



Research Article

Identification and Estimation of Wood Waste in Aac 2-3 of Ufa 1491 of Society Huguette Forest Company (South Cameroon)

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Abstract

This study, carried out in the Annual Cutting Area (AAC 2-3) of the Huguette Forest company (HF) in Southern Cameroon, aims to identify and estimate the types of wood waste found in the parks and in the felling gaps. A sample of seven gaps and seven parks was taken to collect data in the field. The results within the study site showed that the amount of waste recorded in AAC 2-3 of UFA 1491 amounted to a volume of 1,551.776 m³ of felled stems left behind, representing a yield of 21%, followed by 831.805 m³ of logs with a yield of 11%, and 215.136 m³ of stumps with a yield of 4%. The utilization rate of woody material for the eleven selected species showed that the volume of discarded waste is quite significant at 32%, or 2,383.581 m³ of wood waste out of 7,507.754 m³ of felled volume. It turns out that the largest volume of waste is produced during felling and sawing. Finally, turning the recoverable logs near production sites into usable products would add value to this waste. To help increase the amount of woody material in Cameroon, and especially in the study area, measures should be taken to encourage a variety of wood products while minimizing wood waste by making the most of it. The following recommendations are among the actions to take to reach this goal: for a more complete estimate, it would be wise to extend this study to other forestry companies in Cameroon to determine the amount of woody material across the whole country and the potential for making use of residual wood products in Cameroon.

Keywords

Felling Gaps, Yards, Rejects, Spurs, Forks, Estimation

1. Introduction

The 1990s were marked by a reform of the forestry sector in Cameroon. The overall objective of this reform was the implementation of a sustainable forest management strategy: It was specifically a question of reducing or even eliminating the

export of logs and establishing an efficient industrial sector for wood processing. Law No. 94/01 of January 20, 1994 on the regime of forests, wildlife and fishing, in its article 71, calls for 100% processing of logs from logging.

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Cameroon is dominated by primary processing, with a fairly low material yield ($\pm 30\%$), thus showing that a large part of the volume of standing timber from exploited trees is found in forests and in primary and secondary processing factories in the form of waste (spurs, logs, felled and abandoned wood, etc.). [10, 13, 20]

Some authors consider that the overall yield of the chain from logging to the final product is low (15%). Other authors such as [4, 14] who limit the analysis to the strict processing

chain, starting from the sawmill to the final product, without integrating felled and abandoned wood in the forest, estimate that the yield is rarely higher than 25%.

Thus, being the subject of an increasingly growing demand for wood waste, and facing a flourishing market in products derived from wood waste; the HF Company has initiated a reflection on the optimization of its forestry operations by the valorization of waste from the felling of wood from its Forestry Management Unit (UFA) 1491 in South Cameroon.

2. Materials and Methods

2.1. Presentation of the Study Area

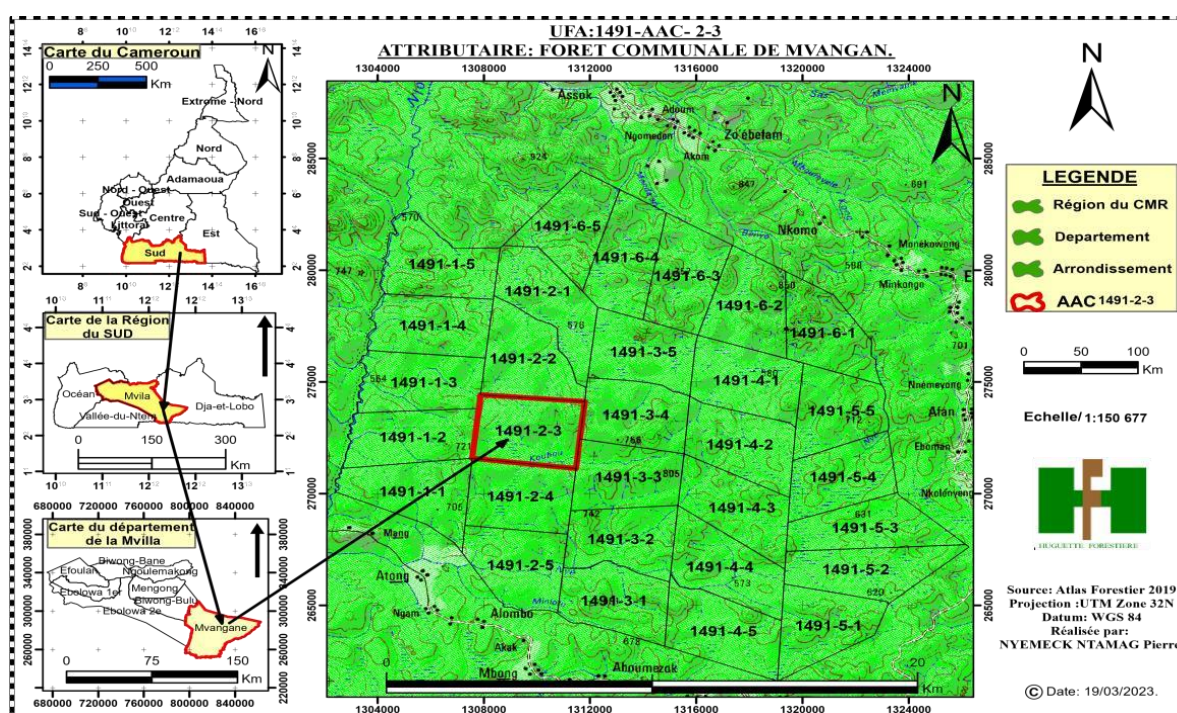


Figure 1. Location map of AAC 2-3-UFA1491.

The Annual Cutting Area (ACA 2-3) of Forest Management Unit 1491 (FMU) is located in the South Region of Cameroon, 100 km from Ebolowa, the capital of the Mvila Department and the South Region. The Annual Cutting Area (ACA 2-3) of Forest Management Unit 1491 (FMU) covers an area of 4,070 km² at longitude 11 -45 East and latitude 2 -40 North. The total population of the commune of Mvangan is estimated at 16,442 inhabitants. Forest Management Unit 1491 (UFA) of the Annual Cutting Allowance (AAC 2-3) can be seen on the 1/200000 e ISH map sheets of Ebolowa. Forest Management Unit 1491 (UFA) of the Annual Cutting Allowance (AAC 2-3) was allocated to the commune of Mvangan by classification decree No. 2012/3552/PM of 07 November 2012 for an area of 33,720.5 ha. [11, 12] Figure 1 shows the location map of the study area.

