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Evaluation of Lumber Recovery and Waste Generation in Selected Sawmills in Three Local Government Areas of Benue State, Nigeria

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ABSTRACT

*Volume of lumber recovered and wood wastes generated in some selected sawmills in three Local Government Areas (LGAs) of Benue State were assessed. Gwer East, Gwer West and Makurdi LGAs were purposively selected from Zone B and a total of ten (10) sawmills were randomly selected. Ten (10) logs were randomly sampled for conversion from each sawmills, making a total of 100 logs. The logs were converted using through and through sawing with band sawing machine. Input volume, volume of lumber recovered, percentage of lumber recovery, volume of sawdust, slabs, and bark were determined. The results revealed that Elmatandi sawmill in Naka, Gwer West LGA had the highest input volume, lumber recovery volume, and percentage lumber recovery of 1.7178 m^3, 1.1698 m^3, 0.6851 m^3 and 68.51 m^3 respectively. IDS sawmill in Makurdi had the lowest input volume, lumber recovery volume, sawdust volume and total volume of waste of 0.6034 m^3, 0.3680 m^3, 0.0063 m^3 and 0.2355 m^3 while Ire-Akari sawmill in Gwer West LGA generated the highest total volume of waste of 0.7561 m^3. There was high positive significant relationship ($p>0.01$) between input volume and lumber volume (0.913**); input volume and sawdust volume (0.687**); as well as input volume and total waste (0.771**). IDS sawmill in Makurdi was the most efficient sawmill in terms of percentage lumber recovery and waste generation in study area.*

Keywords: Sawmill, lumber recovery, volume of waste, logs, volume

INTRODUCTION

Nigeria is faced with the twin problems of solid wastes management, insufficient power generation and because of the lack of better management approaches, wood wastes (especially sawdusts) were variously disposed along road sides, rivers, abandoned at the sawmills or openly combusted (Elijah 2011). Ogunwusi, (2014) observed that generation of vast waste during wood processing operations substantially reduce the quantity of wood resource availability for industrial use. It has been pointed out that less than 40% of round log from the forest are actually used at industrial level while the rest are disposed as waste. This makes the current pattern of industrial wood utilization unsustainable and a source of threat to ability of the forests to sustain the wood industry.

Sawmill account for 93.32% of the total number of wood based industries in Nigeria (Fuwape, 1998). According to Ogunwusi (2014), the installed capacity and capital utilization of sawmills in Nigeria increased from 8,831,750 m^3 in 1988 to 15,793,188 m^3 in 1992. It then decreased to 10,900,000 m^3 in 1996 and subsequently increased to 14,684,000 m^3 in 2002 and 11,734,000 m^3 in 2010. In 2010, the number of sawmills in Nigeria estimated at 1,325 (Ogunwusi and Jolaoso, 2012). With an average recovery rate of between 45-55% the waste generated in this subsector (e.g. bark, sawdust, trimming, split wood, planer shavings and sander dust) was more than 1,000,000m^3 in year 2010 alone (Ogunwusi, 2014). Wood wastes abound in Nigeria due to the activities of sawmill operators. The sawmill operators usually harvest round logs from the forest, transport them to their sawmills and saw the wood into lumbers of various dimensions. In the process, sawdust and other wood wastes such as wood bark, slab, log-ends etc., are generated (Elijah, 2011).

Sawmill industry in Nigeria is characterized by small scale operators who mostly process timber with the CD series machine. Lumber recovery, which is defined as the percentage of the volume of sawnwood output to that of the volume of log input processed in the sawmill, regardless of the type and kind of processing equipment adopted and the species of wood involved (Badejo 1990), is low. Among the reasons for the low lumber recovery rate are; small log diameter, length, taper and quality; kerf width of the sawing machine; sawing variation, rough green-lumber size and size of dry dressed lumber; product mix; decision making by sawmill personnel; condition and maintenance of sawmill equipment; and sawing method (Kukogho *et al.*, 2011). The objective of this study therefore was to assess wood waste generation in selected sawmills in some Local Government Areas of Benue state, Nigeria.

