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Boosting Pulp and Paper Capacities with Non-Wood Fibrous Raw Materials in Nigeria.

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Abstract
The pulp and paper industry in Nigeria was planned to enable the country to be self-sufficient in pulp and paper output in the 1960's-1970's. While two of the integrated pulp and paper mills performed well in the late 1980's they stopped operation in 1996 as a result of inadequate foreign exchange to import long fibre pulp and chemicals. While one of the mill has commenced operation after privatization in 2006, pulp and paper capacities in Nigeria has reduced considerably, necessitating annual expenditure of more than 500 million dollars annually on paper importation. This paper reviews the fibrous raw materials available in Nigeria and observes that a number of wood and non-wood fibres locally available in Nigeria can sustainably be used to promote self-sufficiency in pulp and paper output locally. Most of these fibrous resources are currently being used for paper production in most of the countries Nigeria is importing different types of papers from.
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Introduction.

Paper production is one of the industrial activities regarded as a pointer to industrialization and educational development worldwide. While the use of computer and other forms of technology for data storage and retrieval is on the increase worldwide, the demand for paper has also continued to rise. The role of the paper industry remains important in the digital age as it supplies various paper products to more than 5 billion people worldwide.

Over 400 million tons of papers are used globally in a year; a depiction that world consumption of paper has grown by 400 percent in the last 40 years. According to the Food and Agricultural Organization (2006) paper production will increase globally by 50% in 2050. The steady upswing in global consumption of paper is due to three reasons which include: (i) increasing global population density (ii) increasing utilization of paper beyond office; and (iii) consumer-based lifestyle that stimulates infinite quest and demand for finished goods (Obiora *et a*l 2019). The most produced type of paper is the packaging paper and board which has being growing in demand in recent years due to online shopping boom (Tisco, 2020).

The two largest paper producing countries in the world are China and the United States. While paper production in the United States has been declining, production in China has increased significantly in the past decade. Also the largest paper consuming country worldwide is China due to the rapid economic growth. In 2018, China consumed more 100 million metric tons of paper and paperboard. This was followed by the United States and Japan, both of which consumed 70.6 million metric tons and 25.5 million metric tons, respectively in the same year (Tisco, 2022). In 2019, the global paper and pulp market size was valued at 348.43 billion U.S. dollars and it is expected to grow at a Compound Annual Growth Rate of 0.8 to reach the value of almost 370 billion U.S. dollars by 2027(Tisco, 2022). Products in this market include wrapping paper and packaging, news print, and printing and writing paper. In the same year, approximately 78 percent of the pulp produced worldwide was chemical pulp grade. This was followed by mechanical and half chemical pulp, which accounted for 17 percent of production.

The rapid expansion in the industry in China has been accompanied by sharp increases in demand for wood. Chemical wood pulp imports into China amounted to 24M tonnes in 2020, growing by +10% against the previous year's figure. 7.2 million tonnes of these comes from Brazil and 3.5 million tonnes from Indonesia. Canada exported 2.9 million tonnes to China during the same period (WRI,2021).

In view of the increasing demand for paper products globally, most countries are strategizing to meet national demand and to produce for export. The most gregarious development in this sector occurs in China which over the last few years unveiled aggressive expansion plans to invest in new wood pulp capacity. According to Index Box Estimates (2022), 30 wood pulp projects with more than 30 million tonnes capacity was initiated between

January 2019 and July 2021 (Index Box Estimates 2022). More than 60% of this is concentrated in the Guangxi Zhuang Autonomous Region and Hubei Province. This is due to favorable government policies which support pulp and paper projects by granting permission for new mills and by making loans available for loans to the industry. In the Guangxi Zhuang Autonomous Region and Hubei Province, deliberate government policies are leading to expansion of pulpwood projects. The regional government released the "Industrial Promotion Work Plan for 'Two-pronged Ten Billion Projects and New Projects'" in 2019, in a bid to attract enterprises to invest in the Guangxi Zhuang Autonomous Region. Wood processing and paper making is one of the 12 industrial clusters that the autonomous region is focusing on developing through a "Two-pronged ten billion" projects which refer to major industrial projects with an investment exceeding RMB 10 billion or an output value exceeding RMB 10 billion (Minnie, 2021) . It is envisaged that more pulp and paper companies in China will take advantage of the favorable investment environment, as well as supporting policies such as tax relief and streamlining applications and procedures offered by the government under the Chinese government's 14th Five-Year Plan in the post-COVID-19 era (Minnie, 2021).

