PULP AND PAPER INDUSTRY: A NEGLECTED GOLDMINE IN NIGERIA

An Inaugural Lecture delivered at the University of Ibadan

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By

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The Vice-Chancellor, Deputy Vice-Chancellor (Administration), Deputy Vice-Chancellor (Academic), Registrar, Librarian, Provost of the College of Medicine, Dean of Faculty of Technology, Dean of the Postgraduate School, Deans of other Faculties, and of Students, Distinguished Ladies and Gentlemen.

Introduction

I am highly honoured and humbled to be asked to deliver this inaugural lecture on behalf of my faculty, the Faculty of Technology and more importantly on behalf of the Department of Agricultural and Environmental Engineering. It is gratifying to note that this is the first inaugural lecture from the Department since the change of name of the Department in 2005 to its present name. However, it is the fourth from the Department, but actually the second to be delivered from the Wood Products Engineering Unit of the Department. The first from the Unit was delivered by one of the founding fathers of the Faculty in person of Professor E.B. Lucas, in 1984 entitled: "A Treeless Age Approaches Fast: It's a Lifeless Era as Long as it Lasts...." Today, by the special Grace of God, I stand before you to present the ninth in the series of inaugural lectures for the 2010/11 session. The topic of my lecture is "***Pulp and Paper Industry: A neglected Goldmine in Nigeria***".

The important role, which pulp and paper play in the educational, political, social and economic development of a nation cannot be over-emphasized. Paper has assumed a position of almost incredible significance not only in the highly developed countries of the world but also in the developing ones like Nigeria. It is a product that allows us to enjoy our lives and also go about our daily routines with greater efficiency but which has been taken for granted. There are almost as many different kinds of paper as there are uses for it. For example most of us begin our mornings by enjoying the comfort of paper products—from the thinnest toilet tissue and paper towels, to the morning newspapers, the carton that holds orange juice, and the paperboard packaging that holds the breakfast cereals.

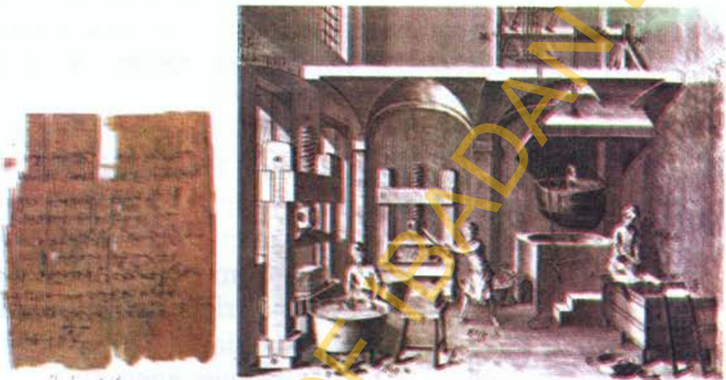
Furthermore, our children also benefit from paper each school day—from classroom drawings and notebook paper to textbooks that our students learn from. At work, office papers help us communicate effectively. Even in this digital age, and despite talks about the "paperless office", paper is essential for copiers, laser printers, brochures, notepads and for other uses. Wherever we go, paper is there to help at every turn. It is the bags that hold your groceries or latest clothing purchase. It is the cards, letters and packages you receive, the paper cups that hold your drinks and the album that holds your memories. Paper is at work in thousands of industrial and manufacturing applications helping to keep the air clean and providing protective apparel and innovative packaging.

Mr. Vice-Chancellor Sir, distinguished ladies and gentlemen, it is this important industry—Pulp and Paper Industry that is responsible for manufacturing the thousand and one paper products of our everyday life. This is the industry that is being neglected in my dear country, Nigeria, and which has formed the subject of my discourse this evening. In the course of my presentation, I will attempt to examine the extent of neglect of the industry, give an update on the state of the country's pulp and paper industry and the potentials, discuss the various sources of raw materials in the country for pulp and paper production, look at the various production methods in use for processing the raw materials into pulp and paper, and offer some suggestions and strategies for resuscitating the neglected industry. Finally, I will share with you my modest contributions thus far in the wood products industry in general and the pulp and paper industry in particular.

The Amazing History of Paper

While I do not intend to bore you with the history of paper manufacture, permit me to provide this brief background on this most essential commodity called "paper". In early times, man wrote messages on the walls of caves or clay tablets. The

Egyptians, however, felt unsatisfied with this and discovered that it was easier to write on the flattened stems of native papyrus plants from which the word "paper" was derived. Other people later developed writing parchment from silt and dried animal skins (fig. 1). This was in use until about 105AD (about 2000 years ago) when a Chinese scholar and government official, Tsai Lun, developed what was the first real paper as we know it today. What did he do? He mixed mulberry bark, hemp and rags with water, mashed the mixture into pulp, pressed out the liquid, and hung the thin mat to dry in the sun, and this became the first real paper.



(a) (b)

Fig. 1: (a) Parchment from silt and dried animal skin (b) Details of the 18th century French paper factory that used rags for paper-making

Source: http://inventors.about.com, http://tappi.org/paperu

During the 8th century, Muslims (from the region that is now Syria, Saudi Arabia and Iraq) learned the Chinese secret of paper-making when they captured a Chinese paper mill. Later, when the Muslims invaded Europe, they brought this secret with them. The first paper mill was built in Spain and soon, paper was being made at mills all across Europe.

Subsequent improvements in the manufacturing process later involved the replacement of wood raw material which Lun discovered, with linen rags. For almost a thousand years, rags were used as a source of paper-making fibre. Other numerous substitute materials, the most notable of which was straw, were tried, but it was not until 1844 that wood gained importance as a fibre source. In that year, a method of grinding wood-pulp was developed by a German bookbinder named Christian Volter, and the process was soon adopted in other countries. Today, wood is clearly the dominant raw material source for paper manufacture, with wood fibre providing over 94% of the fibre used worldwide (Haygreen and Bowyer 1982). The balance is made up of the non-wood fibres which include cereal and seed flax straws, bamboo, sugar cane, bagasse, reeds, abaca asparto, cotton linters, sisal and kenaf, to mention a few.

The Pulp and Paper Industry: Global Perspective

The pulp and paper industry worldwide is huge and technically diverse, operating a wide variety of manufacturing processes on a range of fibre types from tropical hardwoods to straw. It converts fibrous raw materials into pulp, paper and paperboard. The primary raw material in paper-making is cellulose fibre, of which wood constitutes approximately 50 percent, 30 percent lignin, and 20 percent hemicelluloses/-carbohydrates and aromatic hydrocarbons. Hardwood (deciduous) and softwood (coniferous) trees are the major fibre sources for pulp and paper. Secondary sources include straw from wheat, rye and rice, bagasse, woody stalks from bamboo, flax and hemp, and seed, leaf or bast fibres such as cotton. The majority of pulp is made from virgin fibre, but recycled paper accounts for an increasing proportion. Wood must therefore be pulped to separate these fibres in order to obtain the cellulose in usable form for paper and paperboard production. The higher the cellulose content of the pulp and the longer the fibres, the better quality the final paper product.

Different plant (machine) categories exist depending on whether they only produce pulp (pulp mills) for further processing, or only paper out of purchased pulp and /or recycled waste paper (paper mills). The third category (the integrated pulp and paper mills) combines the two processes and is the most common in the paper industry.

The annual production of paper from wood-pulp has grown to a multi-billion dollar industry, concentrated mostly in a few industrialized countries. Today, about 90 percent of all pulps are produced from wood. As shown in figure 2, the global production of paper and board increased continuously over the last decades from 125 million tons in 1970 to 365 million tons in 2006. It is, however, projected that the global market for paper and paperboard will continue to grow at 2.3 percent per annum until year 2030 (Jalan et al. 2009) with particularly sharp increases in developing countries due to increases in population, literacy rates and quality of life.

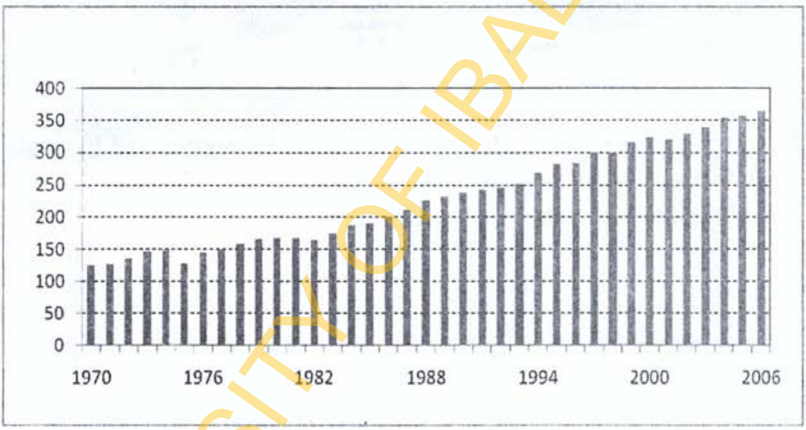


Fig. 2: Global production of paper and paperboard (in millions of tons)

Source: FAO-STAT Forestry Database (2007)

The breakdown of world paper production in the year 2004 by product classification is shown in figure 3. The main paper products are writing and packaging-paper representing more than 60% of the total production. The manufacture of pulp, paper and paper products ranks among the world's largest industries. Mills are found in more than 100 countries in every region of the world and they directly employ more than 3.5 million people (Teschake 2006). The major pulp and paper producing nations include the United States of America, Canada, Japan, China, Finland, Sweden, Germany, Brazil and France (table 1), with each country producing more than 10 million tonnes of the paper and paperboard in 1994.

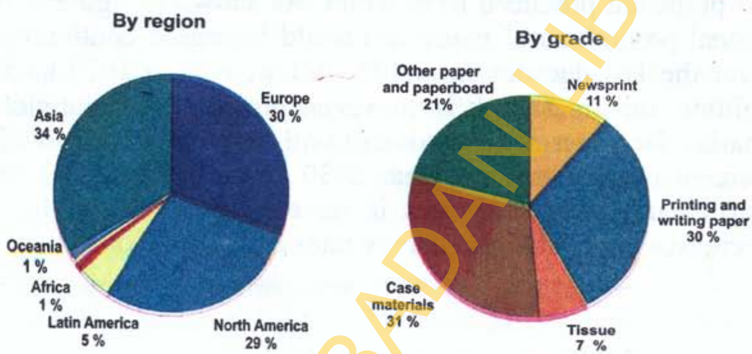


Fig. 3: Pulp and paper production in the world by regions and by grade (2004), with a total of 360 million tons.

Source: Finnish Forest Industries Federation (2004)

Table 1: Employment and Production in Pulp, Paper, and Paperboard Operations in selected Countries (1994)

Country *	Number employed in industry	Pulp Number of mills	Pulp Production (,000 tonnes)	Paper and paperboard Number of mills	Paper and paperboard Production (,000 tonnes)
Austria	10,000	11	1,595	28	3,603
Bangladesh	15,000	7	84	17	160
Brazil	70,000	35	6,106	182	5,698
Canada	64,000	39	24,547	117	18,316
China	1,500,000	8,000	17,054	10,000	21,354
Czech Republic	18,000	9	516	32	662
Finland	37,000	43	9,962	44	10,910
Former USSR**	178,000	50	3,313	161	4,826
France	48,000	20	2,787	146	8,678
Germany	48,000	19	1,934	222	14,458
India	300,000	245	1,400	380	2,300
Italy	26,000	19	535	295	6,689
Japan	55,000	49	10,579	442	28,527
Korea, Republic of	60,000	5	531	136	6,345
Mexico	26,000	10	276	59	2,860
Pakistan	65,000	2	138	68	235
Poland**	46,000	5	893	27	1,343
Romania	25,000	17	202	15	288
Slovakia	14,000	3	304	6	422
South Africa	19,000	9	2,165	20	1,684
Spain	20,180	21	626	141	5,528
Sweden	32,000	49	10,867	50	9,354
Taiwan	18,000	2	326	156	4,199
Thailand	12,000	3	240	45	1,664
Turkey	12,000	11	416	34	1,102
United Kingdom	25,000	5	626	99	5,528
United States	230,000	190	58,724	534	80,656
Total worldwide	approx 3,500,000	9,100	171,479	14,260	268,551

* Countries included if more than 10,000 people were employed in the industry.
** Teschake (2006)

The size of the workforce directly employed in pulp and paper production and "converting operations" in the listed countries are also shown in table 1. These altogether represent about 85% of the world pulp and paper employment and over 90% of mills and production (Teschake 2006). For example in those countries that consume most of what they produce, such as the United States, Germany and France, "converting operations" provide two jobs for every one in pulp and paper production. Furthermore, the labour force in the pulp and paper industry mainly holds full-time jobs within the traditional management structures. Because of their high capital costs, most pulping operations run continuously and require shiftwork. This may not be the case, however, for the paper converting plants. The working hours vary with the patterns of employment prevalent in each country, ranging from about 1,500 to more than 2,000 hours per year. The male workers predominate in the industry, with women usually representing only between 10 - 20% of the labour force.

