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Quality assessment of some timber trees extracted from the afram arm of the Volta lake in Ghana: sawing characteristics

Francis Wilson Owusu*, Joseph K. Appiah, Charles Essien, Bridgette Brentuo and Ernest G. Foli

CSIR - Forestry Research Institute of Ghana (FORIG), University Post Office Box 63, Kumasi-Ashanti, Ghana.

ABSTRACT

Some logs of different wood species harvested from the Volta Lake were assessed for their sawing characteristics. These species included Manilkara multinervis (Berekankum), Erythrophyleum guinense (Potrodom), Diospyros mespiliformis (Savanna Ebony) and Cylicodiscus gabunensis (Denya/Okan). The physical characteristics of the logs before milling were assessed and the average diameter of each of the four species were estimated as 45cm, 44cm, 57cm and 56cm for Manilkara multinervis, Erythrophyleum guinense, Diospyros mespiliformis and Cylicodiscus gabunensis in that order. The estimated total volume of the logs was 6.32m^3. The logs were processed into lumber with a 'Forestor' swivel saw machine using through-and-through sawing method. The observations made during and after the processing of the logs, lumber yields, production and fuel consumption rates are presented. Cylicodiscus gabunensis was the most easily sawn wood while Diospyros mespiliformis and Erythrophyleum guinense exhibited some difficulty during milling into lumber. All the species were hard and heavy, and this generally resulted in slight to moderate blunting effect on the saws used. Generally most of the lumber pieces generated were rated as Grade 1. The results indicate that milling of the timber logs harvested from the Volta Lake into lumber is feasible.

Keywords: *Fuel consumption rate, grading, lumber recovery, production rate, sawing quality,*

INTRODUCTION

Lake Volta, which is located at 6°30′N 0 °0'E / 6.5°N 0°E, is the largest reservoir by surface area in the world, and the fourth largest one by water volume. It is located completely within Ghana, as shown in Figure 1, with a surface area of about 8,502 km^2. Lake Volta lies along the Greenwich Meridian, and just six degrees of latitude north of the Equator. The lake's northmost point is near Yapei, and its southmost extreme is at the Akosombo Dam, which is 520 kilometers downstream from Yapei [1, 6 , 13].

Akosombo Dam holds back both the Black and White Volta rivers, which formerly converged where the middle of the reservoir now lies, to form the single Volta River. The present Volta River flows from the outlets of the dam's powerhouse and spillways to the Atlantic Ocean in southmost Ghana [3, 6, 7, 17].

Figure 1: Lake Volta in Ghana (arrowed)
Source: [8]

The lake, which was originally conceived by the geologist, Albert Ernest Kitson in 1916, is formed by the Akosombo Dam. The construction of the Dam started in 1962 and was completed in 1965 by Impregilo, an Italian Civil Engineering Firm, under the supervision of Volta River Authority of Ghana at the cost of £70 million. [9, 12, 14, 16]. They have reported that the formation of Lake Volta caused the relocation of about 80,000 people to 52 newly-created townships on the lake's higher banks, along with 200,000 animals belonging to them. Over 7,800 km^2 of territory was flooded, of which **a**bout 120 buildings were destroyed, excluding small residences. The Volta Lake, which is one of the largest man-made reservoir in the world, has a storage capacity of 153,000,000,000 cubic meters of water. It is about 400 km long and covers 8,502 square km, making 3.6 percent of Ghana's area. Since 1974 the lowest and highest levels of the Akosombo Dam recorded are 71.6m for 2007 and 84.6m for 2010 [6, 7, 8].