2.2. Field Data Collection

The field data collection phase took place from January 1st to July 2023. The data collected in the field were based on four criteria: the study site and its rationale; sampling and its rationale; the selection of the eleven selected tree species; and subsequently, the other harvested tree species.

2.2.1. Study Site and Rationale

Data collection took place in AAC 2-3 of UFA 1491, located in the Southern Region of Cameroon, more specifically in the commune of Mvangan. The ACA 2-3 contains the parks and felling gaps used in this study to identify wood waste from

logging operations in this study area. Several reasons motivated the choice of this study site:

- 1) The first is related to the proximity of the town of Mvangan, which offers numerous outlets for the domestic market for products derived from waste processing;
- 2) The second reason is related to the land transport method, which reduces the costs of transporting waste to the Huguette Forest company's Wood Processing Unit (UTB).

2.2.2. Sampling and Justification

Field data collected for the identification and assessment of wood waste were collected in 7 felling gaps and 7 forest parks selected based on accessibility to the Annual Cutting Allowance (AAC 2-3) of Forest Management Unit 1491 (UFA).

2.2.3. Selection of the Eleven Species Selected

The eleven species selected were based on the annual operating plan (PAO) of the Annual Cutting Allowance (AAC 2-3) of Forest Management Unit 1491 (UFA), which is currently being harvested for a period of one year, and on the activity schedule of Huguette Forest (HF). The particular interest in selecting these eleven species is based on various factors, including:

- 1) Their importance in log production;
- 2) Dendrometric measurements of stems;
- 3) The various uses of by-products and the constraints imposed by wood processing.

Thus, the eleven species selected for this study are listed in (Table 1), the first column of which gives the trade names, the second the scientific names, and the third the species families.

Table 1. List of species identified in the study area.

Trade name	Scientific name	Family
Ayous	<i>Triplochyton scleroxyllon</i>	Malvaceae
Azobe	<i>Lophira alata</i>	Ochnaceae
Dabema	<i>Piptadeniastrum africanum</i>	Mimosaceae
Frake	<i>Terminalia superba</i>	Combretaceae
Kossipo	<i>Entandrophragm</i>	Meliaceae
Moabie	<i>Baillonelatopsisperma</i>	Sapotaceae
Movingui	<i>Distermonanthusbenthamianus</i>	Fabaceae
Okan	<i>Cylicodiscus gabunensis</i>	Fabaceae
Padouk rouge	<i>Pterocarpus soyauxii</i>	Fabaceae
Tali	<i>Erythrophleum ivorense</i>	Caesalpinia-ceae
Wengue	<i>Milletialaurenti</i>	Fabaceae

2.2.4. Other Harvested Species

Other harvested species whose residual volumes are found on the felled area were not taken into consideration due to:

- 1) Their low proportion in production (2% of total production);
- 2) Limited financial resources allocated;
- 3) The very short timeframe to conduct this research.

2.3. Identification of Wood Residue in FMU 1491

The field visit aimed to collect data on the identification of wood residues encountered within the study area. To this end, two locations for identifying this residue were conducted: felling gaps and forest parks. Regarding these locations, questions were also asked about the spatial location of the forest parks. To this end, each sampled park was located using a GPS receiver, then by following the trunk skidding trails. Thus, the felling gaps were also sampled, but they were not located for this purpose. In addition, the main road of the AAC 2-3 road was the starting point for our park sampling. We then entered each evacuation trail over a distance of approximately 120 m, in order to identify the wood waste encountered in the felling gaps. Subsequently, the marking of the forest number (DF10) and the wood waste encountered in the forest parks were noted. In the case of this study, three types of wood waste were taken into consideration, namely spurs, logs, and felled and abandoned stems. The coordinates of the forest parks were indicated by a GPS with longitude and latitude coordinates. This made it possible to have the position of the parks within AAC 2-3. Table 2 below shows the coordinates of the GPS points of the sampled parks in the study area during the identification of wood waste.

Table 2. Coordinates of GPS points of the sampled parks.

Parks	Latitude	Longitude
1	807705	270323
2	806637	272019
3	807387	271592
4	807991	271015
5	807812	271114
6	808391	271631
7	809016	271181

2.4. Assessment of the Quantity of Usable Timber Volume in FMU 1491

In order to better assess the quantity of usable timber vol-

ume left on the felling area following the eleven species initially selected, which produce the most wood waste in this FMU, it was preferable to clarify seven usable timber volumes, which are presented according to four essential points, namely:

2.4.1. Gross Volume of Felled Stems

The gross volume of felled stems was assessed using measurements of the felled stems after being felled in the felling gaps. These measurements were taken on a sample of 564 felled stems of different species. The following were measured:

- 1) The length of the felled stems;
- 2) The average diameter of the felled stems. The average diameter of felled stems was determined as follows: the large end diameter of the felled stems plus the small end diameter of the felled stems divided by two.

2.4.2. Volume of Merchantable Logs

The volume of merchantable logs was assessed using measurements of merchantable logs after they were cut in the forest parks. These measurements were taken from a sample of 430

merchantable logs of different species. The aim was to measure:

- The length of merchantable logs;
- 1) The average diameter of merchantable logs.
 - 2) The average diameter of merchantable logs was determined as follows: the large end diameter of merchantable logs plus the small end diameter of merchantable logs divided by two.

2.4.3. Volume of Spurs in Parks

The volume of spurs in parks was assessed using spur measurements after the cubing process of marketable logs in the forest parks. These measurements were taken on a sample of 59 spurs of different species. The aim was to measure:

- 1) The length of the spurs;
- 2) The average diameter of the spurs.

The average diameter of the spurs was determined as follows: the large end diameter of the spurs plus the small end diameter of the spurs divided by two. [Figure 2](#) illustrates the measurement of a spur in parks.



Figure 2. Illustration of the measurement of a course on parks.

2.4.4. Volume of Wood Waste Actually Used by the Company

Following the assessment of the gross volume of felled stems and the volume of marketable logs, the total volume of wood waste ($V(\text{waste})$) produced was determined by subtracting the total gross volume of felled stems ($V(\text{felled})$) from the total volume of marketable logs ($V(\text{marketable})$).

2.4.5. Volume of Stems Felled and Abandoned Whole Near the Stump

The assessment of the volume of stems felled and abandoned whole near the stump was carried out using measurements of the felled and abandoned stems after felling. These measurements were taken on a sample of 622 felled and abandoned stems of different species. The aim was to measure:

- 1) The length of the felled and abandoned stems;

- 2) The average diameter of the felled and abandoned stems. The average diameter of felled and abandoned stems was determined as follows: the large end diameter of the felled and abandoned stems plus the small end diameter of the felled and abandoned stems divided by two.