The management and engineering personnel in the pulp and paper mills/plants usually have university level education. In European countries for example, most of the skilled blue-collar workforce and many of the unskilled workforce have had several years of vocational school education. It is also a common practice to provide informal in-house training and upgrading of such personnel, as the case may be in some other countries.

The establishment of pulp and paper plants is capital intensive. For example, a bleached Kraft mill employing 750 people might cost US $1.5 billion to build, while a chemical thermomechanical pulp (CTMP) mill employing 100 people might cost US $400 million. This implies that there are economies of scale with high capacity facilities. Meanwhile, new or refitted plants use mechanized and continuous processes as well as electronic monitors and computer controls. With these state-of-the-art modern technology, they will require relatively few employees per unit production. The installation of such new equipment allows easier change-overs between product runs, lower inventories and customer driven just-in-time production. The productivity gains derived in such cases have resulted in job losses in many of the producing countries in the developed world. However, increases in employment have been reported in the developing countries, where new mills are being constructed.

Development of the Nigerian Pulp and Paper Industry

The development of the Nigerian pulp and paper industry is still very much in its infancy, spanning barely four decades of its existence. As a developing nation, with a rapidly growing population estimated at over 140 million people, the government remains the principal actor in the industry. The Nigerian government originally planned to establish five pulp and paper mills in her efforts at satisfying society's demand and requirements for paper and paper products. However, only three of these mills were eventually established, with the first, the Nigerian Paper Mill, Jebba, commissioned in 1969 to initially produce12,000 metric tons of paper per year from imported pulp (Momoh 1980, Osadare 1995). The second mill was commissioned at Oku-Iboku, Akwa Ibom State in 1986 to supply the much needed newsprints in the country at a production capacity of 100,000 tonnes/year. Iwopin Mill in Ogun State, which is the third was abandoned at about 85 percent completion level in 1983. Efforts made in 1994 to complete the second phase of Iwopin Mill to enable it commence production did not yield the desired result. Today, virtually all the three mills are partially moribund—a rather unfortunate and very pathetic situation indeed. All the paper products requirements of the teeming population of this country are presently being imported with an insignificant amount supplied locally from recycling of wastepaper. Although, only one of the three paper mills is presently partially producing, it is still instructive to know the genesis of each in order to appreciate the laudable objectives of the government at the time of their establishment.

Profiles of the Nigerian Pulp and Paper Manufacturing Companies

Nigerian Paper Mill (NPM) Limited Jebba

The mill was constructed in 1965 and commissioned in 1969 as the first paper mill in West Africa. It was designed to initially produce 12,000mt/year of short fibre and to import about 33,000 mt/year of long fibre for its operations. At the peak of its operation in the 80s, it operated below 70% of its installed capacity. It was primarily a paper mill with no pulping facilities at inception, hence it produced its paper products—Kraft and duplicating papers—from imported pulp. However, in 1978, the mill carried out an expansion programme which added pulping facilities to enable it manufacture pulp from mixed tree species of savanna forests within the vicinity of the mill. With this expansion project, the production capacity of the mill was increased to about 65,000 metric tons per annum from the initial 12,000 metric tons at the inception of the paper mill. The production records of the company, shortly before it stopped production in 1996, show that the mill produced only 188 metric tons of paper products i.e. less than 1% capacity utilization (table 2).

Table 2: Record of Production at the Nigerian Paper Mill Jebba (1985 – 2009)

Year	Installed capacity (Metric Tonnes)	Actual Production (Metric Tonnes)	Capacity utilization (%)
1985	65,000	40,480	62.28
1986	65,000	42,960	66.09
1987	65,000	27,749	42.69
1988	65,000	29,365	45.18
1989	65,000	16509	25.40
1990	65,000	12,498	19.23
1991	65,000	7,707	11.86
1992	65,000	7,747	11.92
1993	65,000	2,314	3.56
1994	65,000	2,720	4.18
1995	65,000	2884	4.44
1996	65,000	188	0.29
1997-2008	65,000	Nil	Nil
2009	65,000	7,887	12.15

Source: RMR&DC 2010

One of the constraints identified then was the high cost of hardwood supply to the mill. Although the mixed hardwoods being utilized by the mill were readily available, they were being supplied to the mill at highly exorbitant costs by the local wood owners. For this reason, the final prices of the company's products became very unrealistically high. The under-capacity utilization of the mill was also attributed to the difficulty involved in the importation of long fibre pulp and other essential chemical inputs, as "the scarce foreign exchange" was needed for their purchase. These were among the factors that led to the premature death of the first paper mill ever constructed in West Africa.

The production records of the paper mill from 1985 to 2009, and its capacity-utilization percentages for the years under consideration are also shown in table 2. It is evident from the records presented that it was only in 1986 that the mill ever produced at the peak level of about 42,960 tonnes of paper which represented about 66 percent of its installed-capacity. Thereafter, the production level took a consistent downward trend until it dropped to only 188 tonnes in 1996, which was the last production before closing down. Ever since, the company remained shut while plans were underway to sell it to private operators. After several failed attempts to get a buyer for the mill, it was eventually sold in year 2006. The new company rolled out its first production in year 2009, with an output of 7,897 tonnes of paper products. It is hoped that with this new owner, the production would be sustained and improved upon in the years ahead.

The Nigerian Newsprint Manufacturing Co. Limited, Oku-Iboku

It was a joint venture, owned by the Federal Government of Nigeria with 90% equity shares and the governments of Cross River and Akwa Ibom States which together had 10% of the remaining shares. It was an integrated paper mill, designed to produce 100,000 metric tonnes of finished newsprint grade papers annually, from *Gmelina* short fibre pulp. The furnish is expected to be 80% short fibre and 20% long fibre pulp imported as supplement. At the peak of its operation, the production level stood at 20,000 metric tonnes per annum.

It eventually closed down in 1993 and has since remained shut down. The reasons identified for its failure as a paper company included low production level and high cost of products among others. This again is a case of mismanagement of a government-owned enterprise, which would have been otherwise if it were privately owned. The company was eventually sold out to a private indigenous consortium in year 2006.

Nigeria National Paper Manufacturing Co Limited, Iwopin

The mill was conceived in 1975 and jointly-owned by the Federal Government of Nigeria with 80% of the share capital and Ogun, Oyo and Ondo States, sharing the remaining 20 percent capital equally. It was designed to produce fine and cultural papers for printing and writing with installed capacity of 100,000 metric tonnes per annum. At inception, the management of the company was contracted out to an Indian firm, Birla Brothers Limited, with Srotthert Management Limited of Canada as technical partners.

The initial agreement for the mill project was signed in 1974 at a cost of ₦205m which escalated to a whooping ₦497m by 1983. By 1986, the total investment on the project was put at about ₦700m. Yet, this could not complete the project, to enable the commencement of production at the mill. Assessment of construction work at the mill carried out in 1984 put the work done at 90% completion. This prompted the government to set up an Administrative Panel of Inquiry into the affairs of the mill, late in 1984. The findings resulted in the review of the project and the summary dismissal of some of the key officers of the company. The feeling of the observers of the industry about the failed project was that of incompetence on the part of the project management/-technical partners who were unable to meet agreed contract terms and construction schedules.

The company was eventually sold to another indigenous firm in the year 2006. The paper mill is now operating under a new name "Iwopin Pulp and Paper Mills Ltd (IPPM)". It is our hope that the new investors will bring their high financial and management expertise to bear in transforming the neglected plant into a viable paper mill for the benefit of the national economy.

Present Status of the Nigerian Paper Industry

Production operational activities of the three paper manufacturing plants in Nigeria have remained comatose. The good news, however, is that the three mills have been sold by the National Council on Privatization and Commercialization (NCPC). The Jebba mill was sold to a private company MINL Ltd in June 2006, and the new owners commenced production by November 2009. This is the only mill where any semblance of pulp and paper manufacturing activities are currently being recorded in the entire country. The remaining two plants—Nigeria Newsprint Manufacturing Company, Oku-Iboku and Iwopin Pulp and Paper Mills Ltd have also been liquidated and sold to private operators. A private indigenous consortium, John Silver Nigeria Ltd bought Oku-Iboku mill at a price of ₦51.5 million in December 2006, while Iwopin mill was bought by another indigenous firm, Noxiems Technologies Ltd, also in December 2006.

There is no doubt that the prolonged closure of the three primary paper manufacturing plants for a period of over 13 years amounted to total neglect of the entire pulp and paper industry in the country. The three paper plants constitute the bedrock of the industry, hence, all other sectors of the industry that depend on the plants are automatically affected by their closure. Among the badly hit are the producers of locally sourced fibre raw materials that had depended on the plants for patronage. They have since abandoned the cultivation of these raw materials. Same goes for the other sub-sector of the industry that had also solely relied on the manufacturing plants for their raw materials. Presently, they have to arrange for the supply of their paper products from outside the country.

In table 3, the cost implications for non-production by the three primary paper manufacturing plants in a period of four years (2006-2009) are shown.

Table 3: Cost Implications for Non-production by the Three Primary Paper Manufacturers in Nigeria

Company	**Product Description**	**Installed Capacity (Metric Tonnes)**	**Revenue Price per (NB)**	**Yearly Revenue at full production**	**Cost implication from non-production (billion)**				**4-year Deficit turnover (billion)**
					2006	2007	2008	2009	
NPM Jebba	Industrial grades of paper	65,000	120,000	7.8	7.8	7.8	7.8	6.85	30.25
NNME Oku-Iboku	Newsprint	110,000	170,000	18.78	18.78	18.78	18.76	18.7	74.8
IPPC Iwopin	Bond paper	60,000	200,000	12.06	12.0	12.0	12.0	12.0	48
			Total						**153.05 Billion**

Source: Raw Material Research and Development Council (2010)

As shown in table 3, a total of ₦153.05 billion was lost due to the non-production of the three primary paper manufacturers in the country for a four year period. Therefore, the thirteen years of closure of these plants would translate into the loss of roughly ₦2 Trillion! It was stated earlier that the non-functioning of the three manufacturing plants forced other sub-sectors that depended on them to procure their raw materials from abroad for their secondary paper conversion processes. Indeed, the trends of the imports of paper and paper products into the country during the period under review are shown in figures 4 and 5. There are three categories that make up the pulp and paper import sub-sector. These are (1) paper-making materials which include, pulp and other fibrous materials; (2) paper and paperboard products which include newsprint, paperboard, writing paper, tissue papers and Kraft paper; and (3) printed books and newspaper, which include finished printed book brochures, leaflets and single sheets. As seen in figure 4, the import figures of the three commodities were consistently on the increase in the four year period examined. The paper-making materials including manufactured pulps reached a peak in 2005 with an import value of over ₦180 billion. However, in figure 5, the trend of the import bill for this same commodity appeared to be on the decline after the 2005 level (NBS 2005). As a developing nation, the high pulp and paper consumption rate recorded is perhaps expected since such parameter has always been used as an indicator of a nation's socioeconomic development. This, however, is not in question; what is in question is the colossus amount of foreign exchange that is committed to the importation of these commodities which would have been saved if the pulp and paper sub-sector of the nation's economy had not been neglected for this long. An urgent and decisive action is therefore needed to resuscitate and develop this sub-sector of our economy.