Likewise a number of other countries are also strategizing on how to promote adequacy in pulp and paper output locally. However it is unfortunate that most developing countries in Africa depend on importation of paper, paperboards and sundry products. In Nigeria, out of the 3 million tonnes of pulp, paper and paperboards required, less than 5% are produced locally as a result of various problems militating against adequate performance of the sector. The effect of these problems is reflected in import trade figures for paper, paperboard and art paper. The import figure for these types of paper from 2010 to 2015 was 658.1 billion naira (RMRDC, 2016). The net amount builds higher to 798.9 billion naira when aggregated together with values for printed books, newspaper, pictures, and other miscellaneous paper products (RMRDC, 2016). According COMTRADE database on international trade (2022), Nigeria import of these items in 2020 alone was $696 million. Fig. 1 shows the buildup of Nigeria imports from 2012 to 2020 while Table 1 shows the different types of papers imported from USA alone and the associated costs for each category. The top trading partners of Nigeria are shown in Table 2. Most of these countries uses non wood fibrous raw materials which Nigeria has in abundant quantities in their production processes. The importation of paper and paper products in Nigeria compromised over 300,000 jobs that would have been available for Nigerians. Also from an econometric point of view, the paper industry has the lowest figures for production and consumption for local products among all the industrial divisions, placing the sector on the rank of likely lowest capital investment and output. This may likely be as a result of the deplorable performance of the existing paper mills. It may also be due to the unwillingness of investors to invest in the paper business due to the long perceptions hinging on the absence of raw material resources. This is so because the situation though changing was a result of decreasing availability of wood due to rapid deforestation globally. This development is of serious concern to policy makers in view of the dwindling foreign exchange availability to aid continuous importation of paper products locally. This paper examines the status of pulp and paper production in Nigeria and highlights the challenges and prospects of increasing pulp and paper capacities in Nigeria with the emerging non wood fibrous resources that are locally available.

Status of Pulp and Paper Production In Nigeria.

The status of pulp and paper industry in Nigeria has been reviewed by various authors (Ogunwusi, 2004: Ogunwusi, 2014; Ogunwusi, 2013; Ogunwusi, 2011; Obiora *et a*l, 2019; Ogunwusi and Ibrahim, 2014; Egbewole et al, 2017; Ogunwusi and Onwual,2013). Nigeria in its first National Development Plan (1962 – 68), gave prominence to establishment of three pulp and paper mills with high dependence on imported raw materials, expertise, machinery and spare parts (Aribisala, 1993). These are the Nigeria Paper Mill, (NPM) Jebba; the Iwopin Pulp and Paper Company, (IPCC) Iwopin and the Nigeria Newsprint Manufacturing Company, Oku-Iboku (NNMC).

The Nigeria Paper Mill, Jebba, commenced production in 1969 with an initial production capacity of 12,000 tonnes of paper per annum. By 1985, the mill had undergone considerable expansion with the production capacity raised to 65,000 metric tonnes per annum of kraft paper, liner and chipboards, sack kraft, fluting media and corrugated cartons. Table 3 shows the production history of the mill from 1985 – 1996. The short fibre raw materials were obtained from indigenous hardwood species around Oke Awon Forest Reserve, near Jebba, while long fibre pulp components were imported. This arrangement worked well at the early stage, however, inadequate availability of foreign exchange in the early 1990's led to serious reduction in capacity utilization (Aribisiala, 1993). Capacity utilization declined from 6.7% in 1993 to 4.3% in 1994 and zeroed out in 1996. From 1996 to 2006, the company was out of production. In 2006, the Nigeria Paper Mill was to MINL Ltd, an Indian company that has rehabilitated and expanded its production capacity to 252,000 tonnes per annum of various kraft paper products ranging from

60 – 250gsm required in the packaging sector. The major fibrous raw materials come from locally sourced and imported waste paper and paperboard.

Iwopin Pulp and paper Company Limited, Iwopin, Ogun State, was planned to produce fully bleached pulp for production of 68,000 metric tonnes of various grades of writing, printing and cultural papers on annual basis. With initial dependence on imported long fibre pulp, the mill was planned to produce long fibre pulp from *Pinus species* established in plantations in different locations in the country. Since initiation, IPPC has been experiencing tottering problems occasioned by equipment installation delays. Joint venture collaboration with Wittermore Paterson Investment BV of Germany led to commissioning of the first phase of the mill in December 1994 (CBN, 1994). Although, the equity contribution of the partners was injected into the company, production did not commence (CBN, 1994). Efforts to run the mill on imported raw materials on one of the paper machines had to stop in 1998 because of the high cost of diesel as the company required approximately 52,000 litres of diesel per day since the mill was not connected to the national grid. Although, the mill was finally privatized in 2006, it is yet to be put in proper shape for production.