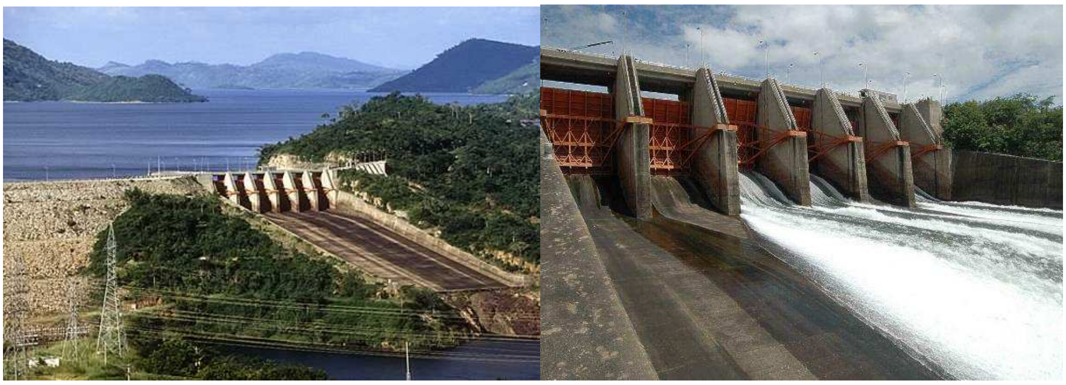

Figure 2a: Lake Volta generates hydroelectric power
Sources: [10, 18]

As seen from Figures 2a and 2b, the lake supplies hydroelectric power, provides irregation water for farmers, serves as fish habitat supporting commercial fishermen, and transport for people and goods that need to move from remote inland villages to markets closer to Ghana's coast and back.

Figure 2b: Commercial fishermen in a fishing boat
Source: **[2]**

Construction of the Dam resulted in a flood in 1966, which submerged a large tract of forest and that thousands of hardwood trees were left standing (Figures 3a & 3b). In such cases the trees die but the wood species are often preserved.

Many of them lurk just below the water surface where they snag the nets of fishermen and are a collision peril for the long wooden kayaks and other boats that transport goods and people. At least 2 million have died from boating mishaps, which were related to the underwater hazards. Hence the lake is described as a killer. Again, most of the wood species that were transported streams and rivers to the sea for export or mill for processing got sank [2, 4].

Figure 3: Some hardwood trees in the Volta Lake
Sources: [2, 8, 9]

For years, the Government of Ghana and Volta River Authority (VRA) have been seeking solutions to remove standing trees that create safety hazards resulting in boating accidents on the lake, and at the same time, the government has been searching for strategies to enhance the socio-economic development of the area.

The Government of Ghana in 2007 completed an agreement with Clark Sustainable Resource Development (CSRD) to harvest, process, and market all the timber trees in the Volta Lake, which were posing a danger to the transport system on the lake and develop an integrated timber harvesting, processing, and marketing industry in Ghana [2, 4]. Meanwhile the logs of the various species to be harvested could be used to feed the country's timber industry. The quality of the submerged timber species is assured as the woods, which are completely submerged haven't been exposed to oxygen hence are in pristine condition. These watery woods, which have been preserved by cold water and protected from rot and insect infestation resulting in high-quality timber, is highly sought after [11]. A report by [2] indicates that the number of trees submerged is significant by which to alleviate stresses on virgin/living forests for some years to come. This will increase the resource base of the timber industry for its sustainability. But the sawing properties of such logs are not known hence their efficient utilization will not be realized. There is therefore the need to determine the properties of the logs and to ascribe uses for them. This will enhance the utilization and promotion of the logs to be logged from the underwater forest, which are non-renewable.

According to [2], the untapped timber resource is estimated around US$2.8 billion, and that the extraction of the submerged logs would benefit the country through injection of direct foreign investment, an estimated amount of about US$100 million worth of investment would be brought into Ghana, in addition to payment of corporate taxes to the government and that the industry would create jobs and generate revenue for Volta Lake communities and the country. The venture, among others, is expected to help fight global climate change by sparing the living trees that are needed to absorb carbon. Another key benefit to Ghana would be lake transportation safety with the harvesting of submerged trees, which have caused fatal boat accidents on the Volta Lake in the past.