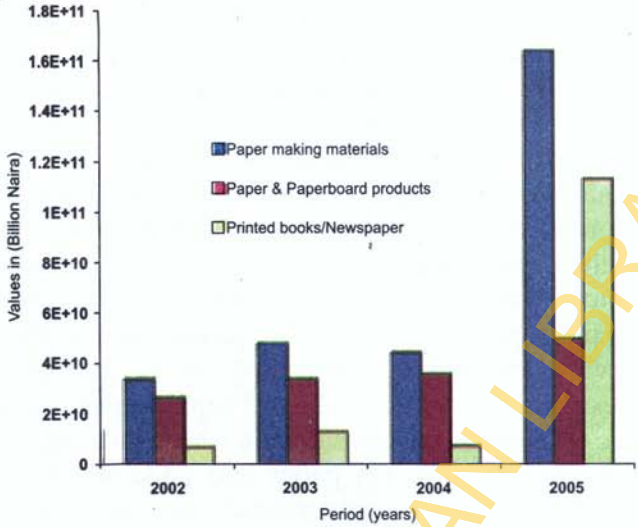


Fig. 4: Import bill of pulp and paper products from 2002 to 2005

Source: National Bureau of Statistics (2005)

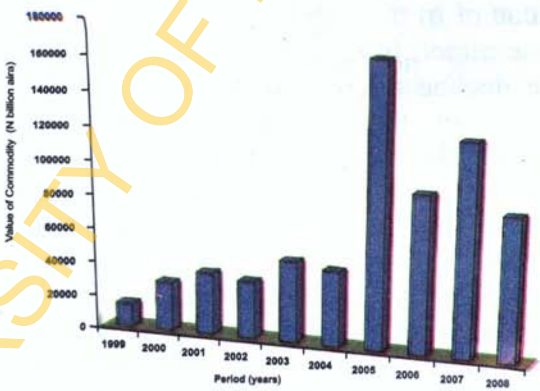


Fig. 5: Import bill of paper-making materials for a period of ten years (1999-2008)

Source: National Bureau of Statistics (2005)

In the paper recycling sector of the industry, there has been evidence of rapid growth and development. Its emergence coincides with the period when the production levels of the three primary paper manufacturing plants were declining. Today, the wastepaper recycling plants are all operating at optimal capacity-utilization. The non-functioning of the primary paper manufacturing plants translates to increases in the importation of the pulp and paper products from abroad with the attendant consequences on the nation's scarce foreign exchange.

It is also important to comment on the present status of the manufacturing process—technology in use by the sector for the production of pulp and paper products in the country. The situation on ground is that the technology is still imported and foreign-based, as all the operating machines and equipment including their spare parts are imported from abroad. There are complaints of difficulties being encountered in sourcing and in the maintenance of most of these imported machines. This has negatively impacted on the productivity of the mills.

Sources of Fibre for Pulp and Paper Manufacture

Conventionally, pulp and paper products can be manufactured from many different fibrous materials, but whether or not such material is well-suited for this purpose depends on the structure of the fibre. For the purpose of my lecture "fibre" here is defined as the fibrous wood and non-wood raw material used in the primary industries producing sawn timber, wood-based panels, and pulp and paper products. The majority of this fibre exists in standing forms in both primary and secondary forests. Another important but emerging source of fibre for the paper industry is the recovered fibres from both wood and non-wood sources. The three main sources of fibrous materials used for paper manufacture worldwide are shown in figure 6. These are the three areas that I will discuss at this point.

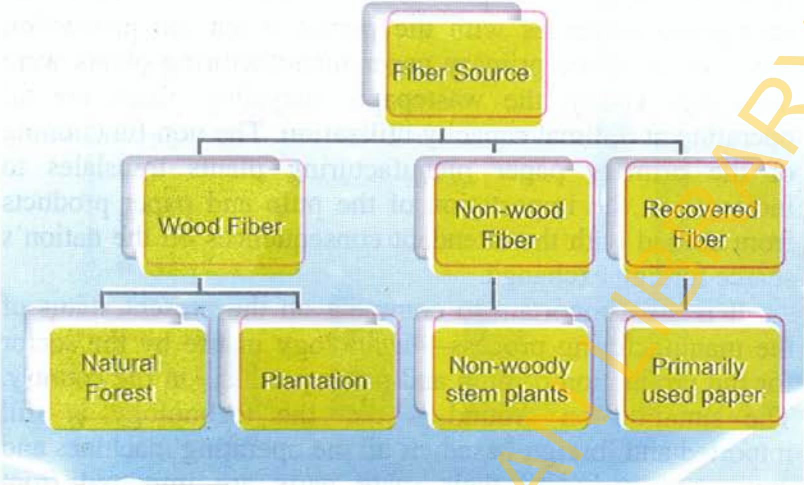


Fig. 6: Simplified illustration of the main sources of fibrous material for pulp and paper-making.

Wood Fibre Sources

Wood is, at present, by far the most widely used raw material for paper pulp. It is composed of tubular or hollow cells, which are mostly the type called fibres in the paper industry. By their general properties, these wood cells determine the properties of whatever wood they compose. If the walls of the fibres are generally thin, the wood will be weak and light in weight. Whereas, woods that are heavy and strong are usually characterized by thick-walled fibres. Thus, the disparity in weights of different woods is generally due to differences in cell structure, since most species are much alike in chemical composition.

Woods and trees that produce fibres are divided into two categories: hardwood and softwoods, which are botanically quite different. Softwoods are classified botanically as **gymnosperms**, a group of plants that bear seeds on scales, as in the coniferous trees (fig. 7b). Whereas the hardwoods belong to the class known as **angiosperms**, which bear enclosed seeds (fig. 7a). Not only do hardwood and softwood trees differ in external appearance, the wood formed by them differs structurally or morphologically. The types of cells, their relative numbers and their arrangement are different. The fundamental difference being that hardwoods contain a type of cell called a vessel element. This cell type is found in virtually all hardwoods but never in softwoods. All hardwoods do not incidentally, produce hard, dense wood. Despite the implication in the names hardwood and softwood, many softwoods produce wood that is harder and more dense than wood produced by some hardwoods. *Araba, Ceiba pentandra,* for example is from a hardwood species but it is a light and soft wood.

(a) (b)

Fig. 7: Typical stands of (a) hardwood (Broadleaf), and (b) softwood (Conifers).

The structure of wood may be best explained by proceeding from larger elements to smaller ones, but some basic ideas involving the smaller elements must first be understood. The fundamental concept necessary therefore for understanding wood structure is that wood is made up of hollow cells cemented together in a honeycomb fashion as mentioned earlier. I will not bother you with the details of this, but will only consider those major cell types of both softwoods and hardwoods that are important in paper-making.

Important Wood-cell Types in Paper Manufacturing

Tracheids: The cell-types found in a typical softwood are shown in figure 8. It is observed that tracheids, which are the water-conducting and supporting cells of trees, form the bulk of the wood, accounting for between 90 and 95 percent by volume. These cells, often called "fibres" in the paper industry are the important paper-making cells, commonly measuring 3.0 to 4.5mm, their length often exceeding their width by more than 100 to 1. Indeed, the value of tracheids in paper-making is due, in great part, to the extreme length of these cells. Other morphological characteristics of the tracheids include small cross sectional area, angularity of outline, thin to medium thick walls, constant width of walls in cross section, and the absence of a distinct end-wall.

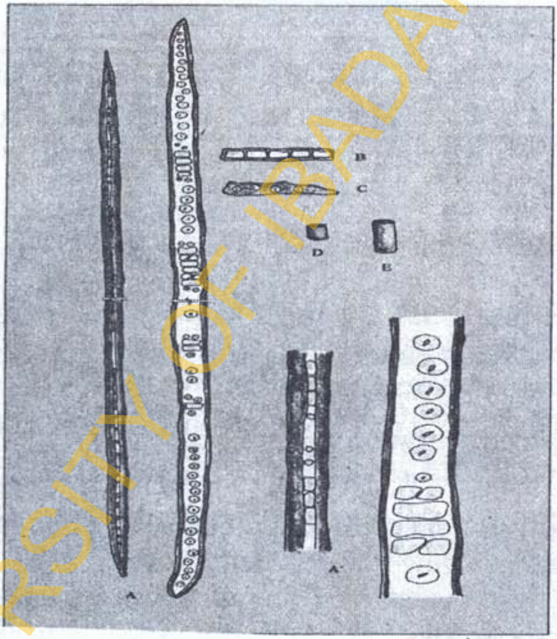


Fig. 8: Cell types of the coniferous softwoods: (A) Tracheids (comprise more than 90% of the wood volume). The remainder comprises mostly ray tissues, either ray parenchyma cells (B); or ray tracheids (C); (D) and (E) are epithelial cells.

Source: Hoadley (1980)

Vessels: As shown in figure 9, vessels are water-conducting tubes of a more specialized type than tracheids and found mainly in hardwoods. The term "vessel" is here applied to the vertical series of united cells and not to a single cell of the series, which is more properly termed a "vessel element" or "vessel segment". Vessel elements are characterized by the possession of vertically elongated cells varying from drum or keg-shaped to elongated tubes, with large cross sectional area, a large central cavity or lumen, and angular or circular outline. They range from 0.3 to 1.0mm in length averaging approximately 0.5 to 0.6mm. The volume of vessels depends upon the size and number, and varies greatly in different hardwoods. In certain woods, they may occupy up to 50 percent by volume while in others they compose well over half of the wood.

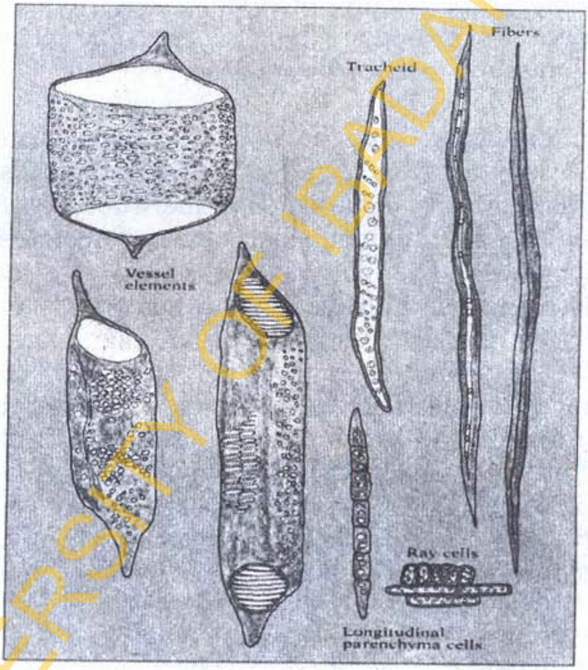


Fig. 9: Hardwood cell types which are extremely varied. (The drawing indicates their relative sizes).

Source: Hoadley (1980)

***Fibres*:** These are strength supporting cells that compose the bulk of the cells of many hardwoods. They vary in form and type but in general, characterized by possessing vertically elongated, slender cells with sharp-pointed ends, very small cross sectional area and typically thick-walled (fig. 9). Their lengths vary from approximately 0.5 to 3mm. The slender form and moderate lengths of fibres make them suitable elements for paper-making, since they constitute the principal fibrous material in hardwood pulp. Often, more than 50 percent of the volume of some hardwoods is composed of these elements.

***Wood-rays*:** Wood-rays are composed of living cells and serve the function of food storage and lateral conduction. Since they vary in size, shape, number and structure, they are valuable diagnostic features of wood. In hardwoods all of the ray cells of the sapwood are living, but in some softwoods the marginal rows of the ray cells are dead.

***Wood Parenchyma*:** Like the wood rays, wood parenchyma cells are also living storage and food-conducting cells; instead of being horizontally disposed as in the wood-rays, they are vertically arranged in strands and often referred to as wood parenchyma cells. The individual cells vary from squarish to vertically elongated with the length often greatly exceeding the width. In diameter, they are usually approximately the same as the fibres among which they are commonly distributed. Wood parenchyma cells are a constant feature of most hardwoods and softwoods and also serve as diagnostic features of both wood types. The average fibre length is shown of some indigenous wood species of both short and relatively long wood fibres that are suitable for pulp and paper production (table 4).

Table 4: Average Fibre Length of Indigenous Wood Species of both Short and relatively Long Wood Fibres

Species	Fibre length (mm)
Acacia nilotica	1.22
Afzelia africana	1.39
Albizia zygia	1.09
Anogeissus leiocarpus	1.20
Daniellia oliveri	1.37
Detarium senegalensis	1.02
Isoberlinia doka	1.48
Hallea ciliata	1.41
Parinarii kerstingia	1.21
Parkia filicoida	1.21
Pterocarpus erinaceus	1.12
Terminalia ivorensis	1.52
Terminalia superba	1.13
Ceiba pentandra	2.22
Adansonia digitata	2.45
Bombav buonopozense	2.22
Sterculia setigra	2.07

Source: Onilude & Bada (2000), Osadare & Udohitinah (1993)

Potentials of Locally Sourced Fibres for the Nigerian Pulp and Paper Industry

Wood Fibre Sources from Nigerian Natural Forest Trees

The wood raw material for the manufacture of pulp and paper products is obtained from the forests (fig. 10). Nigeria, is very much endowed with adequate forested land to enable her provide for her wood products needs including paper products. The distribution of Nigeria's forested areas according to the vegetation zones is shown in table 5 and in fig. 11).