Nigeria Newsprint Manufacturing Company (NNMC), Oku-Iboku, a newsprint mill using the chem.-mechanical process has an installed capacity of 100,000 metric tonnes of newsprint per annum. Due to the establishment of the mill, import of newsprint reduced drastically to 17.5% in 1986, 12.5% in 1987 and faded out in 1988 (CBN, 1994). However, production stopped in 1993 and the status had remained the same due to scarcity of fund to refurbish the equipment and to purchase raw materials (Makinde, 2004). In 2008, Negris Limited acquired the company, and renamed it Oku Iboku Pulp and Paper Limited. As at 2021the facilities at the mill have been extensively vandalized while some other have become obsolete RMRDC, 2022a). Efforts to start production are still at rudimentary stage with no commencement date in sight.

As a result of the deficiencies in the integrated mills, capacity utilization for short and long fibre pulps production in Nigeria since 2006 to 2022 is highly insignificant. Only the waste paper converters operate at about 58.40% average capacity utilization on annual basis. As the primary paper manufacturers form the bedrock of the paper industry in Nigeria, the prolonged shut down of the NNMC and IPPC has devastating and demoralizing effect on the sector. Particularly worrisome is the fact that other subsectors which rely solely on this subsector for their raw materials had no option but to import their requirements.

Thus, despite assiduous planning, pulp and paper production in Nigeria is still at rudimentary level despite the huge money spent on establishment of integrated pulp and paper mills in the country. In view of the continuous expenditure of scarce foreign exchange on paper importation, it is necessary that adequate and sustainable solutions be found to the problems of the industry as presently, only about 5% of all the raw materials needed for making paper in Nigeria are presently sourced locally.

3.0 Challenges of the Pulp and Paper Industry in Nigeria

Recent developments in the paper industry in advanced countries indicated that the capacity of mills being established in recent times is becoming bigger as a result of advances in technology. This development does not hold for many developing countries in sub Saharan Africa primarily due to high dependence on imported inputs. The integrated pulp and paper mills in Nigeria depend overwhelmingly on imported long fibre pulp to mix with short fibre pulps produced from hardwood species to enable optimal development of strength in the paper products. The three pulp and paper mills required approximately 85,000 tonnes of long fibre pulp which as at then would cost more than 3 billion dollars on annual basis. In addition, about 5 billion dollars was required to import different types of puling chemicals.

One of the strategic plans of the Nigerian government for schematic development of the paper industry was to promote plantation establishment of *Pinus species,* most especially*, P. caribaea and P. oocarpa* for long fibre pulp production locally. To achieve this, pine plantations were established in various locations in both the savanna and forest ecologies in Nigeria. While some successes were recorded at the early stage of the project, it did not totally succeed as a result of inability of the micorrhiza supplied to establish itself in the field (Momoh, 1971).

Pinus ocarpa was first introduced and planted in in Nigeria in 1954. Micorrhiza soils for the inoculation of the Pines were imported from Zambia in November, 1954 (Madu, 1967). The micorrhiza spread shortly through the soil although the seedlings readily lose their infection in potted or bear rooted stocks as a result of heat. Consequently, despite the assiduous made to introduce *Pinus species* to Nigeria through adaptation trials, Pinus

specie stands can only be found on trial plots in locations such as Afaka in Kaduna State and Miango in Jos, Ijaye in Oyo State and in a number of other isolated places. More recently, RMRDC and other stakeholders are working out modalities on how further trials can be explored with *Pinus species* from countries such as Brazil and other countries where introduction of *Pinus species* have become very successful (RMRDC, 2022b)

4.0 Prospects for Boosting Pulp and Paper Capacities in Nigeria.

To optimize pulp and paper production in sub-Sahara African countries, a number of factors must be taken into consideration. According to Palmer and Greenhalgh (1987), these include the quantity and quality of the raw materials that are available locally, the amount and cost of capital available and the form it takes, the market for the proposed mill and types of pulp and paper to be produced. Others important factors include the type of mill to be established whether integrated or not, available infrastructure such as water, power supply, transport facilities, managerial, technical and labour resources available; environment and social factors such as pollution control, availability of local sewage systems, ownership of factors of production, labour attitudes and the financial, economic and technical feasibility of the project.

In countries where most of these factors are not optimally available, the tendency is to moderate the type and scale of paper mills to be established. The United Nation's Industrial Development Organization (UNIDO)'s International Forum on Appropriate Industrial Technology for pulp and paper products and small pulp mills held at New Delhi in November, 1978, classified small scale mills as those producing about 30t/d and medium scale mills as those producing between 30 and 100t/d while large scale mills produce above 100t/d. Based on this classification, the three integrated pulp and paper mills established in Nigeria are large scale mills as Iwopin Pulp and Paper Company with the lowest capacity is expected to produce 186 tonnes/day when fully functional.