As at now the CSRD has assessed the timber resource potential in the Volta Lake and the best harvesting, processing and marketing techniques determined. Again, the relevant environmental and social interventions, financing arrangements required to develop the underwater logging industry, and associated value added activities in Ghana have been determined. The important questions now are: Is it possible to process the logs to be harvested from the underwater forest in Ghana? What are the possible challenges to be encountered during processing? What uses can be ascribed for the species to be extracted? To find solutions to these questions, a study had to be under taken with the objectives being to determine the log and lumber yields, lumber production rate, fuel consumption rate and assess the quality of the lumber to be generated from some of the species logged from the Afram Arm of the Volta Lake using portable milling machine.

MATERIALS AND METHODS

Collection of samples and mensuration

Some coded timber logs that had been harvested from the Volta Lake by Clark Sustainable Resource Development (CSRD) were collected for study into their sawing. These timber species were identified as *Manilkara multinervis* (Monghinza/Berekankum), *Erythrophyleum guinense* (Tali/Potrodom), *Diospyros mespiliformis* (African Ebony/Savannah Ebony) and *Cylicodiscus gabunensis* (Okan/Denya) in the order of scientific, trade/local names respectively. Figure 4 shows two logs that were extracted from the Volta Lake. Physical observations of the logs by considering the shape, bark, holes, knots, heart rot and taper were undertaken and recorded (Table 1). This was done to match their features with the milling results. Dimensions of each log (length and diameters at both ends) were taken and volumes estimated (Table 2). To be able to maximize the lumber recovery, because of some defects that were observed on the extracted logs, they were cross-cut into shorter lengths of 2.5 meters. This was one of the standard lengths of lumber at the local timber market. The dimensions of these shorter logs were also taken to determine the yields of the logs with respect to the extracted logs as well as the lumber yields for each species.

Figure 4: Ghana executive director of Clark Sustainable Resource Developments, stands beside a mahogany tree that was pulled from Volta Lake
Source: [2]

Milling of logs

A forestor swivel saw machine with engine type GX 620/V-twin; HONDA 20HP, 14.9 Kw and 614 cc/cm^3 was used in milling the logs into lumber (Figure 5). A circular saw with 20 teeth and of diameter 45cm was mounted on the swivel machine. It is a portable circular saw, which cuts horizontally during forward movement and vertically when returning. All the cross-cut logs were processed into lumber using through and through sawing method. The saw was sharpened twice before milling of the logs was completed. For each log that was processed, the initial and final fuel levels in the container were measured. The time for milling each log was recorded and dimensions of each lumber (thickness, width & length), using a measuring steel tape, were also taken (Figure 6). These were recorded to estimate the total volume of fuel consumed, lumber production time and the total volumes of lumber per log and on species basis. Physical observations were also made during and after milling of each log to identify some characteristics, if any, of the species and the defects generated on the lumber (Table 3). Using Ghana lumber grading rules, the lumber for the four (4) timber species were evaluated and graded.

Figure 5: Milling of *Cylicodiscus gabunensis* (left) and *Manilkara multinervis* (right) logs with a Forestor swivel saw machine

Figure 6: Lumber dimensions being taken by a Scientist

RESULTS AND DISCUSSIONS

Physical observation of logs

Table 1 gives the results of the physical observations that were made before cross-cutting of the extracted logs into shorter lengths of 2.5m.

Table 1: Physical assessment of logs from the Volta Lake

Tree code	Physical observation
Manilkara multinervis	Almost all the logs had no bark; 30 bird holes were identified on one of the logs; some had a cylindrical bole; a knot was identified with a hole at 5cm to the top on one of the logs; another log had a big knot at 1m from the top; One of the logs had a small buttress and dead knots identified at the middle of the log while about a half of the length of the log from the top was covered with bark.
Erythrophyleum guinense	All the logs were crooked and had no bark; one bole was with double heart (pith) at the top portion and 3 bird holes were identified on one of the logs
Diospyros mespiliformis	One of the logs was big with a hole of length 2m from the butt diameter, but decreased in size towards the top; 2 of the logs had big knots at the center of the log and bird holes were observed but had no bark
Cylicodiscus gabunensis	The boles were cylindrical throughout, logs were big with no bark, knots or bed holes