MATERIALS AND METHODS

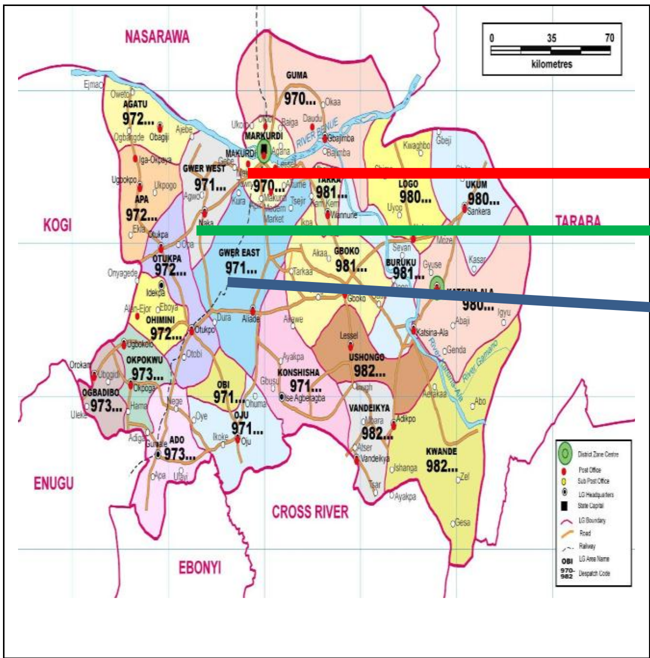
The Study Area

The study was carried out in Gwer East, Gwer West and Makurdi LGAs of Benue State, Nigeria. These three LGAs fall under Zone B geo-political Zone of the State. Zone B comprises of six (6) Local Governments namely; Gwer East, Gwer West, Makurdi, Guma, Tarka, Gboko and Buruku. Gwer west is located between Latitude 7.63°N and Longitude 8.22° E (NGND, 2015a). Gwer East LGA has its headquarters were in the town of Aliade. It has an area of 2,294 km² and a population of 163,647 at the 2006 census Wikipedia, 2015b; NPC, 2006). Gwer East is located between Latitude 7.30°N and Longitude 8.48°E (NGND, 2015b). Makurdi LGA is the traditional home of the Tivs and the capital of Benue State. It is located within the Southern guinea savannah zone and between latitude 7.7306°N, and longitude 8.5361°E with elevation of 97 m above sea level. The total land area of Makurdi Local Government is 3,993.3 Km^2 with a population of 297,393 people (Ityavyar, *et al.*, 2011; NPC, 2006). Gwer West LGA has its headquarters in Naka. It has an area of 1,094 km^2 and a population of 122,145 (NPC, 2006). Gwer West is located between latitude 7° 5°N of the equator and longitude 9° 6°E of the equator. There are a total of 16 sawmills in the study area (Table 1).

Table 1: Number of Sawmills in the Study Area

S/No	LGA	Geographical zone	Total No. of sawmills	No. of Functional sawmills	No. of Sampled sawmills
1.	Gwer East	B	5	5	4
2.	Gwer West	B	10	10	5
3.	Makurdi	B	1	1	1

Source: Field work, 2015.