2.4.6. Volume of Logs Actually Used by the Company Within the Study Area

Following the assessment of the total volume of wood waste produced, and the assessment of the volume of stems felled and abandoned in their entirety near the stump, the total volume of logs produced was determined by subtracting the total volume of stems felled and abandoned in their entirety near the stump V (abandoned) from the total volume of wood waste V (waste) produced.

2.4.7 Volume of irrecoverable spurs in yards. After cubing the spurs in yards, the total volume of irrecoverable spurs in yards was determined by subtracting the total volume of wood waste V (scrap) produced from the total volume of spurs in yards V (spurs).

3. Data Processing and Analysis

3.1. Identification of Wood Waste in UFA 1491

After identifying wood waste in the felling gaps and in the forest parks of AAC 2-3, the GPS coordinates of the sampled parks were, after manual processing, entered into Microsoft Excel (2016) software, then transferred to the Arc GIS 10.0 mapping software for processing. Subsequently, the analysis of the recorded points was used to produce a distribution map of the sampled parks using the Arc GIS 10.0 mapping software and the creation of the spatial location map of these parks was mounted.

3.2. Assessment of the Quantity of Usable Timber Volume in FMU 1491

3.2.1. Gross Volume of Felled Stems

After measuring the felled stems, the assessment of the gross volume of felled stems was carried out by calculating the felled volume, V (felled), of each felled stem after felling in the felling gaps using the cubic capacity formula (1) used in Cameroon:

$$V = \pi \times D^2 \times L / 4 \quad (1)$$

Where: $(\pi/4) = 0.7854$ (Forest peak); V : gross volume of the log (expressed in cubic meters); D : Average trunk diameter (measure in the middle of the log's length, including bark for the gross volume, expressed in meters); L : log length (expressed in meters)

Then, the average diameter (D_m) of the different ends was

determined, based on the volume of each of the felled stems after their felling in the previous felling holes, using the formula (2):

$$(D_m) = (DP + DG) / 2 \quad (2)$$

With: (DP) = Diameter of the small end of the felled stems; (DG) = Diameter of the large end of the felled stems.

Following these operations, the calculation of the percentage of each species in relation to the total population was generated using the Excel (2016) software. Subsequently, the material yield of 564 felled stems was determined by summing the total volume of marketable logs plus the total volume of wood waste divided by the total gross volume of felled stems, then multiplied by one hundred during the month of March. It was given by the formula (3):

$$R_{fab} = V(\text{marketable}) + V(\text{waste}) / V(\text{felled}) \times 100 \quad (3)$$

With: (R_{fab}) = Total gross material yield of felled stems.

Having obtained these values, the Excel (2016) software analysis revealed the categorization of felled volumes by species from the study site. It also revealed the total number of felled stems, followed by the total gross volume of felled stems, and their material yield. The felled volumes are related to the volume of recoverable waste, which provides an overview of the company's material yield. The volumes of felled stems were reported in the site logs and/or official site log (DF10) of Huguette Forest (HF).

3.2.2. Volume of Marketable Logs

After measuring the marketable logs, the volume of marketable logs was assessed by calculating the volume V (marketable) of each marketable log after cutting in the forest parks using the cubic capacity formula (4) used in Cameroon, which is:

$$V = \pi \times D_m^2 \times L / 4 \quad (4)$$

With: $(\pi/4) = 0.7854$ (Forest peak);

(L) = Length of merchantable logs;

(D_m) = Average diameter of merchantable logs.

With a circumference of: $V = C^2 \times L / 4 \times \pi$

The length of merchantable logs was measured along the shortest generatrix and given in decimeters covered, i.e., rounded down to the nearest decimeter. This was followed by the determination of the average diameter (D_m) of the various ends, based on the volume of each merchantable log after cutting in the previous forest parks, using the formula (5):

$$(D_m) = (DP + DG) / 2 \quad (5)$$

Where: DP = Small end diameter of merchantable logs;

DG = Large end diameter of merchantable logs.

Following these operations, the calculation of the percentage of each species in relation to the total population was generated using the Excel software (2016). Subsequently, the material yield of 430 marketable logs was determined by taking the ratio of the total volume of marketable logs and the total gross volume of felled stems and then multiplying by one hundred during the month of March. It was given by the formula (6):

$$RC = V(\text{marketable}) + V(\text{waste}) / V(\text{felled}) \times 100 \quad (6)$$

With: (RC) = Total material yield of marketable logs.

Having obtained these values, the Excel software analysis (2016) made it possible to identify the categorization of marketable log volumes by species from the study site. It also revealed the total volume of marketable logs, followed by the total number of marketable logs and their material yield. The volumes of these logs are compared to the volume of recoverable waste, which provides an overview of the company's material yield. These volumes were transmitted from the site logs of Huguette Forest (HF).

3.2.3. Volume of Spurs in Forest Parks

After measuring the spurs, the evaluation of the volume of spurs in forest parks involved calculating the volume of spurs, $V(\text{spurs})$, for each spur in forest parks after the process of cubing the marketable logs in forest parks using the cubing formula (7) used in Cameroon, which is:

$$V = \pi \times D2m \times L / 4 \quad (7)$$

With: $(\pi/4) = 0.7854$ (Forest peak);

(L) = Length of spurs;

(Dm) = Average diameter of spurs.

The length of spurs was measured along the shortest generatrix and given in covered decimeters, i.e., rounded down to the nearest decimeter. The measurement of two cross-shaped diameters taken at each end was carried out under bark, and the average was rounded down to the nearest centimeter. However, the determination of the average diameter (Dm) of the different ends of each spur, derived from the cubing of each spur in the parks, after the cubing process of marketable logs in the forest parks, is given by the formula (8):

$$(Dm) = (DP + DG) / 2 \quad (8)$$

With: DP = Diameter of the small end of the spurs;

DG = Diameter of the large end of the spurs.

Then, the total material yield of the spurs in the forest parks was calculated by calculating the ratio of the total volume of spurs $V(\text{spurs})$ in the forest parks to the total volume of marketable logs $V(\text{marketable})$ in the forest parks, then multiplying by one hundred. This was given by the formula (9):

$$R(\text{Spurs}) = V(\text{Spurs}) / V(\text{marketable ball}) \times 100 \quad (9)$$

With: $R(\text{spurs})$ = Total material yield of spurs in the stockyards.

Following these operations, the volume of each spur in the stockyard was entered into Excel (2016) to obtain the distribution of the volume and number of spurs in the stockyards in the study area. Subsequently, analysis of this data revealed the total volume of spurs in the stockyards, followed by their total material yield and total number.

