left to dry for 24 hours.
5. Carbon disulfide, (CS_2), is added to the mixture.
6. Bamboo cellulose, NaOH and CS_2 mixture is decompressed to remove excess CS_2, resulting in cellulose sodium xanthogenate.
7. A diluted solution of NaOH is added to the cellulose sodium xanthogenate, which dissolves it into a viscose solution.
8. The viscose is forced through spinneret nozzles into a large container of a dilute sulfuric acid solution, (H_2SO_4) that hardens the viscose and reconverts it to cellulose bamboo fibre.
9. The bamboo fibres are spun into yarns (to be woven or knitted).

In general, viscose fibre is made up of a cellulose (80%), hemicelluloses (15%), and pentosans (3.5%); other components include resin, soaps, sulphur, ash and lignin-like substances (Sadov and Korchagin, 1979).

9.3 Properties of Bamboo Textiles

A number of researchers including Saravana and Prakash (2009), Waite (2009), Das (2012), BambroTex (2010) and Rathod and Kolhatkar (2010) have extensively reported the properties of bamboo textiles. Some of bamboo textile producers used only one species of bamboo while other used as many as 13 species without distinguishing between the species and the textile. Bamboo makes a wonderful clothing material. Due to its hollow fibre, the fibre is filled with micro gaps and micro holes, which allow for better moisture absorption and ventilation than other fibres. In addition, the properties of bamboo textile are different from those of cotton fibres. Some of the properties of bamboo textiles as shown in Table 4 include:

- Comfort: Bamboo apparel is very comfortable, very breathable, fast drying and thermal regulating. Bamboo fabric is anti-static and does not cling. It is often described as having the ultra softness of cashmere and the sheer sheen (lustre) of silk.

- Antibacterial Property: Bamboo has a natural anti bacterial quality due to a bio agent which resists the growth of bacteria on the fibre. This is normally carried through the finished product, allowing it also to resist the growth of the bacteria that causes odour even after numerous washings. This eliminates the need for anti-microbial chemical treatments which causes allergic reactions.

- Thermal Regulating Property: Bamboo fabric is thermal regulating. It reduces temperature in hot weather and warms the body in cool weather,
- Superior wicking capability. Bamboo fibre is highly absorbent and it dries faster than cotton. In warm, humid weather, bamboo clothing does not stick to the skin.

- Hypoallergenic Property: Bamboo is naturally hypoallergenic, which means it is less likely to cause an allergic reaction in sensitive individuals.

- Wrinkle Resistant Property: Bamboo clothing is more wrinkle-resistant than cotton. While it might still require ironing after washing, bamboo fabric can be ironed at a lower temperature than cotton. Shrinkage during washing and drying is minimal at warm temperatures. One technique to reduce or practically eliminate wrinkling, which could apply to cotton and other fabrics, is just to put clothes in the dryer for just two to five minutes to straighten the wrinkles induced by the spinning of the washing machine.

- Colorfast Property: Bamboo textile accepts organic and natural dyes more rapidly and thoroughly, with less dye use, than cotton, modal or viscose (rayon). The colour is much more vivid. Bamboo fabrics do not need to be mercerized to improve their lustre and dye-ability, as is required by cotton.

- Easy Care and Energy Efficiency: Bamboo textile is machine washable in cool water.

Bamboo fabric has been growing in popularity because of the aforementioned unique properties. The use of bamboo fibre for clothing is a 20^{th} Century innovation pioneered by several bamboo corporations. Bamboo fibre resembles cotton in its unspun form. Many companies bleached the fibres to turn bamboo to white fibre, while some of the companies producing organic bamboo fabric leave the bamboo fibre unbleached (Waite, 2009). More recently, newer manufacturing outfits have started to use other more benign and eco friendly technologies to chemically manufacture bamboo textiles. The chemical process used to produce lyocell from wood cellulose can be modified to use bamboo cellulose. The lyocell process, also used to manufacture TENCEL®, uses N-methylmorpholine-N-oxide to dissolve the bamboo cellulose into a viscose solution (Waite, 2009). N-methylmorpholine-N- oxide is a member of the amide oxide family. Amine oxides are weak alkalines that act as surfactants and help break down the cellulose structure. Hydrogen peroxide is added as a stabilizer and the solution is forced through spinnerets into a hardening bath which causes the thin streams of viscose bamboo solution to harden into bamboo cellulose fibre threads. The hardening bath is usually a solution of water and methanol, ethanol or a similar alcohol. The regenerated bamboo fibre threads can be spun into a bamboo yarn for weaving into fabric. This lyocell processing is substantially healthier and more eco-friendly because N-methylmorpholine-N-oxide is non-toxic to humans and the manufacturing processes are close-loop leading to the recovery and recycling of 99.5 per cent of the chemicals used during processing. Other chemical bamboo textile manufacturing processes are also being developed. In a new development, acetic anhydride and acetic acid with sulphuric acid as a catalyst are used to form acetate fibre which is then spun into a yarn. New nano-technologies are also being introduced into the clothing industry. Green Yarn, a new start-up is developing a bamboo clothing line made from nano-particles of bamboo charcoal. Green Yarn's "Eco-fabric" is manufactured from 4 to 5 year-old Taiwanese-grown bamboo that has been dried and burned in 800°C oven until it is reduced to charcoal. The bamboo is processed into fine nano particles which are then embedded into cotton, polyester or nylon fibres. This conventional fibre yarn that contains trapped bamboo charcoal nano particles is then woven mostly into socks and blankets.