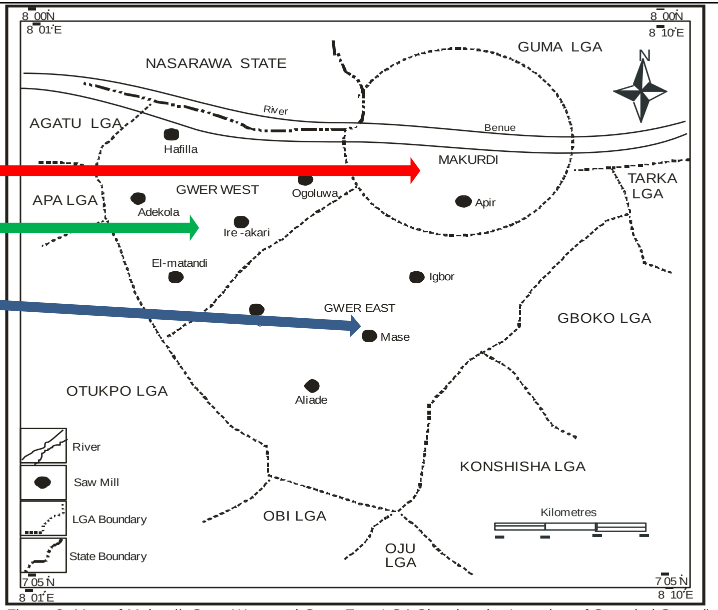


Figure 2: Map of Makurdi, Gwer West and Gwer East LGA Showing the Location of Sampled Sawmil
Source : Field work (2015)

Figure 1**:** Map of Benue State showing all the Local Government Areas in the State
(Source: *http://nigeriazipcodes.com/385/benue-state-zip-code/)*

Sampling Design

Ten (10) sawmills were purposively selected in the study area based on functionality and accessibility. In each of the sawmills, ten (10) logs were randomly selected based on dimension for assessment. Through and through techniques with band sawing machine was used to convert the logs into lumber; the numbers of the lumber pieces obtained were recorded and residues were examined in order to determine the percentage of lumber recovery. The procedure was repeated for all the one hundred (100) sampled logs. Personal interview with five (5) operators in each sawmill was carried out to ascertain the efficiency of workers and machines used in each of the sawmills.

Table 2 shows the number of sampled sawmills in each of the LGAs selected. Five (5) sawmills (50%) were selected from Gwer West, four (4) sawmills (80%) from Gwer East and one (1) sawmill (100%) from Makurdi. The number selected was based on the total number of sawmills available in each LGAs.

Table 2: Sampled Sawmills in the Study Area

S/N	Sawmills	Location	Local Government Area
1.	Ogoluwa	Naka	Gwer West
2.	Adekola	Naka	‘ ’
3.	Ire-Akari	Naka	‘ ’
4.	Hafilla	Naka	‘ ’
5.	Elmatandi	Naka	‘ ’
6.	Segun	Aliade	Gwer East
7.	Aliade	Aliade	‘ ’
8.	Igbor	Igbor	‘ ’
9.	Mase	Mase	‘ ’
10.	IDS	Makurdi	Makurdi

Source: Field work, 2015.

Data Collection

The method of Kukogho *et al.* (2011) was adopted in data collection. Before conversion, the length of each log, top girth, middle girth, basal girth and bark thickness of each log was measured and recorded. The diameter (under bark and over bark) at both ends was measured and recorded. The dimension of slabs and number of planks recovered were recorded in prepared field notebook.

Parameters of Determination

i. Determination of Log Volume: log volume was determined using Newton’s formula:

Log input Volume (v) $= \pi L \ (\frac{Ab}{24} + 4Am+At)$ ……………………..……….. (*Equation 1*)

Where: π =3.142, L = Length of log, Ab = Cross sectional area at the basal
Am = Cross sectional area at the middle and At = Cross sectional at the area top

ii. Determination of Timber Recovered

Timber recovered was determined by the formula bellowed:

$V = W \times L \times T$ ………………… (*Equation 2*)

Where: V = Volume of lumber recovered, W = Width of the lumber, T = Thickness of the lumber and L = Length of the lumber

iii. Determination of Lumber Recovery Ratio

The timber recovery ratio is the volume of timber recovered (output) divided by the volume of log input as showed below.

