

Assessment of Timber Loss and Its Economic Impact on Logging in the Dense Rainforest of the Littoral Region in Cameroon

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Abstract

Logging is widely cited as a source of forest degradation, due to the many irregularities in this sector of activity that cause timber and monetary losses. This study aimed to determine the sources of timber loss and its economic impact on logging within the dense rainforest of the littoral region in Cameroon. The study was carried out in the annual cutting plate 1.1 of the 07-004 unit. Data were collected through the administration of semi-structured questionnaires to 36 staff among preparation cubers, prospectors, fellers, loggers, stevedores and buckers, and direct observations concerning felling, forest cutting, shaping and rolling in the skidding sites and the forest parks. Data collection focused on 9 target species of the logging company. The assessment of the lost timber volume involved the cubing of 549 logs and pieces of trunk, using the Huber's formula. Descriptive statistics were carried out to process quantitative data and generate graphs. The analysis was carried out using SPSS Statistics 26. The monetary value in FCFA of lost timber was evaluated using the free on board price of the year 2017 recommended by the Ministry of Forest and Wildlife. The results showed that there were four sources of timber loss identified at the skidding sites and the forest parks, including poor work planning, unqualified personnel, wood defects and inadequate equipment and methods. These loss sources induce seventeen causes of timber losses, all identified at the forest parks,

with uprooting (16.17%) and excessive purge of bumps (15.25%) as the most frequent. Thirteen among the seventeen loss causes were identified at the skidding sites, with abandonment (24.55%) and oversight (18.18%) being the most frequent. There is a strong positive correlation between most loss causes, with the exception of the rolling and the excessive purging of melot, whose correlation is negative with almost all others. *Julbernardia pellegriniana* recorded the highest loss volumes both at the skidding sites (306.72 m³) and the forest parks (277.29 m³). *Entandrophagma cylindricum* (1.11 m³) recorded the lowest at the skidding sites and *Cyclicodiscus gabonensis* (5.87 m³), at the forest parks. A total volume of 1127.61 m³ of timber losses was recorded, corresponding to 111,117,057 FCFA (169,644.36 €) of economic loss throughout the production chain for an estimated annual of 666,702,342 FCFA (1,017,866.17 €). These results could have been minimized given the small sampling rate (1%) due to the short period of data collection and the difficulty of access to certain sites. It is quite conceivable that the losses could be slightly higher if this sampling rate was increased. Limiting timber losses could reduce harvested forest areas while increasing yield and monetary benefits. This could be effective if monitoring and capacity-building processes were undertaken by both logging companies and the forest administration.

Keywords

Logging, Timber Losses, Economic Impact, Dense Rainforest, Cameroon

1. Introduction

Occupying the northwestern limit of the Congo Basin, Cameroon has about 22 million hectares of forests, representing nearly 46% of the country's total area (MINFOF, 2018). According to Forest Resource Management Ingénierie (FRMi, 2018), 8.5 million hectares are dedicated to forestry production. From 2002 to 2023, the country lost 976 kha of humid primary forest (dense rainforest), making up to 49% of its total tree cover loss in the same time period. Total area of humid primary forest decreased by 5.1% (Global Forest Watch Cameroon, 2025). The FAO (2010) estimated rates between 0.6% and 1.0% of annual loss, making Cameroon the country with the highest annual deforestation rate in the Congo Basin after the Democratic Republic of the Congo. Firewood collection and agricultural expansion are often among the main causes of forest loss (MINFOF and FAO, 2005), while logging is mainly mentioned in the literature as a source of forest degradation (Gbetnkom, 2005). A report of the European Union in 2015 denounced the many irregularities in the timber industry in Cameroon (*Exploitation of Forests, Cameroon, 2023*), applying in the forest production areas.

According to FRMi (2018), Cameroon is the largest logs producer in the region, with its national production reaching 44% of regional production. It is one of the top five tropical log exporters in the world, and its industrial round wood production has increased by 35% since 1980 (Global Forest Watch Cameroon, 2011).

Logging contributes about 6% of the Gross Domestic Product (MINFOF, 2011) and has accounted for roughly 25% of the country's foreign exchange (Topa et al., 2009).

Logging activities have increased rapidly in recent years, wherein a wide use of high-impact conventional logging has led to forest damage and fragmentation (Asner et al., 2009). Studies have so far dealt with damage, timber and economic losses caused by inappropriate logging methods across the world, including Andel (1978) in Southeast Asia; Abdulhadi et al. (1981) in Malaysia; Ayres and Johns (1987) in Amazonian Várzea; Buenaflor (1989) in Papua New Guinea; White (1992) in the Lope Reserve, Gabon; Agom and Ogar (1994) and Agom (1994) in Nigeria; Agyeman et al. (1995) in Ghana; Ahmad et al. (1999) in Peninsular Malaysia; Armstrong and Inglis (2000) in Guyana. In Cameroon, studies focused mostly on ecological damage of logging (Namuene & Egbe, 2022; Global Witness, 2004), illegal logging (Alemagi & Kozak, 2010; Enviro-Protect, 1997), and forest governance in logging (Bigombe, 2004; Brunner & Ekoko, 2000). Very few and unpublished known study addresses the problem of timber losses in logging. The main published ones are the report of the Integrated Pilot Development Project (IPDP) of Dimako in the East region, mentioned by CIRAD (1998), and the final report of the Tropenbos-Cameroon Programme in Kribi in the Littoral region, edited by Jonkers (1999), but these studies did not take into account all the wood lost at the forest parks and did not assess the volume of lost wood, nor the economic value of this loss.