Dimensions of logs

Table 2 shows the average dimensions of the extracted logs with their degree of taper and the total volumes for both the extracted and cross-cut logs for the four timber species. Mean average diameters for the extracted logs ranged between 0.44m (*Erythrophyleum guinense*) to 0.57m (*Diospyros mespiliformis*) while the average lengths varied from 2.9m (*Erythrophyleum guinense* m) to 5.62m (*Cylicodiscus gabunensis*). These show that the sizes of *Erythrophyleum guinense* were minimal as compared to *Diospyros mespiliformis* and *Cylicodiscus gabunensis*. The average log taper (slope) per species also ranged between 0.014 (*Cylicodiscus gabunensis*) and 0.025 (*Erythrophyleum guinense*) indicating that the logs of *Cylicodiscus gabunensis* were slightly uniform in shape than the rest with *Erythrophyleum guinense* being the poorest. The total volume of the extracted logs, on species basis as indicated in Table 2, was higher with *Manilkara multinervis* (3.395 m3) and the lowest was *Diospyros mespiliformis* (0.802 m3). The percentage losses in volume after cross-cutting the extracted logs into shorter ones were higher with the *Diospyros mespiliformis* (24%), which was due to the defectiveness of the logs (rotten heart and tapered – Tables 1 & 2). From Figure 8, the highest percentage log yield was recorded by *Erythrophyleum guinense* (100%), as the length of the logs was maintained without cross-cutting. This was followed by *Manilkara multinervis* (94%) and *Cylicodiscus gabunensis* (88%) while *Diospyros mespiliformis* recorded 76%. These were mostly due to the degree of the defects that were observed on the logs before cross-cutting. The average log yield for all the species put together was estimated as 92%. These values are higher, apart from *Diospyros mespiliformis*, than those obtained for *Piptadeniastrum africanum* (Dahoma) – 75% and *Nesogordonia papaverifera* (Danta) – 81% that were extracted from the natural forest [15].

Table 2: Average dimensions and total volume of logs of the 4 timber species extracted

Species	Butt diameter (m)	Top diameter (m)	Length (m)	Volume m^3 extracted logs	cross-cut logs	Average log taper
Manilkara multinervis	0.52	0.38	4.79	3.395	3.201	0.015
Erythrophyleum guinense	0.51	0.37	2.9	0.939	0.939	0.025
Diospyros mespiliformis	0.63	0.51	3.19	0.802	0.607	0.019
Cylicodiscus gabunensis	0.64	0.48	5.62	1.378	1.215	0.014

Physical observation during and after sawing

The lumber pieces generated were of different thicknesses (30mm – 74mm) and widths (4.6cm – 44.6cm) depending upon the ease of cut. Table 3 gives the results of the physical observations that were made during and after the sawing of the logs into lumber. *Cylicodiscus gabunensis* species whose logs were easily sawn generated good quality lumber while *Diospyros mespiliformis* and *Erythrophyleum guinense* species codes posed slightly difficult in milling because of the hole and crooked nature of the logs of the species respectively as indicated in Table 1. The effect of saw blunting was from slight (*Erythrophyleum guinense* & *Cylicodiscus gabunensis*) to moderate (*Diospyros mespiliformis* & *Manilkara multinervis*). All the species were hard and heavy. Peppery (pungent) smell was felt when *Manilkara multinervis* logs were being milled. The colours of the lumber of the various species were distinct especially between *Diospyros mespiliformis* and the other three species. After a period of time, as shown in Figure 7, the colours between *Erythrophyleum guinense* (*Erythrophyleum guinense* – top right) and *Cylicodiscus gabunensis* (Denya / Okan – bottom left) became difficult for visual identification. This might be due to colour pigment that might have been lost during air drying of the species. The heartwood and sapwood colours as identified from the lumber pieces of the various species are indicated in Table 3.