Lumber Recovery Ratio = $\frac{\text{volume of timber recovered (output)} (m^3)}{\text{volume of log (input)} (m^3)}$ ……. (*Equation 3*)

Wood waste in the selected sawmills

The wood waste generated was in the following forms of waste due to slab, bark, and sawdust

iv. Estimation of the volume of slabs

The slab was sawn from the log to attain rectangular shape and calculated using:

Volume of Slabs (m^3) = $(^1/_2 \ B \times T \times L)$ … (*Equation 4*)

Volume of Slabs (m^3) = $L \times B \times T$ … (*Equation 5*)

Total waste from slabs (m) = Volume of slabs (m^3) x n ……………………… (*Equation 6*)

Where: B = Base of the slab, **T** = Thickness of the slab, **L** = Length of the slab and n = no. of slab removed from a log.

v. Estimation of waste due to sawdust

This was calculated as follows:

$$\mathbf{Wd = V - (Tr + Ws + Wb)}$$

Where: Wd = sawdust, **V** = Total volume of log (m^3), **Tr** = volume of timber recovered (m^3), **Ws** = slab (m^3) and **Wb** = bark volume (m^3).

Method of Data Analysis

Data obtained were subjected to one-way Analysis of Variance (ANOVA). Correlation analysis was carried out to test the significance of parameters determined on converted logs while Duncan Multiple Range Test (DMRT) was used to separate the mean in case of significant difference in the parameters observed.

RESULTS AND DISCUSSION

Table 3 showed that Elmatandi sawmill in Naka, Gwer east LGA had logs with highest diameter 0.86m and Aliade sawmill in Gwer East LGA had logs with highest length. IDS sawmill in Makurdi had the lowest mean log length and diameter at the base of 3.300m and 0.46 m respectively. This implies that Makurdi is under difficulties of obtaining matured trees from the forest. This may be the reason why there is one functional sawmill in Makurdi.

Table 3: Mean value of the parameters determined on converted Logs on sawmill basis

S/No.	Name of Sawmill	Base Diameter of Log (m)	Middle Diameter of Log (m)	Top Diameter of Log (m)	Length of Log (m)	Diameter Under Bark (cm)	Diameter Over Bark (cm)	No. of Logs Sampled
1.	Segun	0.83	0.75	0.7	3.414	0.0795	0.0939	10
2.	Adekola	0.78	0.69	0.64	3.507	0.0671	0.0943	10
3.	Aliade	0.70	0.62	0.56	3.613	0.0621	0.0825	10
4.	Hafilla	0.83	0.74	0.75	3.368	0.0713	0.0863	10
5.	Elmatandi	0.86	0.77	0.76	3.555	0.0776	0.0995	10
6.	Ogoluwa	0.83	0.76	0.74	3.493	0.0669	0.0855	10
7.	Mase	0.73	0.67	0.68	3.466	0.0900	0.0930	10
8.	Ire-Akari	0.83	0.74	0.66	3.423	0.0705	0.0968	10
9.	Igbor	0.76	0.67	0.64	3.521	0.0677	0.0902	10
10.	IDS	0.59	0.46	0.45	3.300	0.04	0.07	10

Source: Field work 2015

Table 4 shows the mean value of the parameters (input volume of log, lumber recovery volume, mean of lumber recovery ratio, % of lumber recovery, volume of slabs, volume bark volume, sawdust volume and total volume of waste) determined on converted logs on the basis of sawmill. It was observed that Elmatandi sawmill in Naka, Gwer West LGA had the highest input volume of log, lumber recovery volume, mean of lumber recovery ratio and % of lumber recovery of 1.7178 m^3, 1.1698 m^3, 0.6851 m^3 and 68.51 m^3 respectively and this is due to the fact that most of the selected logs were fairly large and straight in girth. This agrees with the findings of Kukogho *et al.,* (2011) who asserted that high percentage of lumber recovery was due to large size of logs girth and straight forms. Ogoluwa sawmill in Naka, Gwer West LGA had the highest sawdust volume of 0.5248m^3 while Ire-Akari also in Naka, Gwer West LGA had the highest total volume of waste of 0.7561m^3.