The loss of timber in logging constitutes not only a loss of earnings for the logging companies who pay the felling tax on the wood sometimes abandoned in the forest, but also for the State whose forest resource is not optimally used. This loss of timber is caused by whole stems abandoned in the forest or recoverable pieces of trunk abandoned in forest parks. According to Sofuoglu and Kurtoglu (2012), for higher timber recovery, harvesting trees and their processing with minimal timber loss is essential for local and national economic growth. It is in this framework that this study aimed to determine the loss sources of timber and their economic incidence in the logging unit 07-004, precisely in the annual cutting plate 1.1 in the Littoral region in Cameroon. It specifically intended to identify the loss sources and causes of timber and the frequency of occurrence at the skidding sites, the forest parks and throughout the entire production chain, to determine the volumes of lost timber related to loss sources and species, and finally to evaluate the economic incidence on the logging company.

2. Methodology

2.1. Study Area

This study was carried out in the Annual Cutting Plate (ACP) 1.1 of the logging unit 07-004, located in the Nkam Division of the Littoral Region in Cameroon; precisely in the South-West Nkondjock sub-division of latitude 4° 53' 48" N and longitude 10° 15' 33" E (Figure 1).

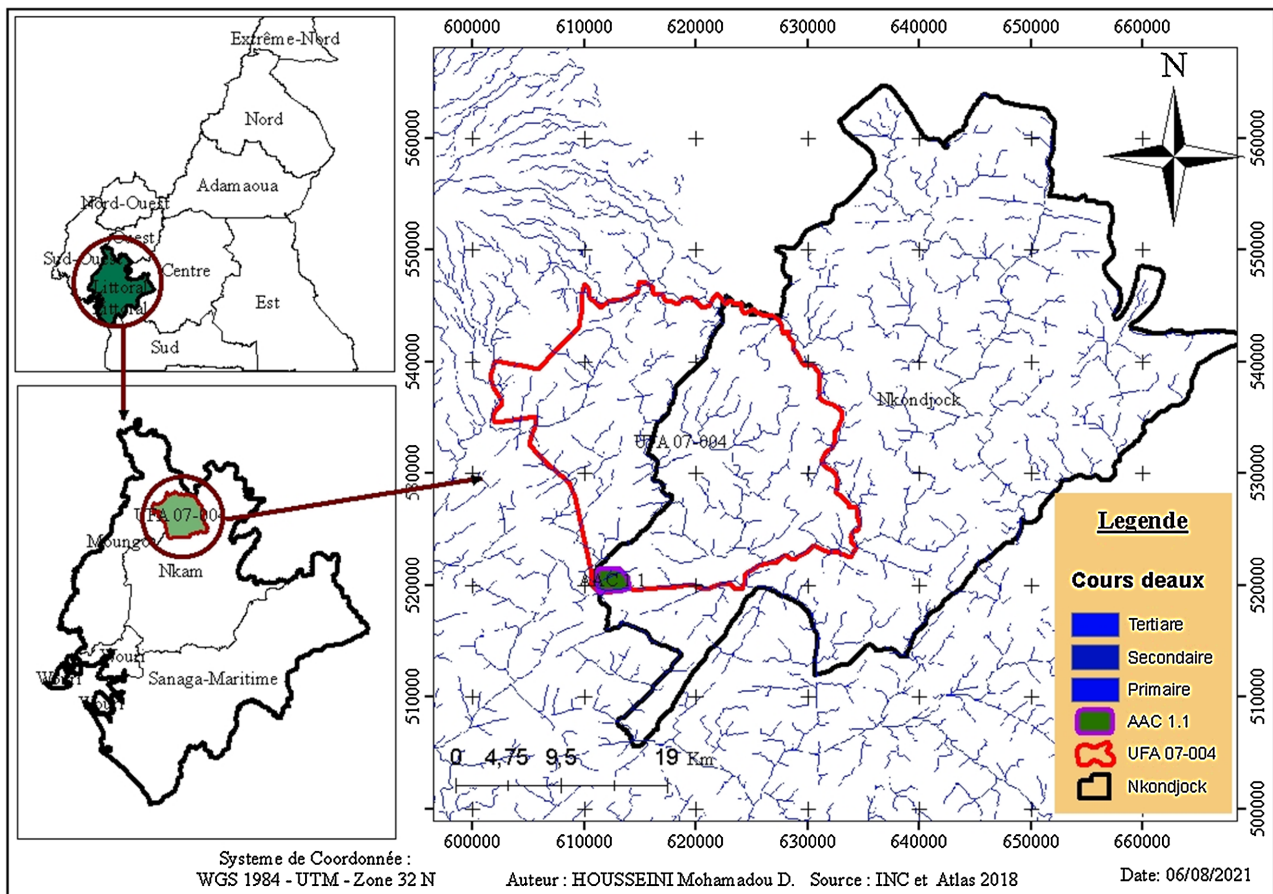


Figure 1. Localization of the ACP 1.1 of the 07-004 logging unit.