Fig. 10: Natural forest stand of mixed tropical wood species

Table 5: Distribution of Nigeria's forest Estate according to Vegetation Zones

Vegetation Zons	Total Land Area (Km^2)	Area of forest reserve Km^2	% of Total Reserve Area	Reserve as % Total Land Area
Sahel	31,463	2,572	3	0.3
Sudan Savanna	342,158	31,247	31	3.2
Guinea Savanna	400,168	38,271	39	3.9
Derived Savanna	75,707	3,208	3	0.3
Low land rainforest	95,372	19,986	20	2.0
Freshwater sawmp.	25,653	259	3	-
Mangrove forest/Coastal Vegetation	12,782	522	1	-
Total	983,303	96,062	100	9.7

Source: FMANR (1974)

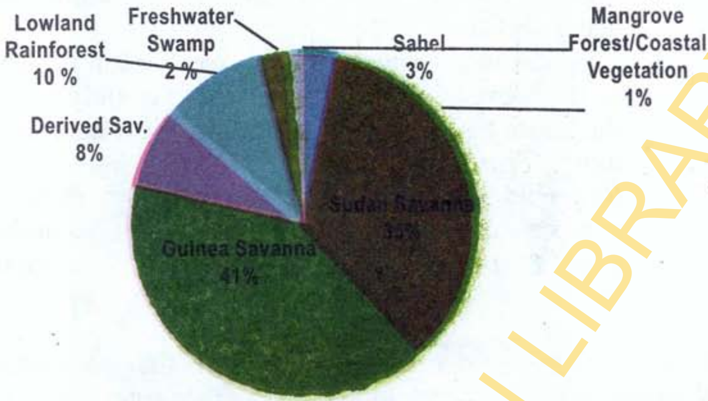


Fig. 11: Percentage distribution of Nigeria's forested land areas by vegetation zones.

Out of a total land area of 983,303 km^2, only 9.7% of it is declared government forest reserve. This has formed the main source of wood supply needs for industrial round wood, sawn wood supply and wood-based panel products. The forested areas estimated at about 5 million hectares are abundantly rich in tropical hardwood, whose current level of utilization is relatively low. For example out of about 600 indigenous hardwood species growing in Nigeria, less than 60 of them are of economic importance.

Presently, the utilization of the wood fibre from Nigerian mixed hardwood species for pulp and paper-making is rather constrained by some technical problems not commonly associated with the pulping of softwoods. Some of these problems include:

1. Tropical forests are usually heterogeneous in composition, thus the selection of a single species for pulping may be difficult, while mixed hardwood-pulping is expensive in terms of chemical consumption.

2. The extraction costs from dense high forests are often high on account of difficulties in communication and accessibility.
3. Tropical forest species often command a higher price as timber products than they would as pulpwood, as is the case with many of the valuable Nigerian large-diameter veneer timbers.
4. Regeneration of tropical forests after cutting is a complex exercise, and often results in secondary re-growth wood formation of very different composition to what was originally existing.

It is therefore evident from the above that to sustain the Nigerian pulp and paper industry, its fibre source will largely come from plantation, rather than from the natural forests.

Fibre Source from Plantations

Plantations are forest stands established by planting and/or seeding in the process of afforestation or reforestation (fig. 12). Historically, the purpose of forest plantations was to supplement the supply of industrial wood from natural forests. Many tropical developing countries increased tree planting after the end of the colonial regimes in the 1950's and 1960's in response to an increased awareness of the need for fuel and industrial wood as a part of overall rural development activities. The traditional paper-making materials worldwide have always been the softwoods derived from temperate or sub-arctic coniferous forests. The establishment of plantations of both exotic and indigenous tree species was primarily to provide for the country's rapidly increasing demands for timber and pulp and paper.

Fig. 12: Tree plantation established for pulp wood supply

In this regard, a number of forest plantation programmes were initiated in some states in the high forest and guinea savanna zones—notably Ogun, Ondo, Edo, Cross River, Kwara, Kogi and Niger States. These plantation programmes were embarked upon in the various locations with emphasis on the creation of man-made forests for a specific end use—pulp wood production. *Gmelina* and teak constituted the two main species planted with the first major industrial forest plantation projects initiated in the mid 1970s and by 1977 the area already planted was about 150,000ha. Presently, there are 89,000ha of *Gmelina arborea* in Nigeria to supply pulp and paper mills with short fibre pulpwood. An additional 127,000ha of plantation including *Terminalia ivorensis, Nauclea diderrichii*, *Triplochiton sceloxylon*, *Eucalyptus* spp. and *Pinus caribaea* and a few other species were also established. As shown in table 6, Nigeria has about 215,000ha of forest plantation and *Gmelina* alone accounts for over 41 percent.

Table 6: Industrial Forest Plantation Establishment in Nigeria as at 1991

State	*Gmelina spp.*	Others	Total
	Area (ha)	Area (ha)	Area (ha)
Akwa Ibom	1,000	2,000	
Anambra	12,000	3,000	
Bauchi	-	1,000	
Bendel	6,000	14,000	
Benue	-	5,000	
Borno	-	9,000	
Cross River	15,000	4,000	
Gongola	-	3,000	
Imo	3,000	-	
Kaduna	-	6,000	
Kano	1,000	10,000	
Katsina	-	4,000	4,000
Kwara	4,000	2,000	6,000
Lagos	-	1,000	1,000
Niger	2,000	3,000	5,000
Ogun	20,000	10,000	30,000
Ondo	20,000	21,000	41,000
Oyo	3,000	15,000	18,000
Plateau	2,000	4,000	6,000
Rivers	-	-	-
Sokoto	-	9,000	9.000
Abuja	-	-	-
Total	**89,000**	**126,000**	**215,000**

Source: FORMECU, (1991)

From the foregoing, it is obvious that with the large hectarage planted up with *Gmelina*, the supply of short fibre pulpwood may be considered adequate for the immediate combined needs of all the pulp mills in the country. However, that of the pulpwood from which the long fibre pulp is obtained is really in short supply. Pine plantation establishment in Nigeria as at 1995 is presented in table 7.

Table 7: Pine Plantations in Nigeria as at 1995

State	Forest Reserve (ha)	Hectare of Pine (ha)
Akwa Ibom	413,972	54
Anambra	95,000	950
Cross River	610,129	13,982
Kaduna	613,484	338
Ondo	337,336	253
Osun	-	EP*
Ogun	273,162	EP

* EP = Experimental Plot
Source: FORMECU (1990)

Only few sites in Nigeria are suitable for the growing of softwood species. Moreover, very few species of tropical pines notably, *Pinus caribaea*, *Pinus oocarpa*, *Pinus merkusii* and *P.radiata* are plantable in Nigeria due to their edaphic and climatic growth requirements. Out of the four species, only *Pinus caribaea* has been very successful in the country.

Non-Wood Fibre Sources

Historically, paper was reported to have been manufactured from non-wood fibres. The original fibre sources for paper at inception were old rags and other textile wastes. The development of chemicals and mechanical pulping technology for wood actually shifted the emphasis of pulping from non-woody to woody materials in the late nineteen century. In the context of this lecture, non-wood fibres are defined as non-woody cellulosic materials from which paper-making fibres can be extracted. The most widely used non-wood fibres for paper-making are straws, bagasse, bamboo, hemp, kenaf, jute, sisal, cotton linters and reed.

Non-wood plant fibres for pulp are generally classified into three main categories, with respect to their source, availability, and fibre characteristics as follows:

1. agricultural and agro-industrial by-products such as straw from various cereals (wheat, rice, sorghum) and bagasse;

2. natural growing plants which include bamboo, reeds, esparto-grass, and sabai-grass; and
3. plants grown for their fibre content and not necessarily for the production of pulp but where the by-products are usable for this purpose, as well as those cultivated primarily for sourcing paper fibres which include flax, hemp, jute, cotton, sisal, kenaf and alfalfa.

In the case of the first group, availability is usually very considerable, but they have other uses even on farms and in agricultural industries. The problems of their being scattered over wide areas and available over short and specific seasons are additional definite economic obstacles. With regard to the other two groups, the costs of production and collection are usually high. A brief discussion of some of these non-woody fibre sources may perhaps be appropriate at this point.

Bagasse – This is the residue (crushed stalk) from the production of cane sugar—after the juice has been extracted. Several million tons of this material is available worldwide annually, much of which is burned for fuel. The percentage used for paper-making is, however, relatively small due to its high pith content which is the major obstacle to bagasse pulping. Pith cells represent about 30 percent by weight of the stalk and are not suitable for paper-making as they consume excessive pulping chemicals. In this regard, pith cells are best removed mechanically before pulping which can be facilitated by controlled partial fermentation of the bagasse in storage, prior to the depithing operation. Once depithed, the bagasse can be readily pulped by alkaline processes and bleached to a good quality pulp suitable for fine papers.

Bamboo – This is an extremely rapidly growing plant and can be cultivated as a crop for pulpwood. Substantial quantities of bamboo pulp are made in India and other Asian countries. The pulp quality is average, compared to other non-wood fibre pulps. As in the bagasse pulping, the high silica content of bamboo complicates alkaline-pulping liquor recovery operation in the use of bamboo for pulping.

Kenaf – This is a plant similar in appearance to corn and can be cultivated in the tropical climate with high yield. Kenaf fibres are typically short and the pulp is generally competitive with hardwood pulps in paper-making.

Wheat, Rice, Grasses – This category of non-wood plant species includes the grass-like plants normally grown for their seeds, but whose stems are generally ploughed-under, burned, or used for cattle feed. The fibre quality varies considerably, as does the silica content. Rice straw in particular, is high in silica content. Quantities of straw available are presently not utilized for pulping and this represents an untapped fibre source which can be successfully pulped for the future.

Cotton Fibres – Cotton fibres are not quite in the class of straw pulps since they come from the seed pods rather than from the stalk or stem. However, the cotton linters, which are the fibres remaining on the seed pod after the long fibres have been removed for textile use, can be used by the paper-making industry both for conversion to cellulose derivatives, such as cellulose acetate and nitrate, and for rag content fine paper. The only preparation normally needed for cotton linter fibres is the removal of waxes and oils by alkaline treatment followed by the proper refining for its end use.

The average fibre lengths of various non-wood fibres are shown in table 8 as compared with those of wood pulp fibres. The data show the wide variation in the fibre characteristics of non-wood fibres. Many of the non-wood fibres are similar to the short fibre indigenous hardwoods (table 4), while others are so long that they must be shortened to optimize their paper-making value.

Table 8: Average Fibre Lengths of various Non-wood Fibres

Non-wood fibres	Average length (mm)
A baca (Manila hemp)	6.0
Bagasses (depithed)	1.0-1.5
Bamboo	2.7-4
Corn stalk and sorghum (depithed)	1.0-1.5
Cotton linters	25
Esparto grass	1.5
Flax straw	30
Hemp	20
Jute	2.5
Kenaf bast	2.6
Rags	25
Reeds	1.0-1.6
Rice Straw	0.5-1.0
Sisal	3.0
Wheat Straw	1.5
Wood fibres	
Temperate zone coniferous woods	2.7-4.6
Temperate zone hardwoods	0.7-1.6
Mixed tropical hardwoods	0.7-3.0

Source: Atchinson and McGovern (1993)

Many non-wood fibres used for paper-making are available as by-products of agriculture and thus, can be potentially cheaper than wood. Plants of this type can frequently be grown in areas that will not support trees, often with very limited rainfall and low quality soil. They often produce high annual yields per hectare. The average annual yield per hectare of kenaf, for example, is about twice that of fast growing softwoods. Non-woody plants can generally be harvested within a year or two after planting compared to the 10 – 20 years needed for trees to attain rotation age for commercial harvesting. Straw fields can be easily harvested with no need for sophisticated machinery for collection and transportation. They also have lower lignin content than woods, and generally, it is easier to delignify non-woods as they have lower activation energies. Similarly, production of papers from non-woody fibres would help in reducing the need to produce pulpwood from natural forests, and for large-scale plantation. Thus, under certain climatic conditions, non-wood fibre production may be a reasonable alternative to tree plantations.

One of the major elements of the use of non-wood plant fibres for paper-making is the high inputs required for growth and harvesting of these annual crops. Even though harvesting is done yearly, it must be accomplished within a short span of time usually limited to a few weeks in the dry season of the year. This means high investment in harvesting machinery, much of which may sit idle for the most of the year. Moreover, given that most non-woods are annual plants, a large storage capacity must be developed to ensure a constant supply, all year round. This is further complicated by the fact that most non-wood fibre sources are high in volume and low in density when compared with wood. Non-wood fibres, particularly straws, are quite susceptible to microbiological degradation, when wet, and this degradation can destroy the pulping potentials of straw in a matter of a few days, as opposed to the weeks and months needed to degrade wood to a similar degree. For this reason, they are best stored under shelter from these elements thus, adding to the cost and complexity of storage.