3.2.4. Volume of Wood Waste Actually Used

The volumes of wood waste left in the forest and stockyards after felling and cross-cutting were calculated using the formula (10):

$$V(\text{waste}) = V(\text{felled stems}) - V(\text{marketable ball}) \quad (10)$$

Having obtained this value, the evaluation of the total material yield of wood waste was calculated by making the ratio of the total volume of wood waste $V(\text{waste})$ and the total gross volume of felled stems $V(\text{felled})$, by the formula (11):

$$Rr = V(\text{waste}) / V(\text{felled}) \times 100 \quad (11)$$

With: (Rr) = Total material yield of wood waste.

Following these operations, the volume of wood waste was entered into Excel (2016) to obtain a wood waste assessment diagram for the study area. This diagram revealed the total material yield of wood waste actually recovered by the company within the study area.

3.2.5. Volumes of Stems Felled and Abandoned in Their Entirety Near the Stump

After measuring the stems felled and abandoned, the evaluation of the volume of stems felled and abandoned in their entirety near the stump is carried out by calculating the volume $V(\text{abandoned})$, of each stem felled and abandoned after felling using the cubing formula (12) used in Cameroon which is:

$$V = \pi \times D2m \times L / 4 \quad (12)$$

With: $(\pi/4) = 0.7854$ (Forest peak);

(L) = Length of felled and abandoned stems;

(Dm) = Average diameter of felled and abandoned stems.

The length of felled and abandoned stems was measured along the shortest generatrix and given in decimeters covered, i.e. rounded down to the nearest decimeter. This was followed by the determination of the average diameter (Dm) of the various ends, resulting from the cubing of each of the felled stems and abandoned after felling through the formula (13):

$$(Dm) = (DP + DG) / 2 \quad (13)$$

With:

(DP) = Small end diameter of felled and abandoned stems;

(DG) = Large end diameter of felled and abandoned stems.

The volumes of felled and abandoned stems were entered and processed using a pivot table in Microsoft Excel (2016) to display the results of categorizing the volumes of felled and abandoned stems after felling in the study area. The analysis also revealed the total volume of stems felled and abandoned in their entirety near the stump in the study area. The calculation of the total material yield of stems felled and abandoned in their entirety near the stump was performed using the formula (14):

$$R_{taea} = V(\text{abandoned}) / V(\text{felled}) \times 100 \quad (14)$$

with: (R_{taea}) = Total material yield of stems felled and left whole near the stump.

3.2.6. Volume of Logs Actually Harvested

The volumes of logs left in the forest and parks after felling and cross-cutting were calculated using the formula (15):

$$V(\text{logs}) = V(\text{waste}) - V(\text{abandoned}) \quad (15)$$

Then, the calculation of the total material yield of the logs was carried out by subtracting the total volume of wood waste $V(\text{waste})$ produced from the total volume of stems felled and abandoned in their entirety near the stump $V(\text{waste})$, then divided by the total gross volume of stems felled $V(\text{waste})$, using the formula (16):

$$R_{rd} = V(\text{waste}) - V(\text{abandoned}) / V(\text{felled}) \times 100 \quad (16)$$

With: (R_{rd}) = Total material yield of logs.

Following these operations, the Excel software analysis (2016) revealed the volume assessment diagram for logs regularly present in the study area. It also provided the total material yield of logs actually used by the company within the study area.

3.2.7. Volume of Irrecoverable Spurs

The volumes of irrecoverable spurs left in the forest and parks after felling and cross-cutting were calculated using the formula (17):

$$V(\text{irrecoverable spurs}) = V(\text{waste}) - V(\text{Spurs}) \quad (17)$$

Having obtained this value, the evaluation of the total material yield of irrecoverable shoots R (irrecoverable shoots), was determined by making the ratio of the total volume of irrecoverable shoots v (irrecoverable shoots) and the total gross volume of felled stems V (felled), by the formula (18):

$$R(\text{ci}) = V(\text{irrecoverable spurs}) / V(\text{felled}) \times 100 \quad (18)$$

With: (ci) = Total material yield of irrecoverable spurs.

Following these operations, the volume of irrecoverable spurs in the yards was entered into Excel (2016) to obtain the irre-coverable spur evaluation diagram within the study area, and its material yield.

4. Results

4.1. Identification of Wood Waste in Forest Management Unit 1491

The results presented relate to the identification of wood waste in the Annual Harvest Area (AAC 2-3) site of Forest Management Unit 1491 (UFA). To this end, the analysis of recorded points was used to produce a distribution map of the sampled parks (Figure 3). However, the wood waste encountered within the study area is listed in Table 3 according to locations such as forest parks and felling gaps.

Table 3. Wood Waste Encountered in Forest Parks and Felling Gaps.

Forest Parks	Felling Holes
Purs	Felled and Abandoned tems
Logs	Abutments
Abandoned Logs	Forks
Purges	Branches
Poles	Trimming Offcuts
Trimming Offcuts	Strains
-	Treetops
-	Crowns

Table 3 shows that the forest resource available for wood energy can be divided into two groups: non-marketable by-products resulting from forestry and harvesting operations (treetops, crowns, branches, etc.), and low-value wood to which wood energy may occasionally add value (logs, abandoned timber, poles, spurs, etc.). This is consistent with the study conducted by [1].

4.2. Spatial Location Map of Sampled Forests

To this end, the analysis of recorded points was used to produce a distribution map of the sampled forests (Figure 3).