Table 3: Observations made during and after milling of the logs

Species	Observation
Manilkara multinervis	Difficult to saw, moderate blunting effect, intermittent lighting, centre splits and checks on lumber, smooth milling. Heartwood, Reddish-brown. and Sapwood, Pale red
Erythrophyleum guinense	Very difficult to saw, moderate blunting effect. Heartwood, Yellowish-brown and Sapwood, Light yellow
Diospyros mespiliformis	Very difficult to saw, Cracking noise, saw blunting was moderate. Heartwood, Dark brown and Sapwood pale in colour
Cylicodiscus gabunensis	Moderately easy to saw, slight blunting effect, good quality lumber generated. Heartwood, Yellow to golden brown and Sapwood, Pale pink

Figure 7: Display of samples of the four species from the Volta Lake

Lumber generated

Figure 8 shows the lumber volume yield from the four species, which varies from 53.1% to 58.9%. The highest yield was recorded by *Cylicodiscus gabunensis*, which was due to the shape of the logs in comparison with the other three species. *Manilkara multinervis* recorded the lowest because most of the logs were defective (had bird holes and dead knots). The percentage lumber volume yield of 53.2 for *Diospyros mespiliformis* is encouraging because one of the logs was hollow, and the volume of the rotten portion of the wood (heart rot) was estimated to be 0.195 m^3. Milling of the logs of *Diospyros mespiliformis* was difficult, some cracking noise was heard and the environment became dusty, which might be due to the hollow nature of the defective log. The average lumber volume yield for all the four species put together was estimated as 54.3% (Figure 8), which is higher than that recorded by small-scale sawmills (40%) and comparable with those of medium-scale and large-scale sawmills in Ghana as reported by [5]. The average lumber volume yield with respect to the extracted logs for the species was 49.8% (Figure 8). The lumber value yield ranged from 39% (for *Diospyros mespiliformis*) to 47% (*Cylicodiscus gabunensis*).

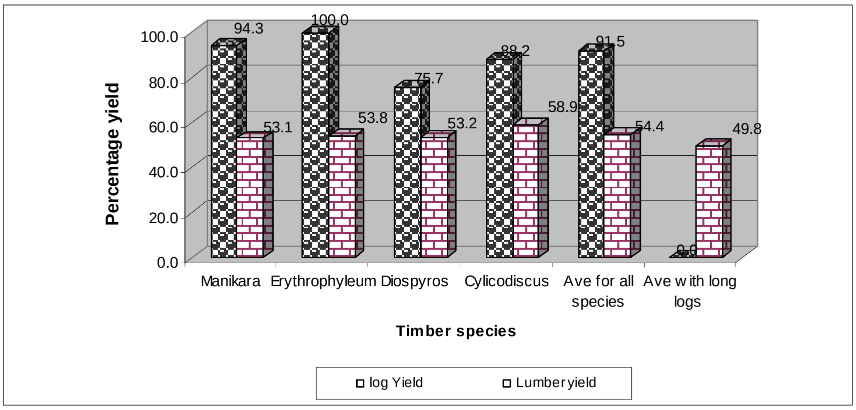

Figure 8: Log and lumber yields of four wood species from the Volta Lake

The time spent in milling the logs of each species (only when the machine was in operation) varied from 0.56hr (for *Diospyros mespiliformis*) to 3.39hrs (for *Manilkara multinervis*) with cross-cut logs of 0.607m^3 and 3.201m^3 respectively. So the total machine time for processing all the logs was 6.94 hrs. The rate at which the cross-cut logs of each species were milled into lumber, as shown in Figure 9, also varied from 0.345 m^3/hr (for *Erythrophyleum guinense*) to 0.574 m^3/hr (for *Diospyros mespiliformis*). This resulted in an average production rate of 0.468 m^3/hr at a standard deviation of 0.168. [15] have reported on the production rates for *Piptadeniastrum africanum* and *Nesogordonia papaverifera* as 1.49 m^3/hr and 1.25 m^3/hr respectively, using a Wood-Mizer of model LT 30. The difference may be due to the large saw kerf for forestor swivel machine (circular saw) that was used in milling the logs from the Volta Lake as that of the Wood-Mizer (narrow band saw) is known to be comparatively smaller.