High silica content is another problem with the non-wood fibres in general. If pulped by strong alkaline liquors (soda or Kraft process), the silica will dissolve in the pulping liquor and re-precipitate on process equipment in the liquor recovery operations. Similarly, the fibres of non-woody plants are generally much shorter than softwood fibres and tend to drain with water slowly. This decreases the production rates during washing and during dewatering operations in pulp and bleach mills and it can also slow down paper machines. In spite of all these demerits, certain non-wood plant crops are still being grown in such quantities that the straw residues are receiving serious attention as fibres.

Recovered Fibre Sources

Recovered fibre refers to any fibre that is recycled, also called "secondary fibres". These are fibres that have been used more than once in the manufacture of a paper or a board product. Over the years, there has been strong and growing pressure particularly, from environmentalists to increase the recycling of wastepapers. The environmentalists are emphasizing the conservation of natural resources while the paper maker is concerned with economic aspect of the venture. The paper manufacturer is interested in the actual and potential value of wastepapers as raw material for the paper and paperboard industry, which currently absorbs the vast majority of all wastepaper that is reutilized.

The economic advantages of wastepapers as a source of fibre in the paper industry include:

(i) Potentially reduced effluent discharges, as only slushing (as opposed to pulping and slushing from virgin fibre) is needed to disintegrate wastepaper into fibres.
(ii) Water consumption is reduced compared with that required for chemical pulping.
(iii) Mechanical processing is reduced, leading to lower energy costs.

The pricing structure of wastepapers in the paper recycling industry is built around a large number of different grades, of which the most common grades are divided into six classifications as follows:

1. ***Mixed Wastepaper:*** contains various qualities of paper not limited as to type or fibre content. Mixed wastepaper product is used in roofing and bituminous asphalt shingles, moulded articles, centre ply in multiple board for boxes, structural dry-wall and common low-cost boards.
2. ***Corrugated Wastepaper:*** contains double-lined Kraft outer surfaces and a fluted medium centre. It also

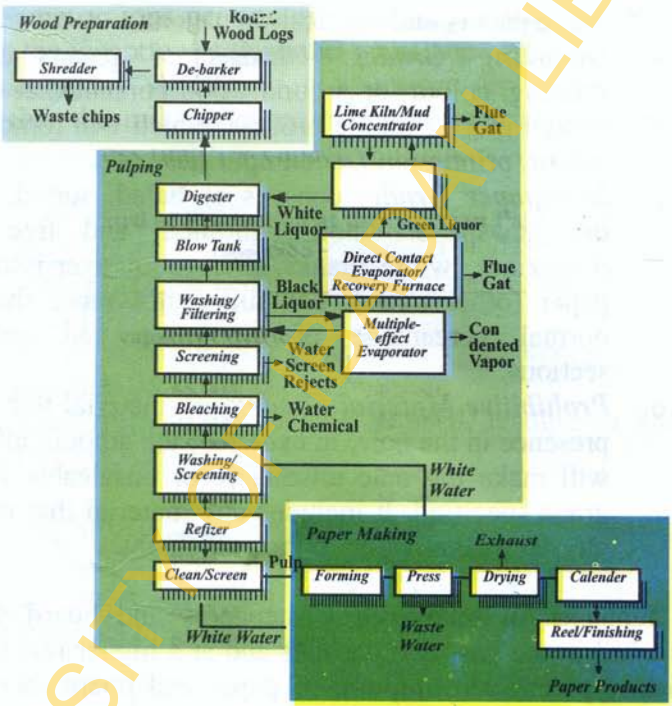
includes double-lined corrugated cuttings, new Kraft corrugated cuttings, and used corrugated containers or boxes. This grade is used in the production of linerboard, corrugating medium, dry wall board, and roofing. It comprises the largest tonnage in the secondary fibre field.

3. ***Direct Entry:*** consists of white paper having no printing. It is of reasonable uniform brightness with no prohibitive material. The grade is used as a substitute for virgin, bleached pulp in fine papers, tissue papers and publication papers.
4. ***De-inking Grades:*** consists of papers having printing, colour, or ground wood content that can be treated in a de-inking process, which will remove the colour, printing ink, and impurities.
5. ***Newspaper Grade***: consists of baled, sorted, fresh, dry newspapers—not sunburned, and free from magazines, white blanks, pressroom over-issue and paper (other news), containing not more than the normal percentage of rotograve and coloured sections.
6. ***Prohibitive Material Grade:*** any material that by its presence in the bale, in excess of the amount allowed, will make the bale unsuitable or unsaleable for the grade specified. It includes any material that may be physically damaging to the equipment.

Tonnages of recovered wastepapers and board greatly increased in the past two decades and at a higher rate than at which apparent consumption of paper and board increased. With a view to further increasing the tonnages recovered and to cope with collection fluctuations, many systems have been devised with some measures of success. Trends in the paper recycling industry are that every user seems determined to make a considerable effort to increase the use of recovered fibre for paper-making for several reasons.

Industrial Processes in the Pulp and Paper Manufacturing

In discussing the industrial processing of fibres for the production of paper and paper products, the following step-by-step description is adapted from the World Energy Council (1995). The five principal steps in pulp and paper production are wood preparation, pulping, bleaching, chemical recovery, and paper-making (see fig. 13).



Integrated Pulp and Paper Making Process

Fig. 13: Flow diagram of an integrated pulp and paper manufacturing complex

Source: http:/papermillpiping.blogspot.com

Wood Preparation

Wood is delivered to the mill either in the whole log form or as wood chips from the sawmills. The logs are debarked using either drum or hydraulic debarkers. Drum debarkers which consist of a slightly inclined, rotating drum is best suited for small diameter logs while the hydraulic debarker uses high pressure water jets to handle large diameter logs. Debarked logs are chipped by multi-knife chipper into suitable sized pieces and are then screened to remove oversized chips. Chip thickness is an important parameter as it determines the speed and penetrability of the cooking chemicals into the wood chip.

Pulping

Various pulping processes are used to convert wood into fibrous materials suitable for paper-making. The goal of pulping is therefore to separate the fibres from the bulk material and this may be classified simply into mechanical, semi-chemical/chemi-mechanical and full chemical processes. In chemical pulping, wood chips are cooked in an aqueous solution at high temperature and pressure. Basically, chemical processes dissolve most of the natural binder called lignin that holds the fibres together, while leaving the cellulose fibres relatively unchanged. The process results in high quality paper with a yield of between 40% and 60% of the weight of the dry wood. In kraft pulping (alkaline-based), for example, which is also the most common method of chemical pulping, sodium hydroxide and sodium sulphide solutions are used while a mixture of sulphurous acid and bisulphite iron is used in the sulphite process (acid-based). The sequence of pulp manufacturing prior to paper-making is presented in table 9.

Table 9: Summary of Pulp Manufacturing Process Sequence

Process Sequence	Description
Fibre Furnish Preparation and Handling	Debarking, slashing, chipping of wood logs and then screening of wood chips/secondary fibres (Some pulp mills purchase ships and skip this step).
Pulping	Chemical, semi-chemical, or mechanical breakdown of pulping material into fibres.
Pulp Processing	Removal of pulp impurities, cleaning and thickening of pulp fibre mixture.
Bleaching	Addition of chemicals in a staged process of reaction and washing increases whiteness and brightness of pulp, if necessary.
Pulp drying and baling (non-integrated mills)	At non-integrated pulp-mills, pulp is dried and bundled into bales for transport to a paper mill.
Stock Preparation	Mixing, refining, and addition of wet additives to add strength, gloss, texture to paper product, if necessary.

The mechanical pulping method involves grinding wood material against an abrasive surface to defibre it without any lignin dissolution. It reduces wood to macerated cellulosic fibres, which are generally damaged and still carry non-cellulosic wood components, resulting in a very high yield. Mechanical pulping process in commercial use is of three types (i) stone ground-wood (SGW), (ii) refiner mechanical pulping (RMP) and (iii) thermo-mechanical pulping (TMP). Stone ground-wood process is the oldest method in which logs are forced into contact with a rotating grindstone in the presence of water. The RMP on the other hand, is a two-stage process, which allows for the use of chips combined with sawdust wastes, while TMP is an improvement on the RMP, but requires three steps to transform chips into pulp. Retention of lignin and other residues results in a higher yield, but with more damage to the fibres obtained. This lower quality fibre limits the use of mechanical pulping process to less expensive grades of paper, such as the newsprint.

The semi-chemical/chemi-mechanical pulping method generally involves a mild chemical pretreatment of the raw material before applying mechanical action to liberate the fibres. Semi-chemical process was first developed in order to use a large range of hardwood species. The principal methods in use include: chemi-thermo-mechanical pulping (CTMP), neutral sulphite semi-chemical pulping (NSSP) and Kraft semi-chemical pulping (KSC). CTMP involves the use of sodium sulphite with a better pulp quality (see table 10).

Table 10: Pulp Manufacturing Methods

Process category	Fibre Separation method	Fibre-Quality	Examples	% of Total 1998 US Wood Pulp Production
Mechanical	Mechanical energy	Short, weak, unstable, impure fibres	Stone roundwood, refiner mechanical pulp	10%
Semi-chemical	Combination of chemical and mechanical treatments	"Intermediate" pulp properties (some unique properties)	High-yield Kraft, high-yield sulphite	6%
Chemical	Chemicals and heat	Long, strong, stable fibres.	Kraft, sulphite, soda	84%

Sources: EPA Sector Notebook Project (2002)

Bleaching

Generally, pulp produced by mechanical or chemical pulping processes is coloured, varying from brown to beige depending on the raw material and process used. To produce white paper from such pulps will require bleaching (see fig. 14). The bleaching exercise therefore, combines the removal and alteration of dark products included in the pulp, depending on the type of pulp concerned and the end product desired. Bleaching of chemical pulp is more or less a continuation of the delignification process of the chemical pulping itself. Because of the initial colour of sulphite pulp, it is much easier than bleaching Kraft pulp.

Chemical pulps are bleached through the use of alternating treatments of oxidizing agents and alkali solutions. Mechanical pulps on the other hand are treated with hydrogen peroxide or sodium hyrosulphite to reduce the light absorption of the lignin rather than remove it.

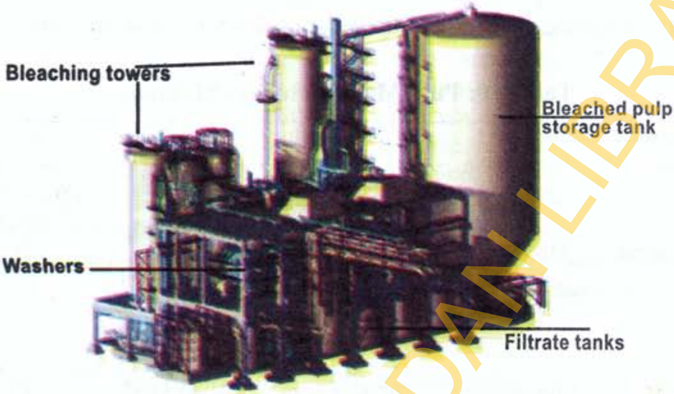


Fig. 14: Pulp bleaching facilities in a pulp and paper plant

Source: Ahonen et al. (2006)

Chemical Recovery

Chemical recovery is a process of recovering the chemicals used at various stages of Kraft chemical pulping. The process produces a waste steam of inorganic chemicals and wood residues called black liquor. In the recovery process, the black liquor is concentrated in evaporators and then incinerated in recovery furnaces, many of which are connected to steam turbine cogeneration systems. The organic wood residues present provide the fuel while the inorganic chemicals are separated as smelt which is then treated to produce sodium hydroxide and sodium sulphide. These constitute the chemicals for the preparation of the white liquor needed for another round of the cooking process.

Paper Manufacturing
Paper-making is the process whereby pulp fibres are treated mechanically and chemically, format into a dilute suspension, spread over a mesh surface, the water removed by suction, and the resulting mat of cellulose fibre pressed and dried to form paper. Much of the strength of paper results from hydrogen bonding of cellulose molecules that make up adjacent fibres. To provide the maximum potential for bonding, fibres are treated mechanically by passing them between moving steel bars which are attached to revolving metal discs called refiners. Refining increases the inter-fibre bonding at the expense of the individual fibre length, but the net result will be an increase in paper strength.