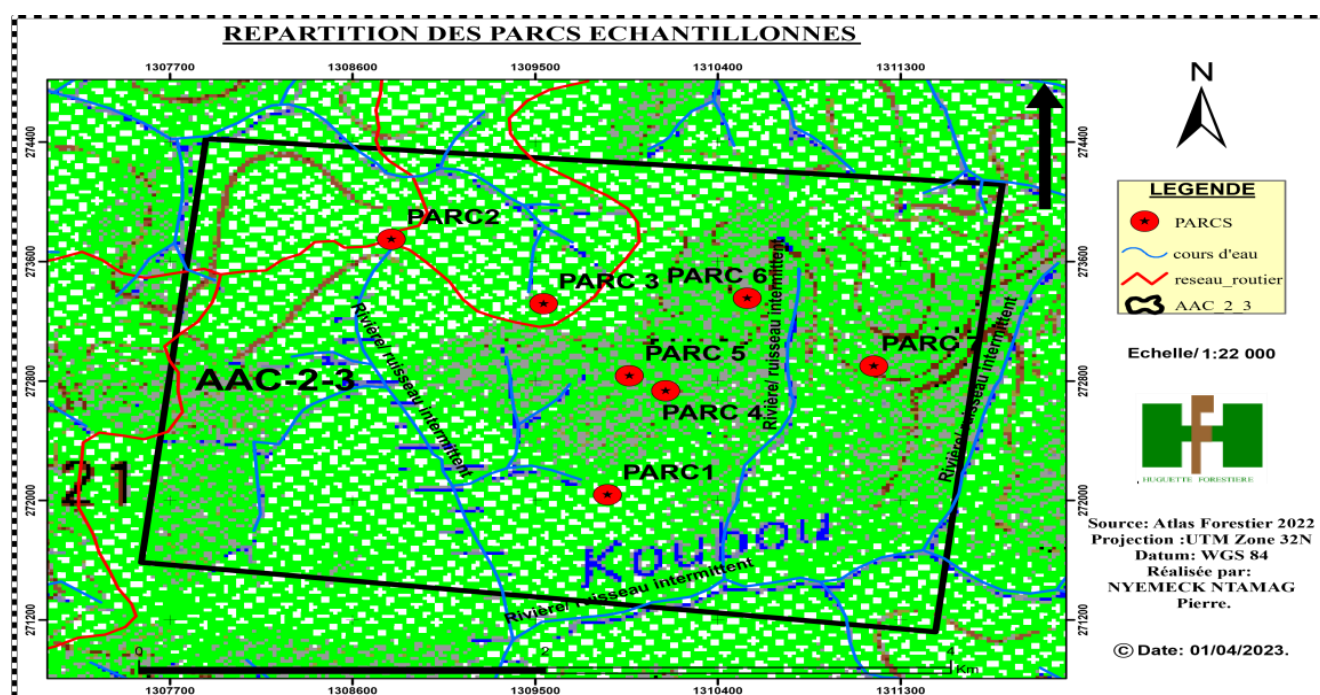


Figure 3. Map of the distribution of the sampled spatial parks.

4.3. Assessment of the Quantity of Usable Timber Volume in FMU 1491

4.3.1. Gross Volume of Felled Stems

Analysis of the data from the gross volume of felled stems revealed the categorization of felled volumes by species from the study site. The analysis also provided the number of felled stems and the volume of felled stems based on the selected species. Figure 4 below shows the categorization of felled volumes by species from the study site.

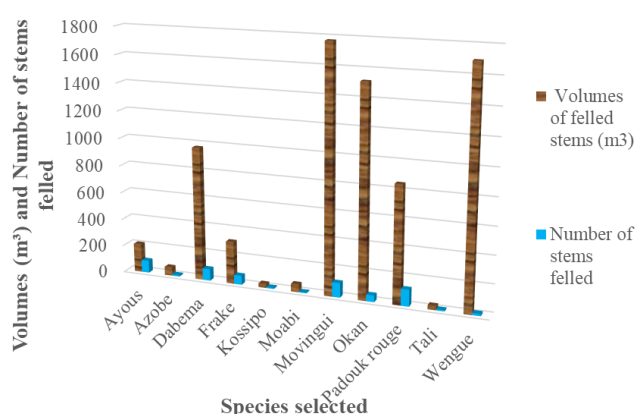


Figure 4. Categorization of felled volumes by species.

Figure 4 shows that the treatment of felled stems after felling in the felling gaps shows that Movingui has the largest

volume of felled stems with a value of 1773.702 m³ and a number of 106 felled stems, followed by Wengue, Okan, Dabema, Red Padouk, Frake, Ayous, Azobe, Moabi, Tali, and Kossipo. Already knowing the volumes of felled stems and the number of felled stems, it is important to know the total gross volume of felled stems and the total number of felled stems. To this end, additional methods to the previous analysis process made it possible to identify the total number of felled stems and the total gross volume of felled stems.

This volume refers to the volume under bark of the boles from the end of the buttresses to the first large branch, without deduction of defects. The total raw material yield from the logs felled in the study area is consistent with the findings of the study, which [15] showed that the marketable volume, when added to the volume of waste wood as a proportion of the total volume felled, represents an overall raw material yield of 100 per cent from the felled trees.

4.3.2. Volume of Merchantable Logs

The analysis of data from the volume of merchantable logs revealed the categorization of the volumes of merchantable logs by species from the study site. The analysis also yielded the volumes of merchantable logs and the number of merchantable logs based on the selected species. Figure 5 below presents the categorization of the volumes of merchantable logs by species from the study site.

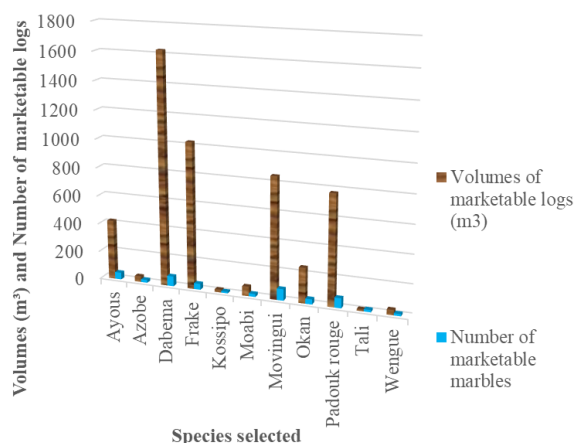


Figure 5. Categorization of volumes of marketable logs by species.

It is clear from Figure 5 that the processing of marketable logs in the forest parks for the preparation of marketable logs shows that, in view of the analysis, only Dabema has the largest volume of marketable logs of 1628,473 m³ and a number of 70 marketable logs, followed by Frake, Movingui, Red Padouk, Ayous, Okan, Moabi, Azobe, Wengue, Kossipo and Tali. Having already the data on the volumes of marketable logs and the number of marketable logs already present within the study site, it is important to know the total volume of marketable logs and the total number of removed (marketable) logs. To this end, the additional methods to the previous analysis process made it possible to identify the total volume of marketable logs and the total number of removed (marketable) logs. Figure 6 below presents the summary of all marketable log volumes from the study site.

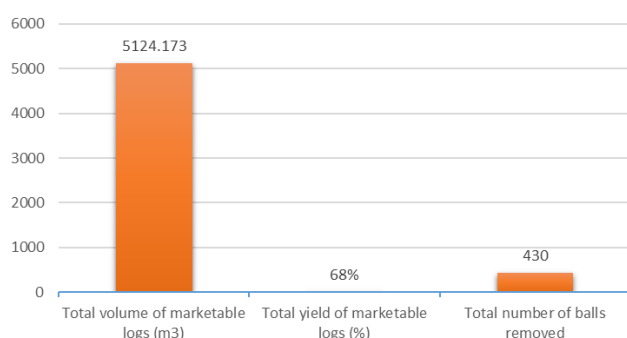


Figure 6. Summary of Total Merchantable Log Volumes from the Study Site.