The climate is equatorial with two seasons: a short dry season (November to March) and a long rainy season (March to November). The average mild annual temperature is between 22°C and 28°C and the moderate annual precipitation between 1800 and 2000 mm (Barbier, 1977). Mainly in a forest area, the vegetation is a dense rainforest, dominated by Azobe (*Lophira alata*), Ilomba (*Pycnanthus angolensis*), frake (*Terminalia superba*) (Osidebea, 2023).

2.2. Data Collection

Choice of species

The study focused on the 9 target species of the company. Their scientific and local names, and Free on Board (FOB) prices in Franc CFA (the currency used in Cameroon) are given in Table 1.

Determination of the sources of timber losses

Data for the sources of timber losses were collected through individual interviews using semi-structured questionnaires, with 36 personnel (5 most ancient per team) among preparation cubers, prospectors, fellers, loggers, stevedores and buckers. These interviews were made possible with the help of the foreman, who explained to his colleagues the scientific purpose of the study and the economic interest for the company, which could lead to a strengthening of their capacities.

Table 1. Studied species with their free on board prices.

Target species	Local name	FOB price 2017 (in FCFA/m ³ of wood/specie)
<i>Lophira alata</i>	Azobe	88,620
<i>Nauclea diderrichii</i>	Bilinga	88,870
<i>Azelia pachyloba</i>	Doussie	134,290
<i>Julbernardia pellegriniana</i>	Ekop beli	98,695
<i>Brachystegia mildbreadii</i>	Ekop naga	98,695
<i>Cyclicodiscus gabonensis</i>	Okan	85,235
<i>Pterocaipus soyauxii</i>	Padouk rouge	101,040
<i>Entandrophagma cylindricum</i>	Sapelli	143,270
<i>Erythrophleum ivorense</i>	Tali	75,670

Respondents therefore gave their free prior verbal consent to participate in the survey.

Direct observations concerning operations including prospection, felling, forest cutting, shaping and rolling were done in order to appreciate the work planning and to determine the timber loss causes. These observations on the field were made at the skidding sites with the help of the stevedore and at the forest parks with that of the foreman.

Assessment of lost timber volume

The determination of the volume of lost timber involved the cubing of all abandoned logs and pieces of trunk of the target species at the skidding sites and in the forest parks. The sampling rate was set at 1% due to the relatively short data collection period and the difficulty of access to certain sites. Forest park daily reports of the company including yield, were also used to consolidate collected data.

The diameter (Equation (2)) was measured at the large and small ends, orthogonally to the axis, and the length from one end to the other. The following Huber's formula (Equation (1)) was used. As mentioned by Briggs (1994), it is among the commonly used volume formulas for harvested wood stems.

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

$$\text{With } D = (DLe + Dse) / 2 \quad (2)$$

where V = Log volume to determine (in m³); π = Phi (22/7 or 3.14); D = Log average diameter to determine (in cm); L = Length of the log (in m); DLe = Diameter of the large end of the log (in cm) and Dse = Diameter of the small end of the log (in cm).

The volumes of timber loss per day, per week and per month were calculated and permitted to estimate the annual total volume per loss cause and loss source, and per specie for whole of the skidding sites and forest parks.

2.3. Data Analysis

Data was processed using Microsoft Excel 2016, for the establishment of a raw

database collected in the field and the production of graphs resulting from the descriptive analysis of data. SPSS Statistics 26 software was used for data analysis. The Pearson correlation was used to establish the link between loss sources. And the Student t-test was used at the threshold of 5%, under the null hypothesis that there is no correlation between the loss causes.

Assessment of economic loss

To evaluate the monetary value of lost timber, the species FOB prices (FCFA/m³/specie) of the year 2017 recommended by the Ministry of forest and wildlife were used (Table 1). The cost of the lost timber volume was estimated by multiplying the FOB price by the volume of wood as in Equation (3):

$$Mv = FOBP * V \quad (3)$$

with Mv = monetary value in FCFA and in euro (1 Euro = 655 Francs CFA, as the rate of change is stable between the two currencies), $FOBP$ = free on board price of specie (in FCFA/m³), and V = volume of lost timber (in m³).

3. Results and Discussion

3.1. Results

3.1.1. Identification of Timber Loss Sources and Causes at the Skidding Sites and Forest Parks

Four sources of timber loss were identified at the skidding sites and the forest parks following the observation of a total of 549 wood stems (110 at the skidding sites and 439 at the forest parks) and the interviews with the personnel. They included poor work planning, unqualified personnel, wood defects and inadequate equipment and methods. These loss sources induce seventeen causes of timber loss, all identified at the forest parks of which thirteen identified at the skidding sites. Some of them are presented in Figure 2.

Table 2 presents each of the loss causes associated with its origin (loss source), the number of wood stem concerned and the corresponding frequency for the various loss sources. Globally, the order of importance of loss sources over the entire production chain was wood defects (55.58%), unqualified personnel (36.45%), inadequate equipment and methods (7.06%) and poor work planning (0.91%). This table also shows that there were four most frequent loss causes at the skidding sites including abandonment of 27 stems (24.55%), oversight of 20 stems (18.18%), the presence of rot on 13 stems (11.82%) and the presence of holes on 12 stems (10.91%). Timber with melot was rarely observed (0.91%). The most frequent loss causes at the forest parks were uprooting of 71 stems (16.17%), excessive purge of bumps on 67 stems (15.26%) and excessive purge of nodes on 54 stems (12.30%), abandonment of 46 stems (10.48%), excessive purge of holes on 36 stems (8.3%) and excessive purge of flats on 34 stems (7.74%). The most rare was bat cutting, excessive purge of melot (both 0.46%), oversight (0.91%) and slot (1.14%).