Following the refining or beating as the case may be, fibre is mixed with water to a consistency of about 1% fibre by weight. It is a common practice to mix different types of pulp (mechanical and chemical pulp) at this stage, with the proportion of each dependent upon the kind of paper to be manufactured. Various chemicals (additives) such as starch (for increased bond strength or wet strength) and resins are often added to the mixture at this point, as well as rays (for brightness and opacity). The mixture is then formed into a thin mat.

The most commonly used paper machine to form the fibre-mat is called a Fourdrinier machine, the first of which was ever used in 1804. It is basically a rapidly moving horizontal screen, fitted with a device to accurately meter a pulp mixture onto it. As the pulp flows onto the screen, water drains away with the aid of suction boxes or other drainage enhancing devices mounted under the wire, leaving a mat of fibres. The mat is then wet-pressed, passed over a series of steam heated drums, pressed again to desired thickness and wound into large rolls. Application of coatings, sheet-polishing operations known as calendaring and splitting of large rolls into smaller sheets are subsequent operations. A simplified flow diagram is shown of an integrated paper-making plant (fig. 15), while figure 16 illustrates the manufacturing stages of transforming solid wood block into paper mat.

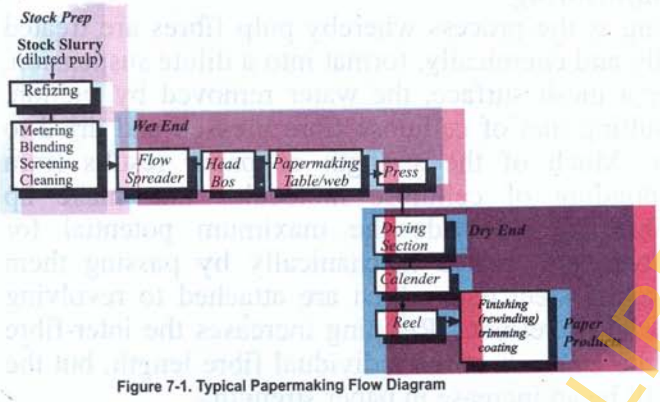


Fig. 15: A typical paper-making flow diagram (*Source:* http:/papermillpiping.blogspot.com)

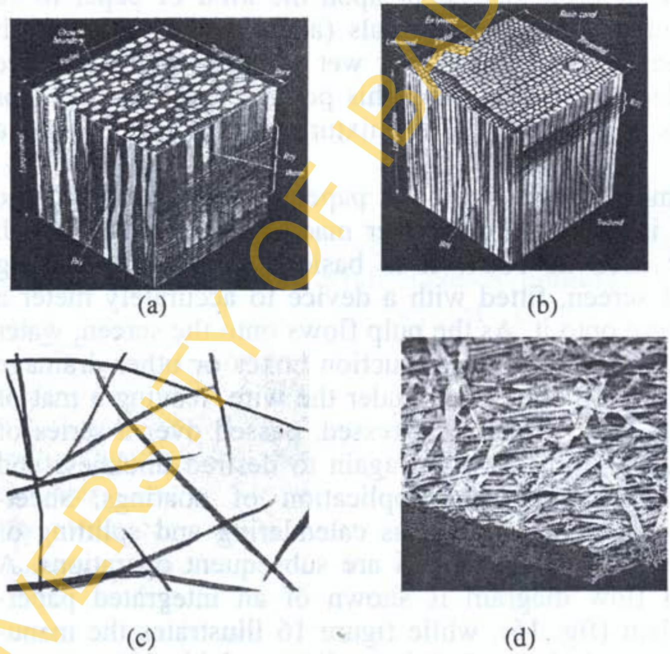


Fig. 16: Manufacturing stages of transforming wood fibres from (a) solid hardwood block; or (b) softwood block; into (c) individual by pulping, and finally made (d) paper.

Processing of Non-wood Fibres

In principle, the same pulping processes that are used for wood-pulping (chemical and mechanical) can also be used for the non-woody materials. The pulping processes include straight soda or modified soda process, sulphate process with varying sulphidity (neutral or mono-sulphite, acid sulphite) and cold soda processes. The selection of a particular process is, however, determined by techno-economic and ecological factors, which vary from one place to the other. Although non-woody materials can be pulped with the same processes used for wood, the technology to do so has not been tried on a commercial scale in Nigeria. For the purpose of my lecture, I will attempt to discuss the established pulping processes for only a few of the non-woody plants that are available for use in Nigeria. These include bagasse, straw and bamboo.

Pulping of Straw: Cereal straw is an important source of raw material for pulp and paper-making where grain is grown in vast quantities. Straw is pulped by chemical processes including soda, sulphate, and neutral sulphite processes. The pulping conditions for straw raw material using the batch digester method are shown in table 11. Continuous digesters are however, more commonly used for the soda sulphate and neutral sulphite processes.

Table 11: Pulping Conditions for Batch Pulping of Straw

Cooking parameters	Lime	Soda	Sulphite
Chemical	CaO 6 – 12	NaOH	NaOH 10 – 12 +
Moisture – to – straw	or MgO 12 – 18	6 – 15	Na_2S 2 – 3
Liquor – to – straw Ratio after steaming	4:1	4:1 – 7:1	4:1 – 6:1
Cooking time	6 – 10hr	2.5 – 4hr	2.5 – 4hr
Cooking temperature	125^0 - 140^0C	150^0 - 170^0C	150^0 - 170^0C
Variety of pulp produced	Coarse	High yield semi chemical and bleachable grade	High yield semi chemical and bleachable grade
Yield (crude yield) from Wheat/trye straws	70 – 85%	48 – 70%	50 – 70%
Rice straw	70 – 80%	40 – 45%	42 – 47%

Source: Casey (1980)

The mechano-chemical process can also be used to produce coarse pulp from straw in the yield range of 70 – 75% which is suitable for corrugating medium. The process was developed specifically for pulping straws and bagasse. In this process, either caustic soda or sodium sulphite is used as the cooking chemical in which pulping is carried out at atmospheric pressure and at a temperature ranging from 95 to 100^0C in a hydropulper for 60 to 80 min. Bleachable grade pulp can be produced by this method using 12 – 13 percent caustic soda with a cooking time of 30 to 35 min.

Pulping of Bagasse: Bagasse, being a by-product of the sugar industry, enjoys a unique position among the non-wood fibres for pulp manufacture mainly due to its availability in large quantities at a central collection point. Its distinct advantage over other non-wood plant fibres is that the costs of collecting, crushing, and cleaning the materials are borne by the sugar mill. Bagasse can be pulped by any of the conventional processes: soda, sulphate with 15 – 20% sulphidity, limesoda, soda-chlorine or even by the mechano-chemical method. Of all these, the soda and sulphite processes have found wide application in the pulping of bagasse. Cooking with neutral sulfite process can also produce bagasse pulp, but of lower strength, while the yield and brightness values may be higher than that of pulp produced by the sulphate process. The mechano-chemical process, using either caustic soda or lime alone or in combination with other alkalis, is also employed mostly for the production of high-yield coarse bagasse pulp for the manufacture of corrugating medium.

Pulping of Bamboo: Bamboo pulping is best carried out by using the alkaline pulping process, particularly the sulphate process, as it affords satisfactory delignification, as well as high yield. A two-stage digestion method for bamboo pulping on a commercial scale is also in common use. It is based on removing starches, degraded products of sugars, gum, tannins and colouring matter by mild cooking in the first stage and completing the delignification under somewhat drastic conditions in the second stage. The partially cooked chips from the first stage are then cooked with 16 – 18% active alkali for about three hours at 140 – 153^{0}C. With this method, the overall chemical requirement for pulping and bleaching is relatively low and pulp of 10 to 12 permanganate number can be produced for bleaching.

Another method for pulping bamboo, which is now widely used, is a single stage process called "overhead-pulping". The permanganate number and yield of pulp using this process are 13 to 16 and 44 to 46% respectively. However, higher yield of between 50 and 52% and permanganate number of 24 to 28 could be attained if milder cooking conditions are used.

Wastepaper Recycling Process: This area of recycling is one in which the pulp and paper industry already leads the world. Rates of recycling are currently high and are likely to continue to increase up to the maximum achievable levels. Similarly, the technologies of recycled fibre separation, de-inking and sorting have improved markedly over the last few years so that much higher value products can be manufactured from recycled fibre. Recycling of wastepaper involves the re-pulping of wastepapers and paperboards. There are two basically different methods of doing this. One is a purely mechanical system involving the use of pulpers, screens and centrifugal separators, while the second one is a combination of chemical and mechanical systems in which chemicals are used in the pulping stage to remove ink and other contaminants. There are a number of differently designed mechanical systems in use in the industry. All systems involve the use of a pulper to break the bundles or bales of wastepaper. This is a device to remove heavy foreign impurities such as clips, strings, and metallic wires. A screening system is the component for removing oversized particles, while the centrifugal separator removes contaminants of all types. In order to accomplish this with a minimum expendi-ture of energy, the wastepaper pulping systems must have a specified tonnage output at a specified consistency and produce pulp having good runability on the paper machine. A flow diagram is shown in figure 17 of a typical modern wastepaper recycling plant which produces paper products from wastepaper and sometimes virgin pulp as supplement.

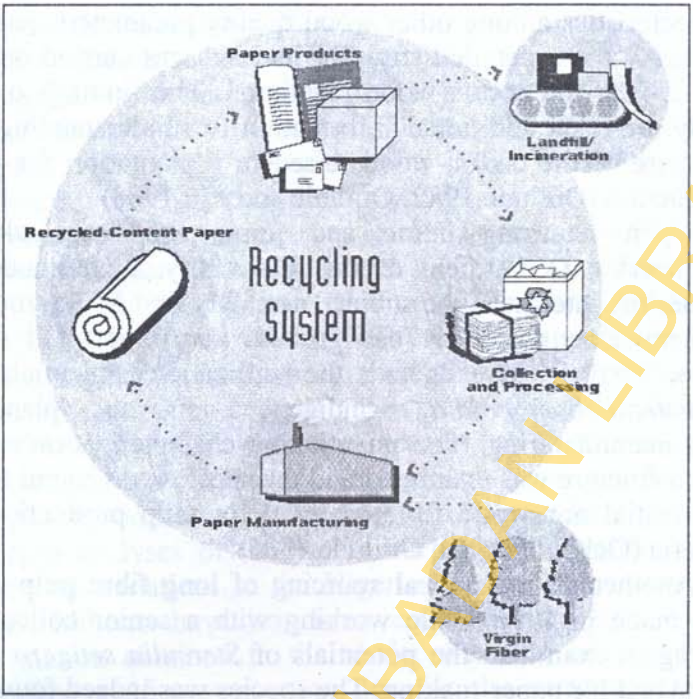


Fig. 17: Wastepaper recycling processing flow diagram

Source: www.epa.gov/climatechange/wycd/

My Contribution

Mr. Vice-Chancellor Sir, I shall now proceed to provide some highlights of my humble contributions to the extension of knowledge in my journey thus far in academics. My contributions in the search for both wood and non-wood fibre resources suitable for pulp and paper manufacture will be examined. I will also highlight the contributions of my activities in other areas of the Wood Products Engineering research in which I have been involved over the years.

My first contact with wood fibre research was in the United States of America during my Ph.D work at Virginia Tech, Blacksburg, Virginia in 1982. Working with a temperate hardwood—*Populus deltoids* grown in plantations for short-fibre pulp production, I was able to evaluate its fibre characteristics among other wood quality parameters. It was the first time a detailed study of its kind was carried out on the 26-year old cotton-wood plantation. The findings of the study provided additional information for understanding the structure of the cotton-wood raised in a plantation for pulp production (Onilude 1982, Onilude and Ifju 1988).

Upon returning home and joining the Agricultural Engineering Department of this University, I continued to further my interest in the subject area. My first M.Sc student, a chemical engineer by background, was supervised on a project which investigated the utilization potentials of *Triumfetta rhomoboidia*, an indigenous non-woody plant for pulp manufacturing. The quantitative characterization of its microstructure was examined and the species was found to be a potential non-wood fibre material for pulp production in Nigeria (Ochonogor and Onilude 1985).

Another effort at local sourcing of long fibre pulpwood was made in 1996 while working with a senior colleague. We again examined the potentials of *Sterculia setigera* as a pulpwood for paper-making. The species was indeed found to be one of those few indigenous hardwoods with relatively long fibre length suitable for paper-making (Onilude and Bada 1996).