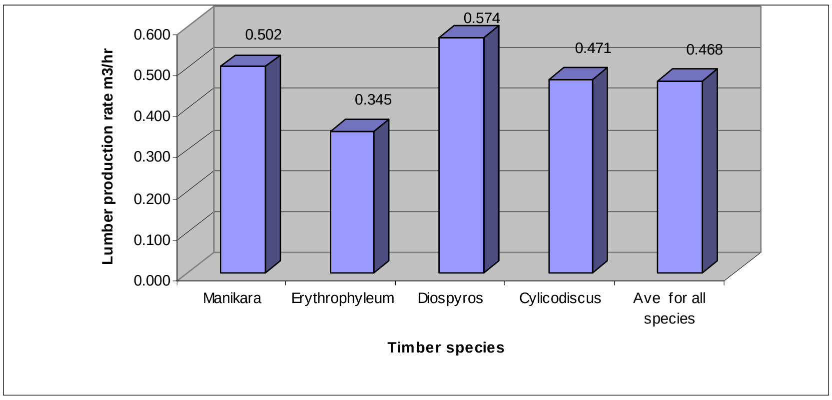

Figure 9: The rate of lumber generation from four wood species from the Volta Lake

The total quantity of petrol that was used in processing all the logs was about 29 litres, of which the consumption rate per species, as shown in Figure 10, ranged between 7.165 lit/m^3 (for *Cylicodiscus gabunensis*) to 10.748 lit/m^3 (for *Diospyros mespiliformis*). These indicate that the fuel used in milling logs to generate 1m^3 of lumber was lower with *Cylicodiscus gabunensis* (7.12 litres) than the rest of the three species. This might be due to the shape of the log, other defects were comparatively less and the ease of milling. This was followed by *Manilkaramultinervis* (8.1 litres) and *Erythrophyleum guinense* (8.98 litres) with 10.75 litres recorded by *Diospyros mespiliformis* (Figure 10). The high fuel consumption could be attributed to the some major log defects (big knots, big hole with dust) exhibited by the logs. The average petrol consumption rate for the four timber species was 8.819 lit/m^3. According to [15], the fuel consumption rates for *Piptadeniastrum africanum* and *Nsogordonia papaverifera* from the natural forest, when a Wood-Mizer was used in milling were 6.58 and 7.1 respectively. These lower consumption rates, in comparison with those obtained from the study, could be due to the differences in the milling machines used and the anatomical properties of the species.