3.1.2. Volume of Timber Losses per Species and Loss Cause

The volume of lost timber was estimated for each of the nine species concerned



Figure 2. Loss causes identified on the field.

Table 2. Sources and causes of wood losses identified at the skidding sites and forest parks.

Source of losses	Causes of timber losses	Skidding site		Forest park		Globally	
		NT	F/LC (in %)	NT	F/LC (in %)	TNT	F/LS (in %)
Poor work planning	Oversight	20	18.18	4	0.91	24	0.92
	Abandonment	27	24.55	46	10.48	73	
Unqualified personnel	Uprooting	4	3.64	71	16.17	75	
	Bad cutting			2	0.46	2	36.45
	Bad stubbing	4	3.64	20	4.56	24	
	Bad topping	6	5.45	21	4.78	27	
	Curvature	3	2.73	21	4.79	24	
Wood defects	Double heart			8	1.82	8	
	Excessive purging of bumps			67	15.26	67	
	Excessive purge of melot	1	0.91	2	0.46	3	55.57
	Excessive purge of flats			34	7.74	34	
	Excessive purge of nodes	3	2.73	54	12.30	57	
	Excessive purge of rot	13	11.82	22	5.01	35	
	Excessive purge of holes	12	10.91	36	8.20	48	

Continued

Inadequate equipment and methods	Broken wood	7	6.36	17	3.87	24	
	Slot/crack	3	2.73	5	1.14	8	7.06
	Rolling	7	6.36	9	2.05	16	
Total		110	100	439	100	549	100

NT = Number of Timber; F/LC = Frequency per Loss Cause; TNT = Total Number of Timber; F/LS = Frequency per Loss Source.

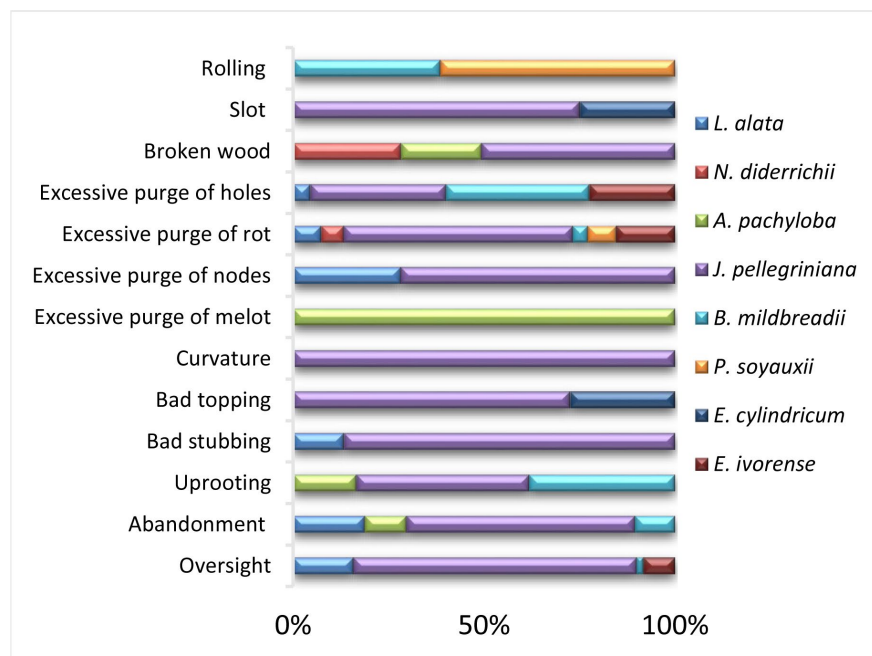


Figure 3. Proportion of species by loss cause at the skidding sites within the study period.

and by cause of loss. **Figure 3** shows that *J. pellegriniana* was most concerned (11 out of 13 loss causes) in the skidding sites. It was also the only specie concerned by curvature. *B. mildbreadii* and *L. alata* followed with 6 out of 13 loss causes. From this figure, it also appears that excessive purge of melot affects only *A. Pachyloba*. Several species (6) including *L. alata*, *N. Diderrichii*, *J. pellegriniana*, *B. mildbreadii*, *P. Soyauxii* and *E. Ivorense*, were affected by excessive purge of rot.

Figure 4 shows that the three main species with higher timber losses were *J. pellegriniana* (306.726 m³); *B. mildbreadii* (85.394 m³) and *L. alata* with (61.501 m³). The species with less losses included *E. cylindricum* (1.116 m³); *N. diderrichii* (13.552 m³) and *A. pachyloba* (29.752 m³).

Figure 5 shows that *J. pellegriniana* was the specie concerned by the entire seventeen loss causes in the forest parks. It was also the only specie concerned by bad cutting and excessive purge of melot; followed by *L. alata*, concerned by 12 loss causes; *B. Mildbreadii* by ten; *P. soyauxii* by nine and *N. diderrichii* by eight.