In India, where per capital consumption is relatively low compared to developed economies, the papermaking holds a considerable share in manufacturing production (Schmecher and Sathaye, 1999). Both small and big mills coexist to produce a variety of different paper and paperboard as well as newsprint products. About 380 pulp and paper companies are in operation. Out of these, 198 mills are operating under the large scale category with capacity of 5.2 million tonnes per annum and 111 are operating under small scale category with actual capacity of 0.3 million tonnes per annum. The average size of mills in India was 10,000 tonnes per annum compared to 85,000 tonnes per annum in Asia and 300,000 tonnes per annum in North America. The industry in India uses wood, agro residues and recycled/waste paper as the major raw materials. The India paper industry mainly produces printing grade, newsprint grade as well as industrial grade paper. Newsprint is mainly produced by mills utilizing mainly recycled waste paper as well as agro residues as major raw materials (Devotta, 2014). Also, in China, the capacities of many of the mills are very small until recently when the country started moving towards wood utilization (Honnold, 2009). Based on the success of the India initiative coupled with Nigeria's extenuating circumstances, a mix of small, medium and large scale mills may help Nigeria tide over pulp and paper importation problems as experienced in India. According to experts, as per capita income grows and society require higher rates of literacy, the demand for paper will grow. As advised by WRF (1997), increase in demand should only be reasonably met with indigenous manufacturing capacity and locally sourced raw materials at a reasonable cost, avoiding import taxes, higher purchase prices and loss of valuable foreign exchange.

As a result developing countries such as Nigeria will do better by having a mix of scale of pulp and paper production outfits using available raw materials. In Nigeria, various studies have indicated massive availability of different fibre resources that can be used to transform the paper industry landscape if adequate investments can be made in utilizing them for paper production. A number of the of fibrous materials that can support small, medium, and large scales pulp and paper industry. These raw materials have played and are still playing important roles in China, India, Egypt and many other countries where there are wood shortages, making experts to observe that non wood fibrous raw materials will help the sector to tide over fibre shortages that are expected to arise in the future. Some of the raw materials include short fibre wood species, non-wood fibres and agricultural residues. In Nigeria, more than 15 million tonnes of agricultural residues are produced annually and these are either burnt or use as landfills. Some of the available emerging raw materials that can be used sustainably in the industry are discussed below.

Waste paper/recycled fibres

Since 1960's when NPM commence operation, waste paper had been one of its major raw material. The company is still recycling waste paper. It is however interesting to note that availability of waste paper has reduced very considerably as about three or four other companies have come on board to produce packaging materials from

recycled fibres in Nigeria. Presently, Nigeria imports waste paper to compliment locally available ones. According to COMTRADE database on international trade (2022), Nigeria imported from Canada waste and scrap paper or paperboard worth $39.1 thousand in year 2020.

Short fibre wood species

Nigeria has copious quantities of short fibre hardwood species. Before the closure of Nigeria Paper Mill in 1996, the Company was pulping 15 mixed hardwood species from the Savanna region. Nevertheless as a result of the processing methods used in papermaking which involved extensive beating and refining, short fibres have to be mixed with long fibres which are mostly produced from coniferous wood species mostly found in temperate regions. This compulsed importation of long fibre pulp for mixing with short fibre pulp produced locally. Nigeria still has reasonable quantities of short fibre wood that can be pulped locally for paper production.

Long fibre wood species.

Research and Development on sourcing long fibre plants locally was intensified in the 1980's and this has led to discovery of some long fibre wood species among the indigenous hardwoods species. One of those that have been reported widely is *Sterculia setigera* wth an average fibre length of 2.41mm (Ogunwusi, 2002). As a result of its mean fibre length value, *S. setigera* is regarded as a medium/long fibre wood species and can be used to produce pulp with properties reminiscent to imported long fibre pulp from temperate softwoods (Ogunwusi, 2014).

Another species that has been widely reported is *Steculia oblonga*. The fibre length of *S. oblonga* growing in Nigeria is 2.07mm. Studies carried out in Nigeria showed that the unbleached kraft paper produced from the plant has similar properties with those of softwood pulp (Ogunwusi, 2014). This also makes it a good candidate for long fibre pulp production.

Non wood plant fibres in Nigeria

Nigeria has a number of non-wood fibrous raw materials. These can be divided into two broad categories as specialty non-woods or softwood replacements such as cotton linters, kenaf, bamboo, etc. and hardwood alternatives such as straws, bagasse, corn stalks, sorghum stalks, etc.

Non wood plant fibres have various average dimensions as compared with those of wood fibres. Some of the non-wood fibres are like short fibre hardwoods, but others are so long that they must be condensed to improve papers produced from them. From practical and quality viewpoints, any type of paper can be formed using appropriate combination of non-wood fibres. The minimum fibre length necessary to produce acceptable paper of adequate strength properties is dependent on many factors, as fiber lengths is not exclusively related to paper properties (Bousious and Worrell, 2017). Different fibre lengths are desirable for different properties. For example while long fibre is required for strength properties in paper, they tend to bunch together. As a result, they do not provide good formation. Shorter fibers on the other hand provide excellent formation (El-Sayed et al, 2020). The non-wood fibres of importance to optimal paper production in Nigeria are as subsequently discussed.