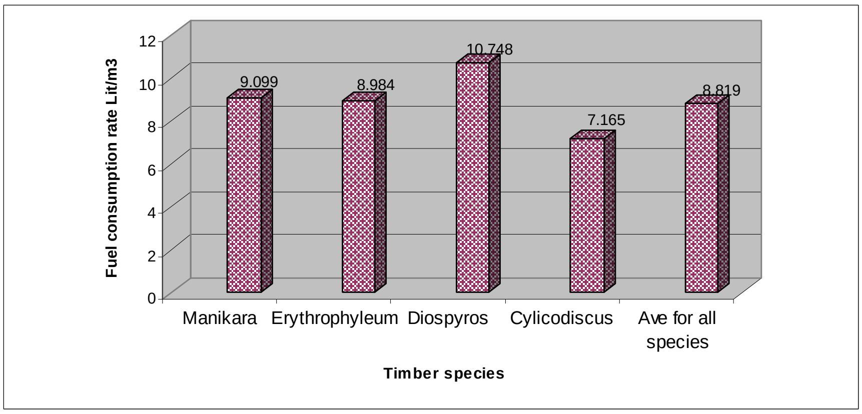

Figure 10: Fuel used for milling four wood species from the Volta Lake

Graded lumber

Lumber grading is the process whereby lumber pieces are classified according to their surface quality. This is based on the quantity and degree of the defects on the lumber surfaces. The lumber pieces obtained from the milling of the logs from the Volta Lake were assessed and grouped into four (4) grades on species basis as shown in Table 4. Ghana lumber grading rules, which are used by the timber industry in grading lumber in Ghana, were used. Grade 1 and grade 4 products were the best and poor respectively. The highest percentage lumber of grade 1 was scored by *Cylicodiscus gabunensis* (84%) followed by *Erythrophyleum guinense* (70%) and *Manilkara multinervis* (55%) while *Diospyros mespiliformis* recorded the least percentage of 46. The logs of the the two species that recorded the best lumber grade (*Cylicodiscus gabunensis*) did not have bird holes, heart rot and dead knots and *Erythrophyleum guinense* had only three bird holes as compared to the other two species (Table 1). The Percentage grade 2 lumber varied from 11% (*Cylicodiscus gabunensis*) to 25% (*Diospyros mespiliformis*) while grade 3 ranged between 5% (*Cylicodiscus gabunensis*) and 18% (*Manilkara multinervis*). Consistently, as shown in Table 4, the percentage lumber grades for *Cylicodiscus gabunensis* and *Erythrophyleum guinense* decreased towards the poor quality grade (grade 4). This is an indication that the logs of the wood species were of good quality and hence less defective as compare to *Manilkara multinervis* and *Diospyros mespiliformis* who had some of the lumber graded 4 (as 12% and 18% grade 4 respectively). Again, the estimated lumber value yield varied from 39% (*Diospyros mespiliformis*) to 47% (*Cylicodiscus gabunensis*).These results indicate that there is high potential of generating high quality lumber from the species extracted from the Volta Lake, which will yield high values.

Table 4: Percentage lumber graded on species basis

Species	Grade 1	Grade 2	Grade 3	Grade 4
Manilkara multinervis	55	15	18	12
Erythrophyleum guinense	70	21	9	0
Diospyros mespiliformis	46	25	11	18
Cylicodiscus gabunensis	84	11	5	0

CONCLUSIONS

The results of the study have shown that the species can be sawn, sawing is moderately easy to very difficult and also cause slight to moderate blunting effect of saw.

Notwithstanding these, there are indications from the results that the wood species in the Volta Lake:

- Can be milled using Forestor swivel machine
- The efficiency ratios are comparable to those from natural forest milled with Wood-Mizer
- Defects observed on the logs did not cause any significant effect on the lumber recoveries of the timber species
- The lumber value yield for the four timber species ranged between 39% and 47%
- The fuel consumption rates were quite okay even though literature results generated from a Wood-Mizer were comparatively quite lower. But the production rates achieved are quite lower as compared to that of literature
- Lumber generated were aesthetically good
- Percentage grade 1 lumber for each of the species was higher than the other grades.
- Sawing quality was satisfactory
- *Cylicodiscus gabunensis* recorded the highest number of quality lumber followed by *Erythrophyleum guinense*, *Manilkara multinervis* and *Diospyros mespiliformis*
- Lack of bark minimized the volumes of residues generated

The results of the study as compared to literature have revealed some differences which are due to the different wood milling machines that were used and the anatomical characteristics of the different species in both cases. In considering portable machines for milling the wood, taking cognizance of the fact that: Wood-Mizer has smaller saw kerf as compared to circular saw for Forestor swivel machine and the results of the milling characteristics of wood, using Wood-Mizer, comparatively gave better results, it is therefore recommended that Wood-Mizer could also be considered in processing timber logs that will be extracted from the Volta Lake. Again, it is recommended that other working properties of the four species studied and that for those “new” species to be extracted from the sea should be investigated for their efficient utilization.

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