10. Conclusion

The textile industry is a major pollutant in view of the high dependence on pesticides and chemical fertilizers and water. In Nigeria, the inadherence to global best practices for cotton production may be responsible for low cotton yield. This is mostly so as small scale farmers that are growing cotton in the country are mostly rural poor. While increase in yield may be anticipated through recommendations that government should provide the requisite facilities for optimum yield under farm conditions, the increasing concern for enviromental degradation demand that caution should be exercised. For the textile industry in Nigeria to perform optimally, it may be necessary that bamboo textiles production be encouraged. The investment cost as dictated by the manufacturing process would be lower that the conventional cotton textiles manufacturing. Apart from investment cost, bamboo availability in Nigeria is high. Presently, the demand for bamboo is low. However, for bamboo to contribute adequately to the development of textile industry in Nigeria, government must encourage the planting of bamboo. This could be achieved by initiating a bamboo policy that will be directed at creating suitable environment for the development of bamboo and its use across relevant sectors of the economy.

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Table 1: Unsustainable Impacts of Textile Industry

Textile Environment Impacts	Textile Social Impacts
Contribution to climate change -burning fossil fuels for (1) electricity needed in manufacturing, (2) agricultural machinery, (3) laundering (electricity and heating water)	*Low wages* -legal minimum wages sometimes lower than realistic minimum living wage -cycle of poverty
Toxic chemicals -fertilizers and pesticides in agriculture -manufacturing stages such as fibre extraction, pretreatment, dyeing, printing	*Low labourstandards* -poor working conditions (unsafe, long hours) -child labour
Waste volumes -non-biodegradable wastes to landfill -large quantities of wastes because of 'fast fashion'	*Low collective bargaining* -some countries do not grant the right to form unions
Water consumption -extensive water use (such as in cotton crop cultivation) -dramatic changes to local water resources (such as in Aral Sea region)	*Lack of fair trade* -subsides and regulations prohibit fair trade of textiles
Non-renewable resources -fossil fuels (coal, oil, gas) used as main product in producing synthetic fibres and auxillary chemicals	
Space consumption -large fields for harvest can take away space needed for food production	

Source: Allwood et al. (2006)

Table 2: Physical Properties of Bamboo, Cotton &Viscose

Properties	Bamboo	Cotton	Viscose
Strength (gm/tex)	45.6	30	44.1
Elongation (%)	15	5.3	14.3
Short Fibre Index	5.28	9.07	5.57
Uniformity Index (%)	92.8	81.1	92.9
UHML (mm)	38.21	29.91	36.97
ML (mm)	35.45	24.25	34.34
Moisture (%)	7.7	7.5	6.9
Micronaire	5.18	3.26	5.19

Source: Rathod and Kolhatkar (2009)

Table 3: Properties of Bamboo & Cotton Yarn- 40Ne

Properties	Bamboo	Cotton
Strength (Rkm Kgf*Nm)	17.03	16.25
Elongation (%)	13.28	6.43
Unevenness (U %)	10.56	10.41
Hairiness Index	3.936	5.55
Coefficient of variation (CVm %)	13.34	13.30
Breaking Force (N)	2.47	2.31
Breaking Work (N.cm)	10.06	4.22
Time to Break (sec)	2.0	0.96
C.S.P	2527	2436

Source: Rathod and Kolhatkar (2009)

Table 4: Comparison of Fabric Properties

Fabric properties	**Bamboo**	**Cotton**	**Viscose**
Strength	Higher	Lower	Higher
Elongation	Higher	Lower	Higher
Feeling	Extremely Soft	Medium	Medium
Lustre	Excellent	Dull	Higher
Comfort	Excellent	Medium	Medium
Breathable & Cool	Excellent	No	No
Anti- Bacterial	Excellent	No	No
Appearance	Luxurious Shiny	Medium	Medium
Anti- UV Radiation	Excellent	No	No
Biodegradable	Biodegradable	Not Biodegradable	Not Biodegradable
Absorbency	Excellent	Medium	Medium
Durability	Higher	Lower	Higher

Source: Rathod and Kolhatkar (2009)

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