Since the introduction of plantation forestry in Nigeria, both federal and some state governments have been involved in the programme as pointed out earlier. Over the years, I have also extended my research activities on the wood quality studies of some of the indigenous wood species used for such plantation programmes. I have shown particular interest in two of such species: *Terminalia superba* and *Triplochiton scleroxylon* (*Afara* and *Obeche* respectively). I supervised a Ph.D student who carried out comprehensive wood quality studies on the latter wood species. Both studies have provided database on the properties of the two economic indigenous species for the first time, from locally established tree plantations [Onilude 2001(a), Onilude 2001(b), Ogunsanwo and Onilude 2000(a), Ogunsanwo and Onilude 2000(b), Onilude and Ogunsanwo 2002].

My research activities in fibre studies for pulp and paper production were not limited to the hardwood only, I also showed interest in some softwood species that are grown in Nigeria, particularly the pines. In 1987, I carried out a preliminary investigation on the wood quality characteristics of *Pinus caribaea* provenances in a plantation established in the northern part of the country. This was the first time a study of its kind was done (Onilude 1987). Other studies on the species involved another Ph.D student I supervised, who carried out studies on the basic wood and pulp properties of a Nigerian grown pine species. This work represents the most detailed studies on the tree species to date, since its introduction into Nigeria as a long fibre pulpwood for pulp and paper production. The findings of the work have provided in-depth analyses of the wood and pulp and paper quality parameter variations in the Nigerian-grown *Pinus caribaea*, which hitherto have not been established. Based on the information obtained in the study, we then conservatively estimated a 15-year rotation age for the sampled species, which is about half the rotation age of the species in its native country. We feel this is a major breakthrough towards initiating improvement programmes vis-à-vis towards achieving adequate supply of long fibre pulp locally, which has been one major bane of the pulp and paper industry in Nigeria [Onilude and Oluwadare 2000(a), Onilude and Oluwadare 2000(b), Oluwadare and Onilude 2000(a), Oluwadare and Onilude 2000(b)].

The search for suitable non-wood fibre raw materials for use in making pulp and paper did not end at the pioneering work carried out with my M. Sc. student in 1988. Attempt was also made at investigating some indigenous non-woody plants found in the country. Bamboo, another non-woody plant has been widely used in its native countries for paper-making. The Nigerian-grown bamboos, have recorded good growth characteristics and hence, attracted our interest to investigate their pulp and paper characteristics. One of the species investigated was *Bambusa vulgaris* and it was found to possess very promising fibre characteristics for use in pulp and paper manufacture (Onilude 2005, Ogedengbe et al. 2008). In 2006, I also participated in a multidisciplinary research funded by an international agency in search of non-woody plants for pulp-making. It was a research on the characterization of two non-woody plant species for their fibre properties. The species were *Thaumato-coccus danielii* and *Hibiscus sabdariffa* and the results obtained so far are very promising (Ogunsanwo et al. 2008). Work was also extended to the pulping of the stalk of banana plant (*Musa paradisiaca*), in which its paper characteristics were examined. Using different chemical pulping trials, a suitable method was recommended for the pulping of banana stalk for paper-making [Ogunsile et al. 2006(a) & (b) and 2008].

My contributions in other areas of Wood Products Engineering research cut across the fields of wood composites, wood utilization, and machine design and fabrication. While in the US as a graduate student, I attempted using a non-durable low-density temperate hardwood, to investigate the feasibility of preserving a flakeboard made of the species and what effects such chemicals would have on board properties. The study was a pioneering work at the time and has continued to provide baseline data for subsequent work in the subject area (Onilude 1983, 1984). I also investigated the use of lignocellulose materials other than wood for board-making. Corn cob of *Zea mays* and groundnut shells were investigated for their composite board-making potentials [Onilude 1989(a) & (b)]. A similar study was also carried out on the use of water hyacinth (*Eichhornia crassipes*) for particle-board production. This was the period when water weed invaded Nigerian waterways in the late 1980s. Both studies found the agricultural residue materials suitable for board-making [Onilude 1989 (a & b), Onilude and Arebi 1990].

In the field of wood processing and utilization research, I also made my modest impressions. Working with my students, we embarked on a few studies in the use of solar energy for processing both agricultural and wood products. A portable solar dryer was designed for yam and cassava flakes (Onilude and Olosho 1988), and in another work, a similar dryer was fitted with electronic devices for drying agricultural crops using solar energy (Onilude and Raji 1992). We extended the work to the processing of wood, using solar energy in which we developed an appropriate solar dryer for the use of small-scale wood users (Onilude and Oseni 1989). Furthermore, in 1988, in cooperation with a colleague and a Ph.D student co-supervised by the two of us, we worked on five selected Nigerian hardwoods growing in the savanna belt. The wood properties of these indigenous species, which were hitherto unknown, were published for the first time (Onilude et al. 1988). Only recently, while working with another Ph.D student, attempt was also made to investigate the utilization potentials of one of the numerous lesser-used indigenous hardwoods, *Ficus mocuso*. It was the first time the tree species was to be studied in greater depth following its taxonomical identification. The information so provided by the study has since formed a data base on the tree species in Nigeria [Adejoba and Onilude 2008(a & b), 2009; 2010 and Adejoba et al. 2009].

In my wood composite research programmes, it became necessary to search for a natural binder other than the synthetic petrochemical-based adhesives that are traditionally used for making composite boards. I had the opportunity of supervising two Ph.D students in this field. In both works, we attempted to develop a natural adhesive for use in the wood industry. In one study, we produced adhesive from the bark of a mangrove plant species while, some selected legumes were used in the second study. Both studies revealed the great potentials in developing natural adhesives from the selected Nigerian-grown raw materials.

My interest and subsequent activities in design and fabrication of equipment/devices were circumstantial. Necessity is said to be the mother of invention. As a newly recruited academic staff in the Department of Agricultural Engineering, I was handicapped by the non-availability of necessary research facilities to work with. The only area of research I could readily embark on with very minimal laboratory equipment was wood composite research. To do this, I needed a hot press to fabricate the composite boards required. I was then forced to improvise, which gave birth to my first equipment fabrication. To date, the product of the adventure (fig. 18a) has remained one of the key research facilities available in the department for students, and for teaching and research (Onilude 1985, and 1988).

(a) (b)

Fig. 18: (a) Hot platent press fabricated for producing composite boards.
(b) Wood, pulp digester for pulping wood chips during chemical pulping process.

With this modest success, I also challenged a student I supervised to embark on a similar project. An appropriate technology paper-sheet forming machine was produced for use in our pulp and paper research activities (Ologunleko and Onilude 1990). In a collaborative research in which I participated in 2006, I was charged with the fabrication of a pulp digester for use on the project. The study was to investigate the utilization potentials of some selected non-woody plants for pulp and paper making. The digester was successfully produced, tested and has since remained in the Department for use by students and for research activities (fig. 18b).

The experience of the above successfully completed fabrication projects encouraged and motivated me to propose bigger projects in collaboration with my colleagues across the University. Two of such projects were conceived in this regard and submitted to the University Mission Research Committee in year 2000 for consideration and they were approved along with others for execution. One of the projects was aimed at the fabrication of appropriate machine with local materials for briquetting wood and agricultural wastes. A manual version of the machine was developed and has since been patented (Patent No RP 16173, 2006, fig. 19a). Work is ongoing on the second machine which is the motorized version of the briquetting machine. The second multidisciplinary collaborative project of the University Mission Research which I also initiated was the development of a production machine system that will recycle wastepapers. To date, three important components of the machine system, Hydropulper, pulp-mixer and a mechanical pulp press were successfully fabricated by the team and have remained in the Department as facilities for teaching and research for both students and staff (fig. 19b, c, & d). The University Mission Research Committee is proud at making reference to these two projects as its greatest achievements, the first of its kind in the history of the University. Indeed, products of the two projects have been exhibited by the University in the past years. Further enquiries about the fabricated products have always been received at the end of such exhibitions, but there has not been any serious follow-up.

(c) Pulp mixer for pulp washing after wastepaper disintegration inside the hydropulper

(d) Pulp lap wet mechanical press for dewatering water from the pulp lap

Fig. 19: Manual briquetting machines

It is heart warming to mention that all these fabrications were displayed in the laboratories and they formed part of the research and teaching facilities presented for the accreditation of the Wood Products Engineering programme of the department. The good news is that the programme was awarded full accreditation after the NUC visitation in November 2010.

Another significant contribution which I will like to share with you is my experience in another collaborative project I initiated with my colleagues and a private manufacturing company, the first of its kind in the Department. A senate research grant of ₦500,000 was applied for and granted for the multidisciplinary research project. It was a collaborative project between the research team led by Professor J.C. Igbeka and a local fabricator in town, to fabricate a CD 4 Band Saw Mill (fig. 20). An agreement was signed stating the specific roles of each of the two parties. The University team was to provide the design, funds for materials and labour as well as the performance evaluation test of the final product for the purpose of establishing the operating specifications and standard for the machine. The fabricator was to produce the machine in his workshop based on his experience. Midway into the project, the fabricator backed out. After prolonged and persistent pressure, he opened up and gave reasons for his action. The main reason given was that a staff of the University who lived in his neighbourhood told him that we had received millions of Naira for the project, only to give him a pittance. In spite of all our persuasion and sufficient paper evidence presented to him, he was not convinced. We ended up taking delivery of the part components of the machine from his workshop, and looked for another fabricator elsewhere to complete the project under our supervision at the Department of Agricultural and Environment Engineering. I was so passionate about the project and determined to ensure that it remained completed and functional. Today, the Wood Products Engineering Programme can boast of having a CD 4 Band Saw Mill at its disposal for use by students and staff for teaching and research.

(a) The saw mill rig showing a log being processed.
(b) The operating control features of the machine.

Fig. 20: A CD 4 Band Sawmilling Machine, product of a collaborative project with a private machine fabricator.

Mr. Vice-Chancellor Sir, before I conclude this lecture I will like to give some strategies, in the form of recommendations, for the development, resuscitation and sustainability of the Nigerian pulp and paper industry based on my experiences in the field and research for the past 29 years in the pulp and paper industry.

Strategies for the Development, Resuscitation and Sustainability of the Nigerian Pulp and Paper Industry

Sustainable Fibre Supply

The sources of fibre supply to the pulp and paper industry have been identified and grouped under the following: short fibre pulpwood, long fibre pulpwood, non-wood fibre and recovered fibre. The strategies being proposed will be discussed for each group.

Short Fibre Pulpwood

The short fibre pulpwood raw material needs of the Nigerian paper plants will largely be sourced from plantations rather than from the natural forest. In this regard, there will still be the need to establish forest plantations to supply the required short fibre pulpwood. As at 1991, over 89,000ha of *Gmelina* *arborea* plantation had been established nationwide. The choice of *Gmelina* for plantation establishment was based on the satisfactory results of experimental studies as a pulpable hardwood species, with very promising pulp yield and good pulp and paper properties. Under any good growth conditions, the species can be nurtured and harvested for pulp and paper in eight years rotation. It is equally found to coppice and regenerate itself very readily.

Eucalyptus spp. is another exotic hardwood species that also merits its use for the establishment of pulpwood plantation. The species is very similar in most respects to *Gmelina arborea*. Since the two tree species have been tried for plantation establishment, it therefore makes economic sense to continue to adopt them in those areas suitable for their growth. There are indigenous hardwood species that have been found with relatively good fibre lengths, desirable for pulp and paper-making. These include: *Adansonia digitata, Bombax buonopozense, Ceiba pentandra, Sterculia oblonga, Sterculia setigera, Sterculia rhinopetala, Sterculia tragacantha, Dracaena arborea, Hildergadia barterii, Rhizophora racemosa* and *Ficus exasperata*. Some of these species are included in the list of those indigenous trees that I have researched on, over the years.

Long Fibre Pulpwood

The country is blessed with suitable land and favourable climatic conditions that will support the establishment of pulpwood plantations for the supply of the required long fibre. This can only be achieved provided the necessary inputs are put in place with respect to the right policies and strategies. The most effective strategies therefore, for sustainable long-fibre production is to ensure that more plantations of long-fibred tree species are established in the country. Efforts should be intensified in the establishment of more pine plantations, particularly in the northern parts of the country where the species have been found to thrive best. This effort should not be restricted to the pines alone, but should be extended to indigenous hardwoods that have been found to be suitable for this purpose. This will require further research into such woods that may need improvement programmes to make them qualify as suitable wood species for paper-making in Nigeria.