Figure 6 shows that the two main species with greater losses were *J. pellegriniana* (277.29 m³) and *L. alata* (151.202 m³). Species with less losses were *C. gabonensis* (7.87 m³); followed by *A. pachyloba* (7.56 m³) and *E. ivorense* (14.32 m³).

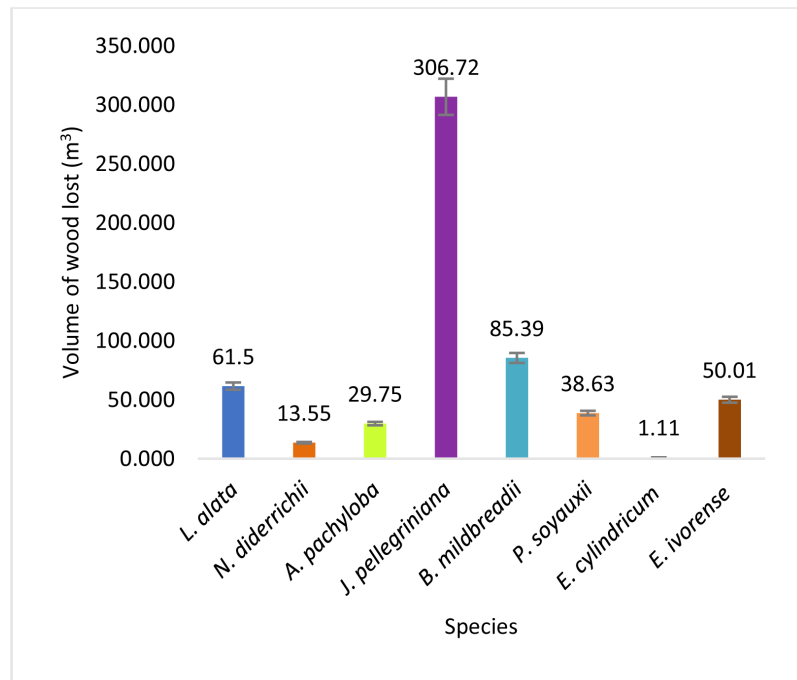


Figure 4. Total volumes of timber loss by species at the skidding sites within the study period.

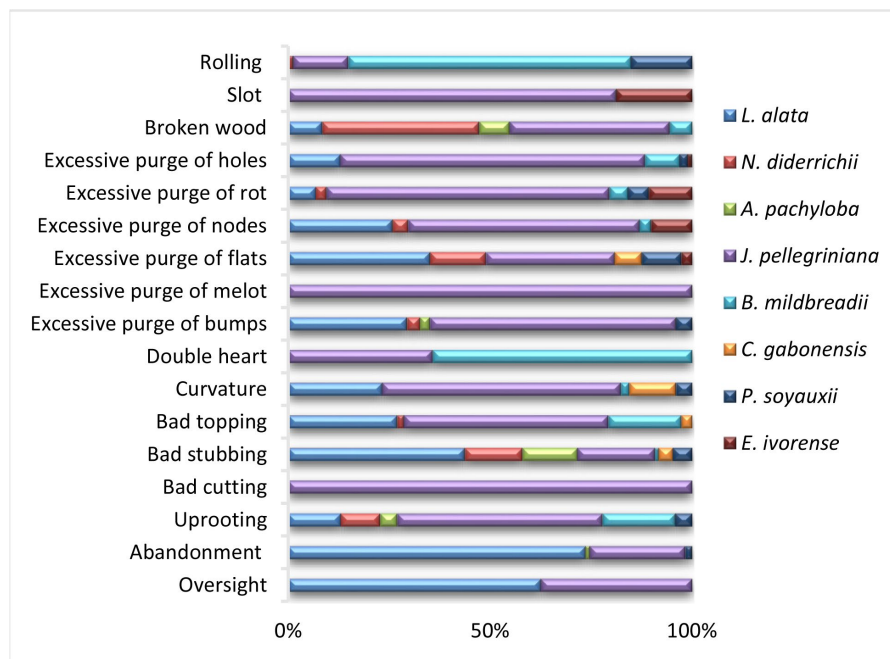


Figure 5. Loss causes at the forest parks within the study period.

Figure 3 and **Figure 5** show that *J. pellegriniana* was the species concerned by all the seventeen loss causes in the entire production chain. It was also the only species concerned by bad cutting, followed by *L. alata* concerned by twelve loss causes; *B. mildbreadii* by ten; *P. soyauxii* by nine and *N. diderrichii* by eight. Slot and bad topping were the only loss causes that affected *E. cylindricum*.