Figure 6 shows that the total merchantable log volume is 5,124.173 m³, which corresponds to a total material yield of merchantable logs of 68%, meaning the total number of removed (merchantable) logs is 430 removed (merchantable) logs. This merchantable timber yield depends, among other things, on the quality and value of the species, the diversity of logging conditions, and consumer requirements. This is in line with the study conducted by [20], which showed that the yield

of merchantable volume to gross volume was 69%, or 3,538 m³ out of 5,133 m³.

4.3.3. Volume of Spurs in Parks

Analysis of the data from the volume of spurs in parks revealed the repair volume and number of spurs in parks in the study area. The analysis also provides the number of spurs in the park and the volume of spurs in parks for each park. Abandoned spurs in parks, with minor defects, grouped in parks, along the roadside, measuring 2.50 m or more in length and 60 cm or more in diameter and which can be transformed, are considered salvageable spurs. Figure 7 shows the distribution of the volume and number of spurs in parks in the study area.

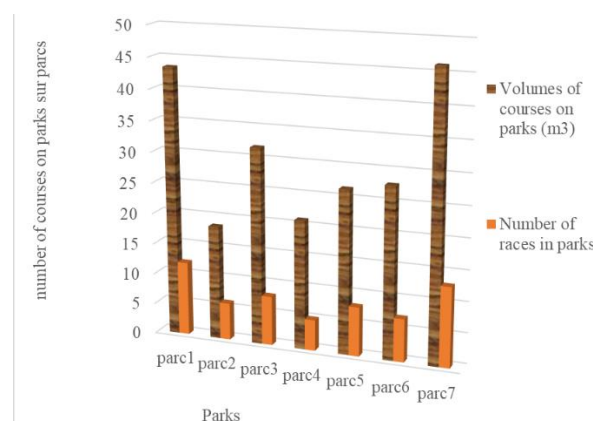


Figure 7. Volumes and number of courses on parks.

Figure 7 shows that the largest number of spurs on pens is found in pens 7, 1, 3, and 5. On the other hand, pens 4, 2, and 6 have fewer spurs. Already knowing the number of each spur on pen and the volume of each spur on pen, it is important to know the total volume of spurs on pens and the total number of spurs on pens. To this end, additional methods to the previous analysis process made it possible to identify the total volume of spurs on pens, followed by the total number of spurs on pens, and its total material yield. Figure 8 presents the summary of all the volumes of spurs on pens in the study area.

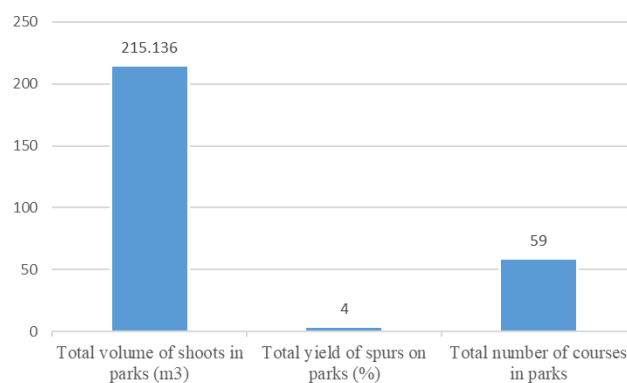


Figure 8. Summary of all log volumes in parks in the study area.

As shown in Figure 8, (59) logs in parks with a volume of 215,136 m³ have a total material yield of 4% of the logs in parks, or 215,136 m³ of the total volume of logs in parks out of 5,124,173 m³ of the total volume of marketable logs. This yield of logs depends, among other things, on the quality of the logs, the diversity of the logs left in the forest parks after cutting the marketable logs, and the means of transportation to collect them, which allows for their recovery.

4.3.4. Volume of Wood Waste Actually Recovered by the Company

After analyzing the total gross volume of felled stems and the total volume of marketable logs, with a view to recovering wood waste within the study area, they are represented in Figure 9.

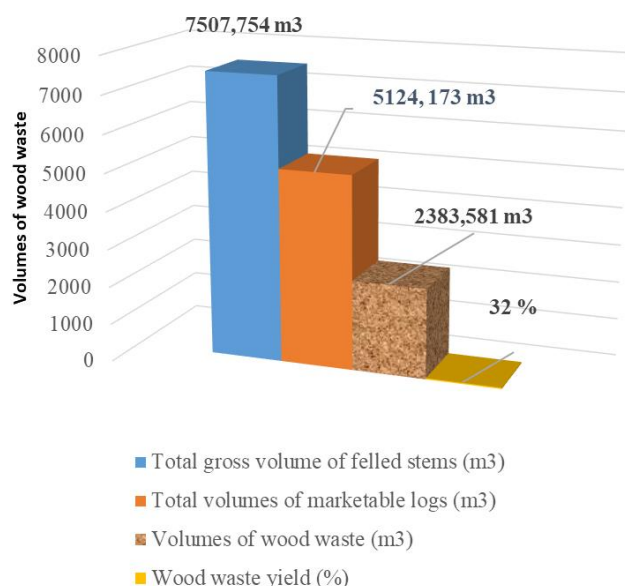


Figure 9. Wood Waste Volume Assessment Chart.

According to the analysis in Figure 9, the woody material utilization rate for the eleven species previously considered shows that the total volume of abandoned wood waste is quite considerable (32%), or 2,383.581 m³ of the total volume of wood waste out of 7,507.754 m³ of the total gross volume of felled stems. This volume is significantly higher than that carried out by [15] who estimates that the volume of waste is quite considerable (31%), or 1,595 m³ of waste out of 5,133 m³ of felled volume.

4.3.5. Volume of Stems Felled and Abandoned in Their Entirety Near the Stump

The analysis of data from the volume of stems felled and abandoned in their entirety near the stump revealed the results of the categorization of the volumes of stems felled and abandoned after felling in the study area. The analysis also pro-

vided the volumes of stems felled and abandoned in their entirety near the stump and their numbers according to the species selected. Figure 10 below shows the categorization of the volumes of stems felled and abandoned after felling in the study site.