Non-wood Fibre Sources

Indigenous non-wood species that are suitable for fibre production abound in the country, and these could provide additional source of fibre on a sustained basis for pulp and paper production. Some of those already listed earlier as abundant in the country and those that can be harvested on short rotations are strongly recommended for use such as Kenaf, Jute and other bast fibres. Indeed, a pilot-scale pulping of Kenaf (*Hibiscus canabinus*) has been carried out by the Federal Institute of Industrial Research, Oshodi, Lagos. The result of this effort shows that the pulp from the bast of Kenaf plant exhibits comparable properties with those of imported long-fibred pulp, and hence, it could be used as a supplement. Here at Ibadan, similar researches have been carried out in which I have been involved over the years as earlier cited in my contribution.

Other non-wood annual plants that have been identified with promising pulp and paper qualities are: *Abelmoschus esculentus, Agave sisalplna, Ananas comosus, Cochorus spp. Crotolaria spp, Hibiscus sabdariffa, Musa sapentium, Musa textilis, Urena lobata* and *Triumfetta spp.* (Osadare and Udohitinah 1993, Ochonogor and Onilude 1985, and Ogunsile et al. 2006(a) & (b) and 2008). A strategy for a sustainable supply of non-wood fibre in this regard will be to embark on the establishment of plantations of any of the annual plants species listed.

Recovered Fibre

The use of waste or recycled paper as raw material for pulp production has increased worldwide in the last few decades. Nigeria is not exempted from this global trend. Recovered fibre can be used to produce new paper products made entirely of 100 percent recovered fibre, or sometimes blended with virgin fibre. It is the practice to recycle fibre between five to seven times before it becomes too short to be usable in new paper products. This is because fibre shortens every time it is used, hence a certain amount of virgin pulp is added to meet the quality demand set for the resources. The typical role of recycled fibre in the resource mix of paper-making is that it substitutes for mechanical pulp in newsprint and in some board grades.

It is envisaged that the fibre recovery sector will grow fast in the future in order to keep up with paper demand increase. In the Nigerian context, this is expected to be experienced. The present trend in the utilization of recovered fibre points to this direction. The number of wastepaper recycling plants has been on the increase. Moreover, a situation where all the pulp and paper manufacturing plants have ceased production and where all the paper and paper products needs of the country are imported, it is expected that recovered fibre will remain an important fibre source in the country for a long time to come.

Development and Resuscitation of the Nigerian Pulp and Paper Industry

In discussing the strategies for the development and resuscitation of the Nigerian pulp and paper industry, I will like to share the Japanese experience with you in this regard. I wish to quote a valuable speech by one of the founding fathers of modern Japan named Eiichi Shibusawa (1840-1931). He said:

> Western civilized nations attained their full development in every field. This is because they have devoted themselves to the cultural and scientific development by promoting the spread of higher education. In Japan we have to strive for cultural and scientific development. In order to attain Japan's development as a modern nation, we have to do a lot of things. The important thing is to promote the printing industry in order to publish a great number of newspapers and books which are conveniently available to everyone.

These words were very influential in encouraging private companies and Japan's government to launch modernization programmes, one of which was to further develop the pulp and paper industries. Currently, these industries hold a very strategic position and are subsequently categorized number 13 among the 15 largest manufacturing industries in Japan, with total sales of USA $83.96 million (6.8trillion Japanese Yen) and engaging about 34,839 employees in 2005 (Hidayat 2007). Three reasons have been advanced for the rapid development of the pulp and paper industry in Japan. Firstly, the role of the government was considered very important in providing a conducive environment for growth of these industries via incentive credit from banks, tax laws, and provision of good infrastructure. Secondly, the sustainability of procuring raw materials (wood trade) from overseas, as well as domestically by their huge tree plantations. Thirdly, the need to ensure that research and development in the field of pulp and paper are well-coordinated and properly funded. Today, Japan is listed among the world's top 10 largest producers of pulp and paper products.

It is quite evident from this Japanese experience that the government played a critical and very prominent role in the development and sustainability of the Japanese pulp and paper industry. Perhaps it will not be out of place to learn from the Japanese experience in strategizing the way forward in the development of the Nigerian pulp and paper industry. The suggestions in this regard are as follows:

1. Having sold out the paper mills, government should provide a conducive environment for the growth of the industries via incentive credits from banks, tax laws, and provision of good infrastructure. The provision of infrastructural facilities is considered an important enabling factor in the rapid growth and performance of the industry.
2. Operations of the small-scale paper mills should be encouraged.

3. Government should disengage from raising tree plantations for use by the paper mills and encourage such mills to establish their own plantations as it is the practice worldwide.
4. As the existing pulp and paper manufacturing plants are sold out, government should allow the new owners to operate without any interference.
5. The present trend of privately-owned wastepaper recycling plants should be encouraged and more new plants established to fill the vacuum created by the non-operation of the three paper mills.
6. The concept of private forestry practice should be looked into by the government and all modalities for its adoption in Nigeria be worked out. It is only when the awareness is propagated by the government that the public can show interest.
7. With the abundance of non-woody plants growing naturally in the country, there is need for the government to popularize their propagation by the rural farmers. Such fibres can be produced locally and supplied to the existing wastepaper recycling plants that are growing in number. The virgin fibres so supplied will be used as long fibre supplements needed by the operating mills. These virgin long fibres are currently being imported.
8. The role of research and development cannot be overemphasized. The Japanese model used it as the third most important tool for the development of their pulp and paper industry. There are still a lot of areas to be researched into in respect of the pulp and paper industry in Nigeria.
9. In the area of development of appropriate technology, the on-going projects being carried out in the Department of Agricultural and Environmental Engineering, Faculty of Technology, University of Ibadan are commendable and should be encouraged in other institutions. Staff of the Department have been designing and fabricating appropriate technology

machines for use by the small operators of the wastepaper recycling sector of the industry. Indigenous capacity building is very crucial for self-reliance, hence the need to encourage local fabrication of various equipment and spare parts required in the sector.

10. There will also be the need to upgrade and strengthen the country's science and engineering infrastructural base to fast-track our indigenous capacity building. The University of Ibadan, is well-placed to be made a centre of excellence in the field of pulp and paper technology. It is the only institution running the Wood Products Engineering Programme in the entire country. The programme offers specialization options in pulp and paper technology at both the undergraduate and postgraduate levels. A centre of excellence of this nature will go a long way in promoting and facilitating the growth of the pulp and paper industry in Nigeria.

Summary and Concluding Remarks

The pulp and paper industry is one of the most important industries in the world. It supplies an essential product called paper to over 5 billion people worldwide. Few materials can compare to paper. It is simply an amazing product, playing a crucial role in our daily lives with its endless range of applications. Can you imagine a world without toilet papers in the morning, no newspapers to read, no bank notes to transact our buying and selling, no letters or faxes in the office, no paper to print out emailed reports, no paper to write on, no photos of loved ones to keep, no magazines or books to read, no file jackets for documents/office business, no paper boxes to protect important or fragile goods...? Without paper the world would be very different indeed.

Mr. Vice-Chancellor, distinguished guests, ladies and gentlemen, it is this pathetic case of neglect of the industry that manufactures these products which are essential to our daily lives that I have presented to you today. The Nigerian government, realizing the great importance of the paper industry to her educational, political, social and economic development, decided to build three pulp and paper plants. Unfortunately, the goals of these laudable projects were never fully realized. The three mills went bankrupt and were closed down for over thirteen years. During the period of closure, the country imported all her pulp and paper products from abroad with import bills soaring to record high level of over ₦180 billion in year 2005. The consolation today, however, is that all the mills have been sold out, which is a good decision taken by the government. This is in conformity with the practice in other countries that are the major world producers of pulp and paper products. It is purely a business for the private sector and not for the government.

In the course of my lecture, I was also able to demonstrate the great potentials that exist in the country for the development and sustainability of the Nigerian pulp and paper industry. The various raw materials to sustain the industry abound in the country. The vegetation and other climatic conditions of the country favour the establishment of both short and long fibre tree species that may be selected for propagation. The present growth and activities of the paper recycling plants portray a promising future for the sector and an indication that the growth is sustainable. The manufacturing technology being adopted in the industry is still foreign-based as all manufacturing facilities are still being imported. Frequent breakdowns and non-availability of spare parts for replacements are some of the constraints identified, coupled with mismanagement of the plants.

I have attempted to profer some strategies and suggestions for the way forward in the development and resuscitation of the pulp and paper sub-sector of the economy. In borrowing from the Japanese model used for the rapid development of Japanese paper industry, the three steps or strategies reported have been suggested. These are: (i) government to provide the conducive environment for the growth of the industry via incentive credit from banks, tax laws, and provision of good infrastructure; (ii) the sustainability of the raw material sources, by encouraging the establishment of huge tree plantations for raw material supply; and (iii) to ensure that research and development in the field of pulp and paper are well-coordinated and properly funded.

Acknowledgements

First and foremost I wish to give all praises and thanks to Almighty Allah, the Lord of the worlds, the Creator of heaven and earth, for His infinite mercies. I will like to pay a special tribute to my late parents, Mr. and Princess Y.A. Onilude, who both struggled hard as a teacher/educationist and trader respectively, to send me to school. I salute you and pray God to grant you Al-Janah Fir-Daus (*Amin*). The support and fatherly role played by my uncle Alhaji Rafiu Onilude, since the passing on of my parents are appreciated.

I thank the current Dean of Technology, Professor A. E. Oluleye who is also a friend, for giving me the rare opportunity to deliver this year's inaugural lecture on behalf of the Faculty. I am also indebted to the immediate past Dean, late Professor Segun Omole, a very good friend, and during whose tenure, my professorship was announced. I pray God to grant him eternal rest (*Amin*).

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Mr. Vice-Chancellor, ladies and gentlemen, I thank you for listening and God bless you all.

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BIODATA OF
PROFESSOR MUSILIUDEEN ADEMUIWA ONILUDE

Professor Musiliudeen Onilude was born on 18th December 1950 to Mr. and Princess Yunus Adisa Onilude of Onilude compound, Badagry, in Badagry Local Government Area of Lagos State. After his secondary education at Awori-Ajeromi Grammar School, Agboju-Ojo (now Government College Agboju-Ojo) in 1970, he was immediately employed by the Lagos State Ministry of Agriculture as a Forest Assistant in training. Between 1971 and 1973, he was sent to the Federal School of Forestry, Ibadan for his in-service training as a Forest Assistant. He graduated from the school with a First Class Certificate. He worked briefly with the Ministry of Agric, Forestry division as a trained Forest Assistant between 1973 and 1975.

In August 1975, he proceeded to the United Kingdom, on the Lagos State overseas scholarship to study Wood Technology at High Wycombe College of Technology England where he obtained his degree in Wood Technology in 1978. Upon the completion of his first degree, he got admitted to the graduate school at the University of Maine, Orono, Maine USA for his Master's degree in Wood Science and Technology, which he completed in August 1980. While on his M.Sc. programme, he registered for a one-year Diploma in Pulp and Paper Technology in the Department of Chemical Engineering of the same university. He later proceeded to Virginia Polytechnic Institute and State University Blacksburg, Virginia, where he obtained his Ph. D degree in 1982.

He returned home immediately and embanked on his mandatory one-year NYSC service at the Department of Forest Resource Management, University of Ibadan. After the NYSC programme, Professor Onilude was given appointment as a Lecturer 1, in the Department of Agric. and Environmental Engineering in November 1983. He rose through the ranks to become a Professor of Wood Products Engineering in October 1, 2002.

Professor Onilude is an erudite scholar and a renowned researcher who has made significant contributions to the Nigerian Wood Products Industry. He has produced six Ph. D graduates and co-supervised another four, while several M. Sc graduates have also been produced by him over the years. He has to his credit over sixty publications in reputable journals, home and abroad, and a patented work along with his colleagues. He is a fellow of the Forestry and Forest Products Society of Nigeria. He has held a number of administrative positions and served on various committees at the University of Ibadan. For example, he has been Acting Head of the Department of Agric and Environmental Engineering (1992 – 1994), member, Appointments and Promotions Committee (2006 – 2008, 2010- to date). Member, Council Committee on Campus Tree Management (1996 – 2005) Chairman of the same committee (2005- to date), Chairman, Faculty of Technology Consultancy Committee (2004 – 2006). Manager, University Furniture Project of the University Consultancy Services (1985 – 1987).

He has also served in other capacities outside university system both at the state and national levels. He was Chairman, State Advisory Committee of the National Directorate of Employment Lagos State (1990 – 1994), Chairman, Caretakers Committee NRC Political Party, Badagry Local Government (1992 – 1993) and independent observer for the National Census Post Enumeration Survey, 2007. He has in addition served as external examiner to a number of Nigerian universities.

Professor Onilude is a practising Muslim and married with children.