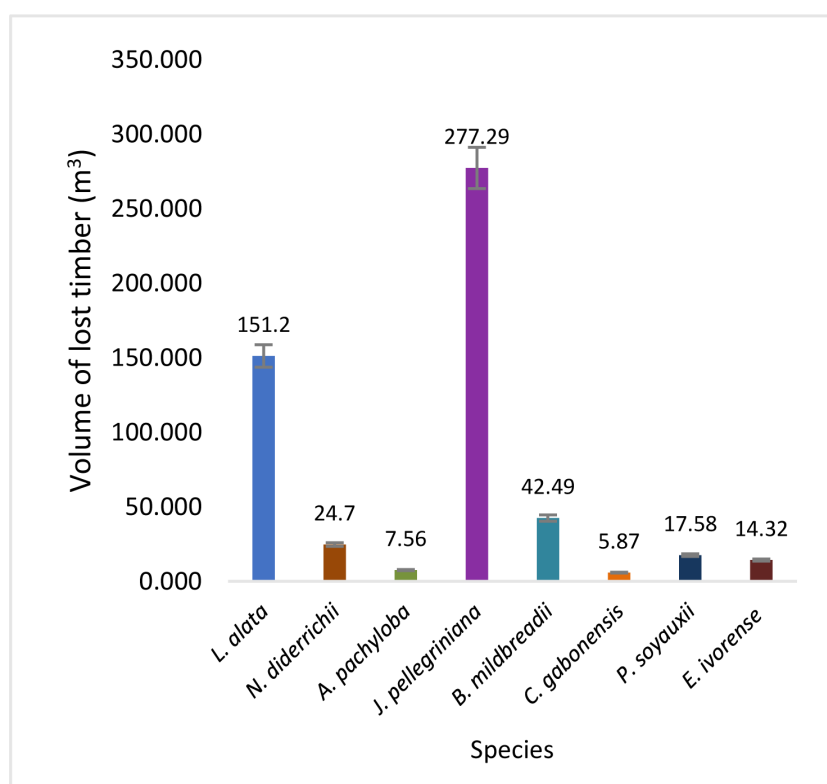


Figure 6. Total volumes of timber losses for species at the forest parks within the study period.

Table 3. Timber loss rate per species (in m³).

Species	FTV (a)	TLV (m ³) (b)	FVE (m ³) (c = a - b)	LR (%) (b/a) × 100
<i>Lophira alata</i>	741.28	212.7	528.58	28.69
<i>Nauclea diderrichii</i>	285.58	38.25	247.33	13.39
<i>Azelia pachyloba</i>	142.13	37.31	104.82	26.1
<i>Julbernardia pellegriniana</i>	1751.52	584.01	1167.51	33.34
<i>Brachystegia mildbreadii</i>	528.98	127.88	401.10	24.17
<i>Cyclicodiscus gabonensis</i>	23.91	5.87	18.04	24.55
<i>Pterocarpus soyauxii</i>	142.81	56.21	86.60	39.35
<i>Entandrophagma cylindricum</i>	20.87	1.11	19.76	05.31
<i>Erythrophleum ivorense</i>	126.18	64.33	61.85	50.98
Total	3763.26	1127.67	2635.59	29.96

FTV = Felled Tree Volume; TLV = Total Loss Volume within the study period; FVE = Final Volume for Exportation during the study period; LR = Loss Rate.

The data obtained over the two-month period of this study permitted to estimate the loss rate of timber loss. **Table 3** shows that 6 of the nine species studied recorded high annual estimated loss rates, including *E. ivorense* (50.98%), *P. soy-*

auxii (39.35%), *J. pellegriniana* (33.34%), *L. alata* (28.69%), *A. pachyloba* (9.64%), *C. gabonensis* (24.55%) and *B. mildbreadii* (24.17%). *N. diderrichii* (13.39%) and *E. cylindricum* (5.31) recorded the lowest loss rates.

It appears that more than 50% of the species are concerned by loss volume above 50 m³; the higher the number of trees felled, the greater the losses in volume of wood. And the final volume for exportation was reduced by 29.69% from felled tree volume (3763.26 m³) (Figure 7).

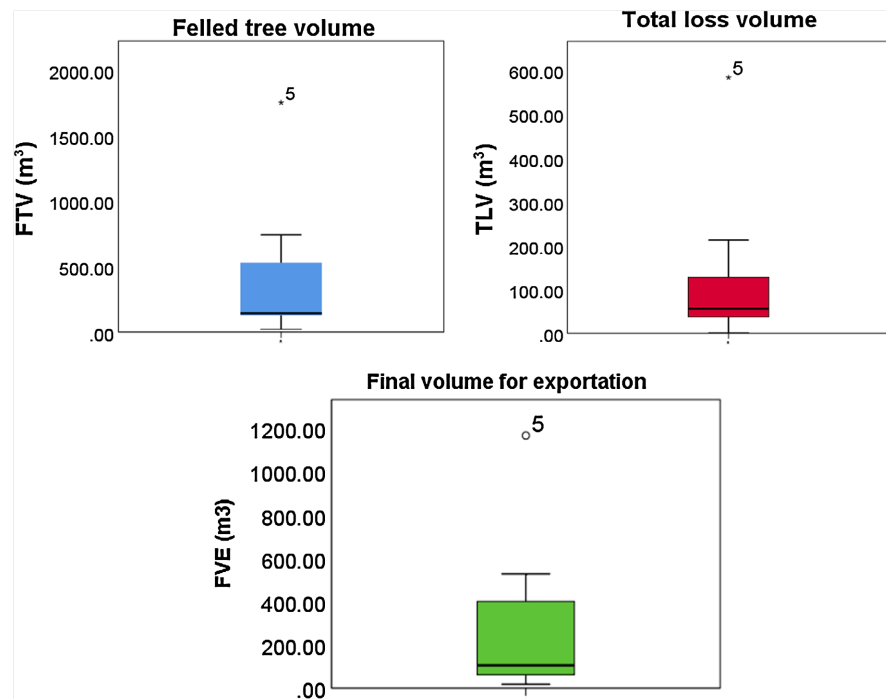


Figure 7. Box plots showing the variation in total felled tree volume, total loss volume of timber and final volume for exportation, within the study period.