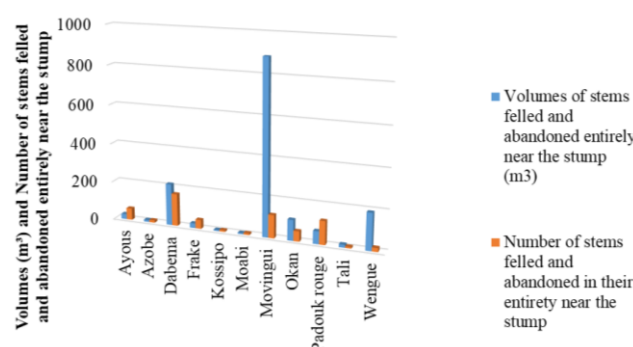


Figure 10. Categorization of the Volumes of Felled and Abandoned Stems after Felling.

Figure 10 shows that the treatment of entire felled and abandoned stems near the stump after felling shows that Movingui has the largest volume of felled and abandoned stems, with a value of 887,940 m³ and a number of 119 felled and abandoned stems, followed by Dabema, Wengue, Okan Red Padouk, Ayous, Frake, Tali, Azobe, Moabie, and Kossipo. Given the aforementioned volumes and the number of these stems, it is important to also know the total volume of felled and abandoned stems after felling in the study area and the total number of felled and abandoned stems. For this, additional methods to the previous analysis process made it possible to identify the total volume of stems felled and abandoned after felling in the study area and the total number of stems felled and abandoned. Figure 11 below presents the summary of all volumes of stems felled and abandoned after felling in the study area.

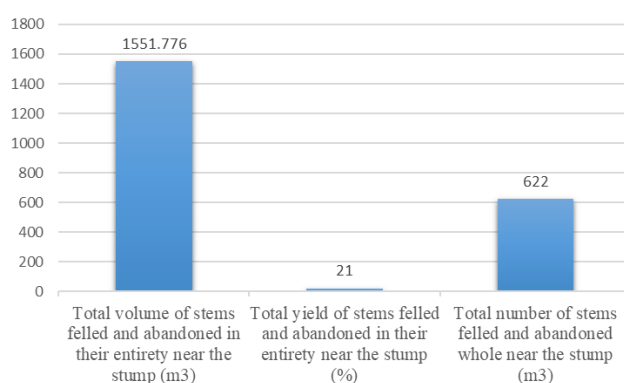


Figure 11. Summary of all volumes of felled and abandoned stems after felling in the study area.

As shown in Figure 11, (622) stems felled and abandoned whole near the stump, with a volume of 1551.776 m³, have a

total material yield of 21% of the stems felled and abandoned whole near the stump, or 1551.776 m³ of the total volume of stems felled and abandoned whole near the stump, out of 7507.754 m³ of the total gross volume of felled stems. This total material yield of felled and abandoned stems is significantly higher than the studies conducted by [10] which showed that felled and abandoned stems represented 7% of the log volume.

4.3.6. Volume of Logs Actually Recovered by the Company Within the Study Area

After analyzing the volume of wood waste and the total volume of stems felled and abandoned in their entirety near the stump, with a view to recovering the wood logs within the study area, they are represented in Figure 12.

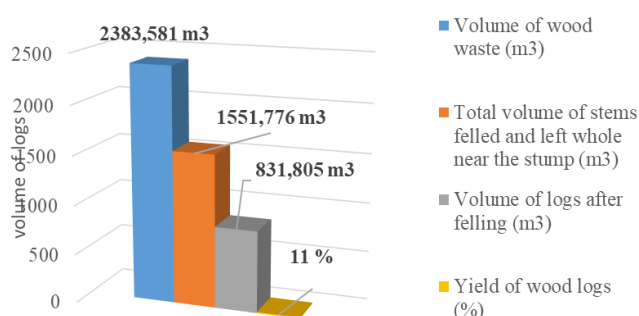


Figure 12. Log Volume Assessment Diagram in the Study Area.

Figure 12 shows that the log volume is 831.805 m³, which corresponds to a total log material yield of 11%, or 831.805 m³ of log volume out of 7507.754 m³ of the total gross volume of felled stems.

4.3.7. Volume of Irrecoverable Spurs in Yards

After analyzing the volume of wood waste and the total volume of spurs in yards, with a view to adding value to the product, these are represented in Figure 13.

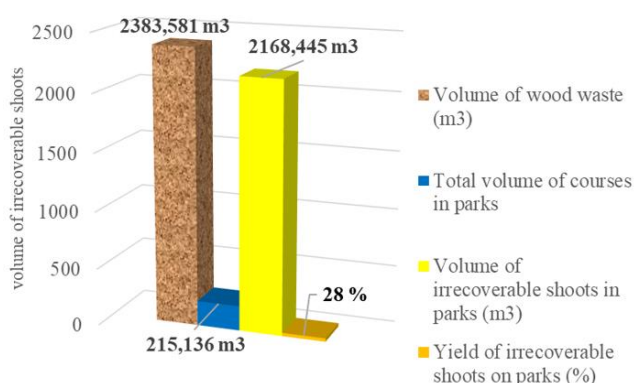


Figure 13. Diagram showing the volume of irrecoverable shoots in the parks.

The analysis of Figure 13 shows that the volume of irrecoverable shoots left in the parks is 2,163.445 m³. It also shows that the yield of irrecoverable shoots in the parks represents approximately 28% of the total gross volume of felled stems, or 2,163.445 m³ of the volume of irrecoverable shoots in the parks out of 7,507.754 m³ of the total gross volume of felled stems.

5. Discussion

In view of the above, the production of residual wood products is very important in forestry. It is noted that in AAC 2-3 of UFA 1491, the material yield is 21% of felled and abandoned stems, followed by 11% of logs, and 4% of spurs. We can deduce from these observations that the study area is full of a multitude of different species of potentially usable waste abandoned in the gaps after felling and during cutting in the yard. Thus, the dominant waste in the study area is mainly felled and abandoned stems as noted by [10]. However, these values are significantly higher than the proportions found by [6], who estimate that spurs, stumps or abutments represented 7% of the volume of the log, followed by felled and abandoned stems which represented 7% of the volume of the log, abandoned logs which represented 7% of the volume of the log, and abandoned logs 6.75% of the volume of the log. In fact, the company Huguet Forest (HF) produced approximately 7507.754 m³ of felled volume from felled stems and 5124.173 m³ from marketable logs during the month of March in AAC 2-3 of UFA 1491; which gives a recovery percentage of wood scraps of around 32%, this is well below the values found by the [7] which shows that 65% of the average wood lost during exploitation, presents a large number of non-recovered scraps. Added to this are the observations of [17] which show that ($\pm 30\%$) of the volume of wood from felled standing trees is found in forests in the form of waste (spurs, logs, felled logs, etc.). We can valorize these potentially usable scraps through recovery methods by further processing the wood using carbonization following the method proposed by [9] or cogeneration following the principle proposed by [16] or the use of wood energy for heating greenhouses following [1].