Kenaf

This is a shrub that has been cultivated in Africa for a long time. Its utilization for pulp and paper production has been internationalized. It is an annual plant with a single, straight, unbranched stalk composed of fibrous bark and an interior woody core. The outer bark, is around 40% of the stalk by bulk.

Kenaf has been used as a substitute for wood pulp and paper production in Thailand and China. Studies carried out in Nigeria shows the fibre length of kenaf bast fibre to be 2.90 mm while the fibre diameter was 28.16 um, lumen width of 6.08 um and cell wall thickens was 11.04 um respectively. Kenaf cooked with kraft, soda, or neutral sulfite processes produce better quality pulp than hardwood pulp (Udohitinah and Oluwadare, 2011). Apart from tear resistance, the pulp is as good as softwood kraft pulps (Keshk et al. 2006). Kenaf bast fibre could go a long way in alleviating the problems posed by a shortage of long fibre pulp to Nigeria paper mills. Mixed with different percentages of hardwoods, it is used to make printing and writing paper, newsprint, linerboard, tissue, bleached paperboard, cigarette paper and other light weight specialty papers (El-Sayed, 2020).

In Nigeria kenaf cultivation dated back to the pre-colonial days when peasant farmers used it for chord making. The plant assumed a national significance in the 60's when government established two cottage industries for jute bag production in Jos and Badagry (Ogunwusi, 2003). One of the companies, the Nigerian Fibre Company started commercial cultivation of kenaf in 1965 in several parts of the south west. The other company, Nigerian Fibre Products Limited sourced its fibre through the Northern Development Corporation's Plantation at Jama'a (Ogunwusi, 2003).

In the recent past, the Raw Materials Research and Development Council (RMRDC) collaborated with the Institute of Agricultural Research and Training (IAR&T), Ibadan to produce foundation seeds which was multiplied by the Kenaf Association of Nigeria (KEAN) in Kwara State. This collaboration with IAR&T, later led to the production of four varieties of kenaf breeder seeds for further multiplication by the association. RMRDC has also carried out technical study on commercial scale pulping of bast kenaf fibres for long fibre pulp production (Ogunwusi, 1997). The report is available for use, study or consultations by investors.

Bamboo.

Five species of bamboo are indigenous to Nigeria. The most prominent one of these in Nigeria is *Bambusa vulgaris* (Ogunwusi, 2014). The pulping properties of the species have been studied. The fibre length varies from 2.37-2.92mm, showing that strong paper with good tearing resistance could be obtained from the plant.

It is one of the fastest growing plants in the world. Compared with wood, bamboo has the advantages of short growt cycles (3 to 5 years), self-reproduction and low maintenance and regeneration cost (Chen et al, 2019) It was commercially used for kraft paper production by the NPM before its closure in 1996 (Oguwusi,2011, 2012). Bamboo is also popular as raw material for pulp and paper making in many countries of the world. Examples include China, India and Malaysia. Several new bamboo pulp and paper projects have been planned in Sichum Province of China according to the 2017 Almanac of Chinese Paper Industry (Chen et al, 2019). In various ratios, it is used to prepare printing and writing paper, duplex and triplex paper, linerboard, wrapping and bag paper, multiwall sack and newsprint.

RMRDC constituted a team made up of experts from UI, FUTA and RMRDC to carry out a nationwide survey of bamboo availability and utilization in Nigeria. The study indicated that bamboo is widely distributed especially in the south and middle belt regions (Ogunwusi and Onwualu, 2011b). Presently, Nigeria has more than 400,000m^3 of bamboo culms by volume that can be deployed for paper production.. The report of the study has been published and available in the Council. RMRDC is presently collaborating with a number of investors, most especially, Gamla Nigeria Limited, to establish bamboo plantation in Delta State (RMRDC, 2017).

Agricultural Residues

One of the major options available to countries with substantial agricultural produce is the production of paper from agricultural residues. As Nigeria is an agrarian country, it is expedient to promote the use of agricultural residues for paper production instead of burning them annually and increasing Nigeria's contribution to climate change problems. Some of the agricultural residues that are sustainably available and can be used in the paper sector in Nigeria are discussed below.