Conversely, IDS sawmill in Makurdi had the lowest input log volume, lumber recovery volume, sawdust volume and total volume of waste of 0.6034 m^3, 0.3680 m^3, 0.0063 m^3 and 0.2355m^3 and this due to the fact that most of selected logs are small in girth and are deformed.This is also in line with the findings of Kukogho *et al.,* (2011) who stated that lower lumber recovery % was due to small log girth and deformity. However, IDS sawmill in Makurdi had the second highest lumber recovery of 60.98% after Elmatandi sawmill (68.51%). This implies that IDS sawmill in Makurdi was more efficient sawmill in terms of lumber recovery than any other sawmills in the study area. This could be as result expertise of the operators. Ire-Akari in Naka, Gwer West LGA had the highest total volume of waste of 0.7561m^3 with corresponding low of lumber recovery 49.10% after Aliade sawmill (0.4767). This implies that Ire-Akari sawmill is the least efficient sawmill in terms of lumber recovery and volume of waste generation compared with other sawmills in the study area. The efficiency rate of lumber recovery ranges between 40 and 50 % as reported by Alviar (1993). Lumber recovery efficiency is widely used as a measure of assessing the performance of any sawmills (Babatola, *et al.,* 2012).

Table 4: Mean Value of the Parameters Determined on converted lumbers

Name of Sawmill	Input Volume of Log (m^3)	Lumber Recovery Volume (m^3)	Mean of Lumber Recovery Ratio	% of Lumber Recovery	Volume of Slabs (m^3)	Volume Bark Volume	Sawdust Volume (m^3)	Total Volume of Waste (m^3)
Segun	1.5187	0.8035	0.5221	52.21	0.2096	0.1150	0.4070	0.7316
Adekola	1.3407	0.7431	0.5537	55.37	0.0772	0.2153	0.3093	0.6018
Aliade	1.1029	0.5250	0.4767	47.67	0.0867	0.1446	0.3899	0.6212
Hafilla	1.5135	0.9023	0.5944	59.44	0.1813	0.1224	0.3136	0.6173
Elmatandi	1.7178	1.1698	0.6851	68.51	0.0757	0.1939	0.2762	0.5458
Ogoluwa	1.6226	0.8686	0.5348	53.48	0.0734	0.1549	0.5248	0.7531
Mase	1.2654	0.6367	0.5031	50.31	0.1607	0.0274	0.4415	0.6296
Ire-Akari	1.4865	0.7294	0.4910	49.10	0.1221	0.2098	0.4243	0.7562
Igbor	1.2823	0.7138	0.5567	55.67	0.1083	0.1719	0.2884	0.5686
IDS	0.6034	0.3680	0.6098	60.98	0.0739	0.1554	0.0063	0.2356

Source: Field work 2015

The results of mean separation on Table 5 revealed no significant difference ($p>0.5$) between input volume in Segun and Hafilla sawmills as well as between Mase and Igbor sawmills. In contrast, there was significant difference in input volume among other sawmills in the study area. It was observed that there was no significant difference in lumber volume and total waste among sawmills in the study area. However, there was no significant difference ($p>0.5$) in sawdust volume from Elmatandi and Igbor sawmills.

Table 5: Results of analysis of variance for the parameters assessed in the various sawmills

Name of Sawmill	Input Volume (m^3)	Lumber Volume (m^3)	Slab Volume (m^3)	Bark Volume (m^3)	Sawdust Volume (m^3)	Total Waste (m^3)
Segun	1.5187^g	0.8035^g	0.2096^h	0.1150^b	0.4070^g	0.7316^h
Adekola	1.3407^e	0.7431^f	0.0772^b	0.2153^i	0.3093^d	0.6018^d
Aliade	1.1029^b	0.5250^b	0.0867^c	0.1446^d	0.3899^f	0.6212^g
Hafilla	1.5135^g	0.9023^i	0.1813^g	0.1224^c	0.3136^e	0.6173^e
Elmatandi	1.7178^i	1.1698^j	0.0757^b	0.1939^g	0.2762^c	0.5458^b
Ogoluwa	1.6226^h	0.8686^h	0.0734^a	0.1549^e	0.5248^j	0.7531^i
Mase	1.2654^c	0.6367^c	0.1607^f	0.0274^a	0.4415^i	0.6296^f
Ire-Akari	1.4865^f	0.7294^e	0.1221^e	0.2098^h	0.4243^h	0.7562^j
Igbor	1.2823^c	0.7138^d	0.1083^d	0.1719^f	0.2884^c	0.5686^c
IDS	0.6034^a	0.3680^a	0.0739^a	0.1554^e	0.0063^a	0.2356^a