From an exploitation point of view, the conditions are quite favorable: an average felled volume of around 26 m³/ha, or an average number of 3.5 stems/ha, these results exceed the average generally recognized for forests of the same type and which is of the order of 10 m³/ha, or one to two stems/ha [3]. As a general rule, any felled tree is likely to yield a merchantable log more than 6 meters long. Trees that are completely hollow or whose split reaches 2/5 of the length of the bole are not hauled according to [18]. Furthermore, the study by [2] showed that the conformity of tree trunks can be linked to the presence of uneven relief. Just like the pressure of the winds; areas that are difficult to access strongly influence commercial trees. The rate of use of woody material for the eleven species selected shows that the volume of scraps abandoned is quite

considerable 32%, it is less than 68%, or 2383.581 m³ of wood scraps out of 7507.754 m³ of felled volume. The difference between the merchant volume and the gross volume comes from a first processing at the stump and others at the woodyards or even along the roadsides. This difference represents the volume of rejects. Columns 2, 4, 6 and 8 of Table 4

respectively present the total number of stems felled, the total gross volume of stems felled, the total number of logs removed and the total merchantable volume. Columns 3, 5 and 7 give the percentages of each species in relation to the total population.

Table 4. Quarterly number (No.), percentage (%) and volume (m³) of merchantable and felled logs by species.

Species	Downed logs				Merchant notes			
	Nbre	%a	(m ³)	%b	Nbre	%a	(m ³)	%b
Ayous	90	15,96	209,242	2,79	48	11,16	420,235	8,20
Azobe	10	1,77	61,287	0,82	20	4,65	39,837	0,78
Dabema	86	15,25	972,139	12,95	70	16,28	1628,473	31,78
Frake	66	11,70	309,995	4,13	42	9,77	1027,942	20,06
Kossipo	8	1,42%	28,055	0,37	11	2,56	18,475	0,36
Moabi	5	0,89	55,983	0,75	21	4,88	66,333	1,29
Movingui	106	18,79	1773,702	23,62	81	18,84	851,231	16,61
Okan	48	8,51	1519,792	20,24	36	8,37	248,447	4,85
Padouk rouge	122	21,63	850,071	11,32	70	16,28	775,82	15,14
Tali	8	1,42%	29,255	0,39	16	3,72	11,51	0,23
Wengue	15	2,66	1698,231	22,62	15	3,49%	35,87	0,70
Total	564	100	7507,754	100	430	100	5124,173	100

With a: percentage expressed in relation to the total number of logs (felled or merchantable); b: percentage expressed in relation to the total volume of logs (felled or merchantable).

From Table 4, it appears that Movingui represents 23.62% of the total volume felled and 18.79% of the total number of stems felled, followed by Wengue, Okan, Dabema, Padouk rouge, Frake, Ayous, Azobe, Moabi, Tali, and Kossipo. While Dabema constitutes 31.78% of the stock of marketable logs and 16.28% of the total number of marketable logs, followed by Frake, Movingui, Padouk rouge, Ayous, Okan, Moabi, Azobe, Wengue, kossipo and Tali.

5.1. Most Represented Species

A manual count of waste on parks and gaps showed the family most represented in the parks and gaps in the study area. This family is that of Fabaceae and appears to be the most diverse with at least three (3) species present (*Cylicodiscus gabunensis*, *Pterocarpus soyauxii*, *Milletialaurenti*). This family is followed by the Mimosaceae with one (1) species present (*Piptadeniastrum africanum*) and the other families are less

represented. The above result is in agreement with the observations of [19] who found that classically in tropical forests, some species are represented by a large number of individuals, and many species are rare or very rare. However, if we are interested in the undergrowth trees or those in the canopy: Fabaceae dominate all strata, they are followed by Mimosaceae in the middle wood [8].

5.2. Volume of Purs on Parks

The results in Figure 3 and 8 showed that parks numbers 7, 1, 3 and 5 are the richest in coursons. On the other hand, the most commonly encountered thorn defects are heart rolls 15.07%, followed by galls 9.62%, bumps 6.17% and bends 3%. The other defects are less represented. Thus, the distribution of the volume and number of spurs in these parks varies considerably. The average volume of recoverable wood for all the courses is approximately 17,928 m³/park or 12 courses/park. These results reflect a strong variability in the volume and number of spurs in the 7 parks sampled. This variability of shoots on the park is perhaps due to the conformity of the trunks. Which is in line with the study carried out by [5].

6. Conclusion

The overall objective of this study was to contribute to the optimization of the sustainable valorization of felled resources through the improvement of knowledge on the recovery of wood waste in UFA 1491. The study area was full of a multitude of different species of potentially usable waste and abandoned in the gaps after felling and during crosscutting on the park. Thus, the results of this study made it possible to achieve the objectives set initially. These results are divided into four points, namely:

The identification of wood waste in UFA 1491. For this purpose, we have identified as wood waste: spurs, forks, felled and abandoned stems, logs, branches, abutments, stumps, crowns, purges, poles, and trimmings. These rejects therefore depend on the distribution of the parks sampled in AA 2-3 of UFA 1491.

Evaluation of the quantity of usable wood volume in UFA1491. However, the quantity of rejects recorded in AAC 2-3 of UFA 1491 constituted a volume of 1551.776 m³ of stems felled and abandoned for a yield of 21%, followed by 831.805 m³ of logs for a yield of 11%, and 215.136 m³ of spurs for a yield of 4%. The rate of use of woody material for the eleven species selected showed that the volume of waste abandoned is quite considerable 32%, or 2383.581 m³ of wood waste out of 7507.754 m³ of the felled volume.

To contribute to increasing the quantity of woody material in Cameroon, and within the study area in particular, measures must be taken to promote the diversity of wood production, while minimizing wood waste through its recovery. The following recommendations are among the actions to be undertaken to achieve this objective:

For a more comprehensive estimate, it would be wise to extend this study to other forestry companies in Cameroon, in order to determine the quantity of woody material throughout the country and the potential for recovering residual wood products in Cameroon;

Abbreviations

AAC	Annual Cutting Area
UFA	Forest Management Unit
UTB	Wood Processing Plant
PAO	Annual Operating Plan
GPS	Global Positioning System
HF	Huguette Forest Company

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Author Contributions

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Nyemeck Ntamag Pierre: Conceptualization, Investigation

Conflicts and interest

The authors declare no conflicts of interest.

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