Sugarcane bagasse

Among the many agricultural fibers used in the pulp and paper industry, sugarcane bagasse is one of the most promising. Bagasse is the waste from the manufacture of sugar from sugarcane. The main problem with the pulping of bagasse is the high pith ratio of stalks, which is about 30% by weight of the stalk. However, a depithing process has been developed. Sugarcane is grown widely in Nigeria and is being processed by some companies for sugar production. The fibrous bagasse residue is usually burnt in sugar mill boilers. However, bagasse has greater economic value when pulped. Bagasse has been used in South China as fibers for paper production (Varshney et al. 2019). It has been used to prepare printing and writing paper, tissue, glassine and grease proof paper, duplex and triplex paper, corrugating medium, linerboard, wrapping and bag papers, and newsprint if mixed with appropriate proportions with wood pulp (Bian et al, 2019).

Average fiber length of sugarcane is 1.7mm and average fiber width his 0.02 mm. The chemical composition analysis of bagasse varies from season to season. The chemical analysis of partially depithed bagasse was: α-cellulose 43.2%, Pentosans 21.2%, Lignin 18.2%, Ash 1.98% and methanol-benzene extractives 8.3%.

Cornstalks

Corn is one of the main crops grown in Nigeria. The stalk is a good fiber source for low grades of paper. Corn stalks are like sugarcane in physical structures with an average fiber length of 1.5mm and average fiber width of 0.018 mm. Their fibres are narrow, thick walled and have sharp or pointed ends. The chemical analysis of cornstalk sample show it to contain 77% Holocellulose, 53.6% αcellulose, 16.2% Hemicellulose, 22.2% Lignin and 3% Ash (El-Sayed et al, 2019).

Cotton stalks

Cotton is another prominent agricultural produce in Nigeria. The whole stalk after the removal of cotton fibers can be used in the pulp and paper industry. A number of studies have been done on cotton stalk as alternative source of fiber for paper manufacture (van Dam *et al*. 2018, Jiang *et al*. 2019). The results confirmed the possibility of using cotton stalk pulp in mixture with other pulps to produce good quality paper. Cotton stalk fibers have an average fiber length of 0.6–0.8 mm and an average fiber diameter of 0.02–0.03mm (Pfaffli and Sisko1995). The chemical analysis of cotton stalks differs from season to season and depends on species. The woody core contains about 42% alpha-cellulose, 21% lignin, 21% pentosan and 2% ash. The bark contains more ash and less lignin.

Wheat straw

Straw was an important raw material for the pulp and paper industry in Europe and North America until the wood paper making process was fully recognized. Currently, wheat straw is used in regions where wood is scarce such as in Europe, Asia, Central and South America. Wheat straw fibers have an average length of 1.4mm and a width of 0.015mm. In combinations with different ratios of wood fibers, it is used to make printing and writing paper, glassine and greaseproof paper, duplex and triplex paper, and corrugating medium paper (Bian *et al*. 2019). Wheat straw fibers derived from the bast cells in the internodes are quite long (about1.5mm). However, the high ratio of non fibrous cells in the straw decreases the strength of paper produced from it. Also, a significant ratio of these non-fibrous cells, called fines, is usually lost during washing of the straw pulp. This decreases the yield of the pulp while it enhances the paper strength. The epidermis cells are high in mineral and silica content which constitute a drawback for paper properties.

Sorghum residues

Sorghum stalk is also a good non wood fibrous material for pulp and paper production. The pulp from the raw material has been used to manufacture writing paper, wrapping paper and other paper products in India. The chemical composition of sorghum straw is comparable to those of bagasse and wheat. Compared to other raw materials, sorghum leaves and stalks are easier to convert to pulp. They require smaller volume of chemicals during pulping and produce smooth and malleable pulp. Pulp produced from sorghum stalks and leaves have good transparency and brightness plus good folding and bursting qualities.

Rice straw

Rice straw is used for papermaking in China, India, Myanmar and in Egypt. Rice straw has high silica content and it is very costly to collect. Despite these advantages, it is a sustainable source of fiber owing to its ready availability in Nigeria. With addition of long fibre pulp, it is used for producing printing and writing paper, glassine and grease proof paper, duplex and triplex paper, corrugating medium, and various grades of wrapping paper (Bian *et al*. 2019). The silica in rice straw could be as high as18% of the whole straw composition.

Cotton linters

Cotton fibers come from the seed shell of cotton plants. Normal cotton fibers are too lengthy and costly for conventional papermaking. They are therefore only used in specialty papers. Across the globe, most of the cotton fibers produced are used in the textile industry. The average fiber length of cotton fibers is 25 mm and the average fiber diameter is 0.02mm Liu et al. 2019). Mixed with different proportions of wood pulp, it is used to make high grade bond ledger book and writing paper.