Source: Field work, 2015; *Means in the same column having the same letter were not significantly differen*ce at p<0.05

Table 6 showed that there was high, strong positive and significant relationship (p> 0.01) between input volume and lumber volume (0.913**); input volume and sawdust volume (0.687**); input volume and total waste (0.771**). However, there was weak positive and significant relationship between lumber volume and sawdust volume (0.361**); lumber volume and total waste (0.449**); slab volume with sawdust volume and total waste (0.290** and 0.380**). Also there is weak positive and significant relationship (p>0.05) between input volume and slab volume of 0.254*; bark volume and lumber volume (0.217*). However, there was strong negative and significant relationship between slab volume and bark volume (-0.600**) and weak negative relationship was found to exist between sawdust volume and bark volume (-0.230*). The correlation between input volume and bark volume (0.132^{NS}), lumber volume and slab volume (0.112^{NS}) as well as bark volume and total waste (-0.52^{NS}) were negative and not significant.

Table 6: Correlation analysis of the parameters determined on converted logs

	Input Volume	Lumber volume	Slab volume	Bark volume	Sawdust volume	Total waste
Input vol.	1	0.913**	0.254*	0.132^{NS}	0.687**	0.771**
Lumber vol.	0.913**	1	0.112^{NS}	0.217*	0.361**	0.449**
Slab volume	0.254*	0.112^{NS}	1	-0.600**	0.290**	0.380**
Bark vol.	0.132^{NS}	0.217*	-0.600**	1	-0.230*	-0.52^{NS}
Sawdust vol.	0.687**	0.361**	0.290**	-0.230*	1	0.951**
Total waste	0.771**	0.449**	0.380**	-0.052	0.951**	1

Source: Field work data, 2015; ** Correlation is significant at 0.01 Level (2-tailed); * Correlation is significant at 0.05 Level (2-tailed); NS means not significant at p<0.01

In Table 7, *Daniellia oliveri* was the predominant timber species sawn in all the sawmills in the study area. This implies that *Daniellia oliveri* is the commonest timber species sawn in the study area. Table 7 indicated that natural forest was the main source of timber for sawmills in the study area. This will possibly put more pressure on the remaining natural forests in Benue state and may lead to forest degradation and/or deforestation. The forest serves as sinks for carbon dioxide, maintains diverse plants and animal life and regulates the flow of water. Their loss, as mentioned earlier, may lead to soil erosion, desert encroachment and loss of soil fertility (Sambo, 2005). It was also observed in Table 7 that out of the ten (10) sawmills sampled, five (5) depended on Power Holding of Nigeria (PHCN) and generator for their energy supply; three (3) depended entirely on PHCN while two (2) depended solely on generator.