Concerning the loss volume per loss sources and causes, Table 4 gives the total loss at the skidding sites, the forest parks and throughout the entire production chain. It shows that globally throughout the production chain, 1127.67 m³ of loss were recorded. The most important loss source with the highest loss (566.39 m³) was wood defects. The four main loss causes were abandonment (231.7³ m³); excessive purge of holes (193.47 m³) and excessive purge of rot (136.44 m³). The causes of less loss were bad cutting (0.34 m³); excessive purge of melot (6.64 m³), double heart (7.19 m³) and slot (9.2³ m³).

In the skidding sites, a total timber loss of 586.36 m³ was recorded. There were five main loss causes, namely in order of importance: abandonment (160.06 m³); oversight (117.87 m³); excessive purge of holes (111.71 m³); excessive purge of rot (98.76 m³); rolling (50.82 m³) and broken wood (27.36 m³). The others are responsible for very little loss of less than 7 m³.

Concerning the forest parks, a total timber loss of 540.95 m³ was recorded. Four main loss causes were identified, including in order of importance, excessive purge

of bumps (87.88 m³); excessive purge of holes (81.76 m³); excessive purge of nodes (73.44 m³) and abandonment (71.67 m³). Excessive purge of melot (0.5³ m³) and bat cutting (0.35 m³) were less responsible for timber loss.

Table 4. Volume of lost timber by loss source in m³.

Sources of timber losses	Causes of timber loss	TVL (SK)	TVL (FP)	TVL in 2 months (study period)	Proportion
Poor work planning	Oversight	117.87	16.56	134.44	11.92
	Abandonment	160.06	71.67	231.73	20.54
Unqualified personnel	Uprooting	2.33	29.71	32.34	2.86
	Bad cutting		0.34	0.34	0.03
	Bad stubbing	1.44	12.14	13.58	1.20
	Bad topping	1.68	10.91	12.59	1.11
			165.51	124.77	290.58
Wood defects	Curvature	4.022	29.34	33.36	2.97
	Double heart		7.19	7.19	0.63
	Excessive purge of bumps		87.87	87.87	7.79
	Excessive purge of melot	6.11	0.53	6.64	0.58
	Excessive purge of flats		26.40	26.40	2034
	Excessive purge of nodes	1.58	73.44	75.02	6.65
	Excessive purge of rot	98.76	37.68	136.44	12.09
	Excessive purge of holes	111.71	81.76	193.47	17.15
		222.18	344.21	566.39	50.22
Inadequate equipment and methods	Broken wood	27.36	23.67	51.03	4.52
	Slot/crack	2.62	6.61	9.23	0.81
	Rolling	50.82	25.15	75.97	6.73
		80.8	55.43	136.23	12.08
Total		586.36 (15.58%)	540.95 (14.37%)	1127.67 (29.96%)	100

TVL = Total Volume Lost; SK = Skidding Sites; FP = Forest Parks.

3.1.3. Volume of Lost Timber Related to Responsible Personnel

The interviews with responsible personnel permitted to evaluate their implication in timber losses. **Table 5** shows that a total loss of 587.86 m³ was recorded at the skidding sites. Prospectors (382.24 m³) and fellers (176.24 m³) recorded the highest volume of timber loss. The skidding stevedores (25.06 m³) and the forest buckers (3.02 m³) made less losses.

At the forest park, a total loss of 540.95 m³ was recorded. The preparation cubers (326.97 m³) and prospectors (71.23 m³) recorded the highest volume. The losses

Table 5. Volume of lost timber (in m³) at the skidding sites and forest parks related to responsible personnel.

Responsible personnel	Causes of wood loss	VLT _{SK}	VLT _{FP}	TVLT/RP
Prospectors	Abandonment (non-consideration of accidental area)	160.06	18.88	
	Non-detection of melot	6.11		
	Non-detection of holes	111.71	49.87	471.41
	Non-detection of rot	98.76	20.48	
	Non-detection of nodes	1.58		
	Non-detection of curvature	4.02		
		382.24	89.23	
Fellers	Rolling	50.82	25.15	
	Uprooting	2.63		
	Responsible for broken wood	27.36	23.67	231.67
	Oversight	92.81		
	Causes slot/crack	2.62	6.61	
		176.24	55.43	
Loggers	Oversight		16.56	16.56
Buckers	Bad topping	1.68	10.91	
	Bad stubbing	1.44	12.14	55.88
	Uprooting		29.71	
		3.12	52.76	
Preparation cubers	Bad cutting		0.34	
	Inability to handle curvature		29.34	
	Excessive purge of bumps		87.87	
	Excessive purge of holes		31.88	
	Excessive purge of nodes		73.44	326.97
	Excessive purge of rot		17.20	
	Excessive purge of flats		26.40	
	Excessive purge of melot		0.53	
	Inability to handle double heart wood		7.19	
Abandonment		52.78		
			326.97	
Stevedores	Oversight	25.06		25.06
Total		586.36	540.95	1127.61

VLT = Volume of Lost Timber; TVLT/RP = Total Volume of Lost Timber per Responsible Personnel.

caused by fellers and buckers were almost the same, respectively 55.43 m³ and 52.76 m³.