Essentially, cotton linters are the fibers that are found on the husk after the real fibers have been removed and used for textiles production. Cottons seeds oil mills normally remove the cotton linters from the seeds before oil production. Linters are used in the paper industry for fine paper production (Liu *et al.* 2019). The fiber length of linters is as long as fiber length of softwoods. Linter as a raw material is better than softwood due to its higher cellulose content. It is used only for production of specialty paper such as security paper, document paper, filter paper etc., where permanence and strength are required.

Cotton rags and textile wastes

Cotton rags are among the finest fibers accessible for papermaking. These are the old and discarded cotton textiles. Due to the mechanical action that these fibers undergo during their conversion to textiles, they do not require a lot of refining for papermaking. Likewise, textile wastes are also good source of fibre for paper production. Linen is especially significant in paper manufacture. As with cotton rags, textile wastes does not require extensive refining during paper production.

Others

Apart from the fibrous materials highlighted above, a number of other pulpable resources also exist in Nigeria. Some of these include hemp (*Canabis sativa*), elephant grass, carpet grass, etc., which can also be harvested and in the pulp and paper industry. Some of them like hemp can be cultivated purposely for papermaking. Hemp has an average fibre length of 20mm and a diameter that varies between 0.016-0.22mm. In blends of various proportions, it is used in making speciality papers like cigarette paper, lightweight printing and writing paper and security and currency paper (Chandra, 1998).

The development of innovations such as nanotechnology, recent advances in paper machine operations and more innovative paper processing practices have made non-wood fibrous materials more attractive for use as raw materials for paper making. In most cases, agricultural-residues are locally available for free or at a very low cost. The cost of the residues to the mills will be the cost of collection and transportation. However, the pulping of non-wood fibres and agricultural residues has some challenges. Among these are the difficulties encountered in small scale black liquor recovery. Also, agricultural residues are huge and thus are not easy to handle and transported. Likewise, most non wood fibres are annual. The mills need to procure material during harvest and store it for the rest of the operating year. Most of the raw materials are bulky and requires large storage facilities where they will be protected from deterioration. Studies in storage of straw have specified that straw moisture contents should be between10–12%. At higher humidity content, straw is subject to microbiological degradation and decay. Another problem is the risk of slow combustion developing in the stack creating a potential fire hazard. Likewise, the fibres of straws drain slowly. This decrease production rates during washing and dewatering operations. In addition, many straws have high silica contents. In a number of cases, the silica dissolves in the pulping liquor and re-precipitates on process equipment in the liquor recovery operations. Evaporator tubes can be plugged and lime mud setting rates seriously disturbed by silica deposition. Despite these, they have become indispensable raw materials for the paper industry. Efforts are ongoing globally to solve some of the problems. For instance new technologies such as silicon removing/ silicon retention have been developed to overcome disadvantages of bamboo as pulping raw material as well as improve quality of products (Xu *et a*l, 2015, 2016). A good example of this can be found at Chinitianhus operation in Guizhou Province of China where black liquor concentration reaches 70% and the alkali recovery rate is above 92% (Chen *et al*, 2019).

Conclusion

The Federal Ministry of Industry, Trade and Investment in line with Federal Government directives is working out modalities that will ensure that the privatized mills become operational as early as possible. RMRDC is a member of the committee set up for this. One of the major strategies being adopted is come up with a national policy on pulp and paper production. This is a good initiative. The policy should highlight the fact that paper requirements in Nigeria has increased drastically. As at now the total production capacity of the primary pulp and paper mills is about 408,000 tonnes per annum. After is has been upgraded by its new owners, NPM is producing 240,000 tonnes of kraft paper per annum, while IPCC upon completion is to produce 68,000 tonnes of printing and duplicating paper. The Oku Iboku mill has a total capacity of 100,000 tonnes of newsprint per annum. The total production capacity of these mills if all are fully operational is now far below the 3 million tonnes of different types of paper and board required locally. This shows that at even at optimal capacity utilization, the total output from the mills will not be able to satisfy national demand. As a result, there is need to expand national production capacity by more than 2.5million tonnes per annum for different types of paper, most especially, writing, duplicating and specialty papers including hand made paper.

To achieve this, the government will have to permit establishment of small, medium and large scale mill as it done by Indian government. Small scale paper production has the potential of low initial capital requirement despite its disadvantages. This makes it easy for prospective investors. Government however needs to support this initiative by putting in the national policy, measures that will make small scale pulp and paper mills to flourish. Such policy measures should include access to one digit interest loans, tax cut, increase tariff on importation of and paper and paper products produced by the mills and mandatory usage of locally produced paper in industries, schools and government offices. This was the approach adopted by India in the 1970's. It is also being used by the Chinese government to increase production capacities in China. Also to encourage development of non-wood small scale pulp and paper making industries in Nigeria, there is need to earmark certain products exclusively in the domain of the small scale paper industries to protect them from competition from the large scale mills that have been privatized. Despite the advances being recorded in China on the introduction of wood pulp to feed the paper industry, the utilization of non-wood fibres remains important. Also imperative is the improvement of access to technology, skill and market information. The commercial pulping of the fibrous raw materials that are locally available will save Nigeria more than 500 billion naira annually in foreign exchange equivalents. It will also enable the country to acquire the necessary skills pertaining to pulp and paper processing and management.