Table 7: Wood Species Commonly Sawn in Sawmills

S/No.	Name of Sawmill	Species Commonly Sawn	Native Name	Sources of Timber	Source of Power Supply
1.	Hafilla	*Daniellia oliveri*	Chiha	Natural forest	Generator/PHCN
2.	Ogoluwa	*Daniellia oliveri*	Chiha	Natural forest	Generator
3.	Adekola	*Daniellia oliveri*	Chiha	Natural forest	Generator
4.	Elmatandi	*Daniellia oliveri*	Chiha	Natural forest	PHCN/Generator
5.	Mase	*Daniellia oliveri*	Chiha	Natural forest	PHCN
6.	IDS	*Daniellia oliveri*	Chiha	Natural forest	PHCN
7.	Igbor	*Daniellia oliveri*	Chiha	Natural forest	PHCN
8.	Segun	*Daniellia oliveri*	Chiha	Natural forest	PHCN/Generator
9.	Ire-Akari	*Daniellia oliveri*	Chiha	Natural forest	PHCN/Generator
10.	Aliade	*Daniellia oliveri*	Chiha	Natural forest	PHCN/generator

Source: Field work 2015

Table 8 revealed that the years of experience of the operators vary between some sawmills but similar in some others. Hafilla sawmill in Naka, Gwer West LGA had the highest number of experienced operators (20 – 30 Years), while Mase sawmill in Gwer East LGA and Ire-Akari sawmill in Gwer West LGA had the least number of experienced operators (5 years). The year of experience of machine operators did not positively affect the efficiency of sawmills. This is at variance with the findings of Smith and Joe (2006) and Kukogho *et al.* (2011), who opined that skill and years of experience of machine operator play a major role in deciding what the lumber recovery factor (LRF) from a given log will be.

Table 8: Years of experience of operators at the selected sawmills

S/No.	Sawmill	Band Saw	Circular Saw	Saw Doctor
1.	Hafilla	20 – 30 Years	20 – 30 Years	20 – 30 Years
2.	Ogoluwa	20 – 30 Years	15 – 20 Years	5 – 10 Years
3.	Adekola	20 – 30 Years	10 – 15 Years	15 Years
4.	Elmatandi	5 – 10 Years	10 – 15 Years	15 – 20 Years
5.	Mase	10 Years	14 Years	15 Years
6.	IDS	20 – 25 Years	10 Years	5 Years
7.	Igbor	15 – 20 Years	10 – 15 Years	6 – 10 Years
8.	Segun	18 – 20 Years	15 Years	9 Years
9.	Ire-Akari	15 Years	5 Years	11 Years
10.	Aliade	7 – 10 Year s	18 Years	10 – 15 Years

Source: Field work, 2015

Plates 1&2 showed A – Debarked logs in the Log Yard in Ogoluwa Sawmill, Naka, Gwer West LGA; D - Log being prepared for sawing in Elmatand Sawmill, Naka Gwer West LGA; C - Band saw machine in Adekola sawmill, Naka, Gwer West LGA and D - Sawn planks from sampled logs in Ogoluwa, Naka, Gwer West LGA.

Plate 1: A – Debarked logs in the Log Yard in Ogoluwa Sawmill, Naka, Gwer West LGA. **B -** Log being prepared for sawing in Elmatand Sawmill, Naka Gwer West LGA.

Plate 2: C - Band saw machine in Adekola sawmill, Naka, Gwer West LGA.
D - Sawn planks from sampled logs in Ogoluwa, Naka, Gwer West LGA

CONCLUSION

The efficiency of any sawmill could be measured by the quality and quantity of sawn plank recovered from a log compared to those resulting into residue. Efficiency of wood conversion in sawmills implies that wood residue generated during conversion is reduced to the barest minimum. In this study, IDS sawmill in Makurdi, had the second highest percentage of lumber recovery after Elmatandi sawmill with least total volume of wastes. Therefore, IDS sawmill in Makurdi was the most efficient sawmill in terms of percentage of lumber recovery and waste generation in selected study areas. The study further showed that Makurdi is under difficulties of obtaining matured trees from the forest for sawmill operation. *Daniellia oliveri* is the commonest timber species sawn while natural forest was the main source of timber for sawmills in the study area. This will possibly put more pressure on the remaining natural forests in Benue state and may lead to forest degradation and/or deforestation. This observation therefore call for aggressive efforts from sawmill owners, private individuals, NGOs and government at all levels to establish plantation forestry to meet the needs of wood and wood products in the state.

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