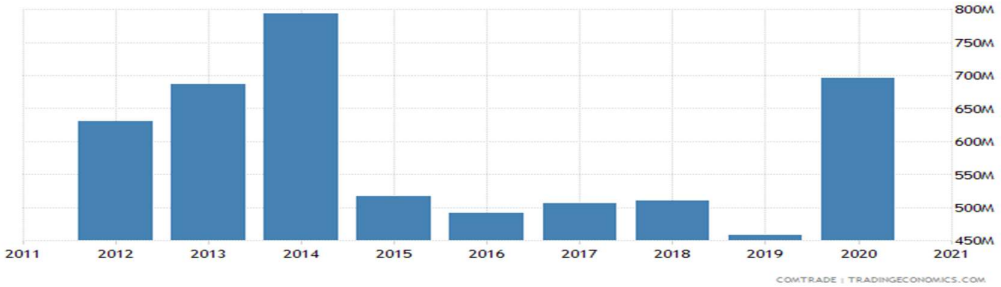

Fig. 1: Imports of Paper and paperboard, articles of pulp, paper and board by Nigeria 2020.

Source: COMTRADE database on international trade (2022)

Table 1: Nigeria Imports from United States of Paper and paperboard, articles of pulp, paper and board

Nigeria Imports from United States of Paper and paperboard, articles of pulp, paper and board	Value	Year
Paper, uncoat, for writing, rolls, handmade paper	$19.64M	2020
Uncoated Kraft Paper and Paperboard (In Rolls or Sheets)	$10.95M	2020
Other Uncoated Paper and Paperboard (In Rolls or Sheets)	$1.10M	2020
Toilet or Facial Tissue Stock, Napkin Stock, Cellulose Wadding	$405.72K	2020
Coated Paper and Paperboard	$347.88K	2020
Toilet Paper, Towels, Similar Household, Sanitary Articles, of Paper	$217.7K	2020
Articles of Stationery, Notebooks, Folders, Albums, of Paper, Paperboard	$132.22K	2020
Envelopes, Letter Cards, Plain Postcards, Boxes, Pouches of Paper, Paperboard	$124.39K	2020
Other Paper, Paperboard, Cellulose Wadding, Other Articles	$35.76K	2020

Nigeria Imports from United States of Paper and paperboard, articles of pulp, paper and board	Value	Year
Labels of paper or paperboard, printed or not	$21.57K	2020
Newsprint, in Rolls or Sheets	$15.54K	2020
Paper, Paperboard, Cellulose Wadding, Webs of Cellulose Fibres (Coated, Printed)	$9.55K	2020
Wallpaper and Similar Wall Coverings, Window Transparencies of Paper	$8.51K	2020
Cartons, Boxes, Cases, Other Packing Containers, of Paper, Paperboard	$7.19K	2020
Cigarette Paper	$2.35K	2020
Bobbins, spools, cops and similar of paper and paperboard	$566	2020
Filter Blocks, Slabs and Plates of Paper Pulp	$179	2020
Vegetable Parchment, Tracing Papers, Other Glazed Transparent Paper	$155	2020

Source: COMTRADE database on international trade (2022)

Table 2: Top trading partners (import of "Paper and paperboard; articles of paper pulp, of paper or of paperboard") of Nigeria in 2020:

- China with a share of 24% (180 million US$)
- Indonesia with a share of 11.9% (87 million US$)
- India with a share of 11.9% (87 million US$)
- Germany with a share of 7.78% (57 million US$)
- USA with a share of 4.48% (33 million US$)
- South Africa with a share of 3.92% (28 million US$)
- Finland with a share of 3.78% (27 million US$)
- Brazil with a share of 3.64% (26 million US$)
- Turkey with a share of 2.51% (18.4 million US$)
- Egypt with a share of 2.11% (15.5 million US$)

Source: COMTRADE database on international trade (2022)

Table 3: Trend of Production History of Nigeria Paper Mill Ltd. (NPN), Jebba, 1985 - 1996

Year	Installed Capacity (MT)	Actual Production
1985	65,000	40,480
1986	65,000	*42,960
1987	65,000	27,749
1988	65,000	29,365
1989	65,000	16,509
1990	65,000	12,498
1991	65,000	7,707
1992	65,000	7,747
1993	65,000	2,314
1994	65,000	2,720
1995	65,000	2,884
1996	65,000	188

*Highest yearly output.

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