Throughout the production chain, prospectors (471.41 m³), preparation cubers (318.8 m³) and fellers (173.6 m³) recorded the highest losses. The stevedores recorded the lowest loss (41.5 m³), with the loggers (55.4 m³) and buckers (69.6 m³).

The proportions of lost volume are given in **Figure 8**. This figure shows that the personnel responsible for the greatest timber losses were prospectors (42%), preparation cubers (28.99%) and fellers (20.54%). Buckers, stevedores and loggers were responsible for less losses with respectively 4.95%, 2.22% and 1.46%.

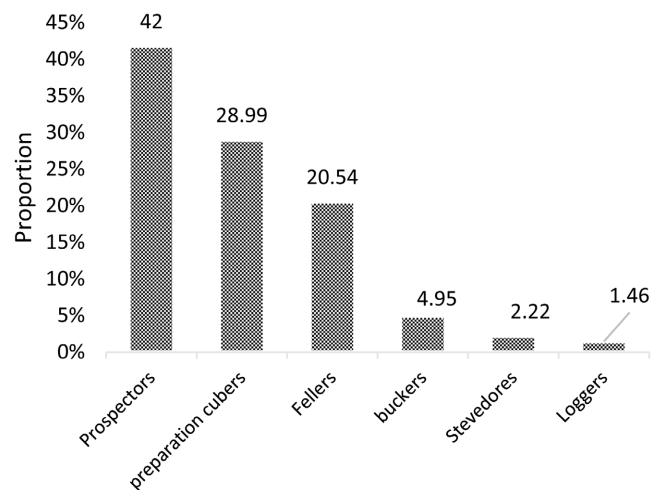


Figure 8. Proportion of timber loss per responsible personnel.

The correlation between loss causes was established in the entire production chain. **Table 6** shows that there is a high positive correlation close to +1 ($r > 0.7$), (p -value < 0.05), between most loss causes, with the exception of the rolling and excessive purge of melot whose correlation is negative with almost all the other causes. The first (rolling), it is positively correlated but weakly with excessive purge of holes ($r = 0.138 < 0.3$) and strongly with double heart ($r = 0.573 > 0.5$), and has no correlation ($r = 0.098 < 0.1$) with uprooting. The second (excessive purge of melot), has a weak correlation with broken wood ($r = 0.150$) and no correlation with abandonment ($r = 0.0 < 0.1$) and bad stubbing ($r = 0.066 < 0.1$).

The double heart is weakly positively correlated with almost all, with the exception of excessive purge of holes ($r = 0.725$), bat topping ($r = 0.543$) and rolling (already mentioned). It is exceptionally negative with bad stubbing ($r = -0.044$).

There is a significant difference between loss causes with $r < 0.695$ (p -value > 0.05).

3.1.4. Monetary Loss at the Skidding Sites, the Forest Parks and throughout the Entire Production Chain

The cost of losses at the skidding sites, the forest parks and throughout the production chain, within the two-month study period and annually, was evaluated

Table 6. Pearson correlation between loss causes.

	Abandonment	Uprooting	Curvature	Double heart	Bad cutting	Slot/crack	Broken wood	Bad stubbing	Bad topping	Oversight	Excessive purge of bumps	Excessive purge of melot	Excessive purge of flats	Excessive purge of nodes	Excessive purge of rot	Excessive purge of hole	Rolling
Abandonment	1	0.832*	0.900*	0.323	0.774*	0.727*	0.558	0.847*	0.937*	0.911*	0.961*	0.000	0.860*	0.935*	0.771*	0.739*	-0.170
Uprooting	-	1	0.889*	0.654	0.913*	0.860*	0.756*	0.505	0.946*	0.902*	0.877*	-0.057	0.613	0.876*	0.891*	0.929*	0.098
Curvature	-	-	1	0.332	0.945*	0.909*	0.663	0.619	0.946*	0.978*	0.970*	-0.117	0.768*	0.957*	0.923*	0.825*	-0.164
Double heart	-	-	-	1	0.397	0.357	0.216	-0.044	0.543	0.345	0.274	-0.146	0.011	0.311	0.378	0.725*	0.573
Bad cutting	-	-	-	-	1	0.984*	0.761*	0.409	0.888*	0.951*	0.894*	-0.038	0.574	0.901*	0.973*	0.872*	-0.120
Slot/crack	-	-	-	-	-	1	0.709*	0.338	0.848*	0.940*	0.856*	-0.075	0.515	0.893*	0.980*	0.873*	-0.174
Broken wood	-	-	-	-	-	-	1	0.448	0.619	0.686*	0.678*	0.150	0.507	0.665	0.722*	0.569	-0.272
Bad stubbing	-	-	-	-	-	-	-	1	0.643	0.619	0.758*	0.066	0.914*	0.695*	0.418	0.313	-0.324
Bad topping	-	-	-	-	-	-	-	-	1	0.952*	0.949*	-0.156	0.747*	0.946*	0.873*	0.895*	-0.035
Oversight	-	-	-	-	-	-	-	-	-	1	0.976*	-0.098	0.752*	0.989*	0.959*	0.870*	-0.188
Excessive purge of bumps	-	-	-	-	-	-	-	-	-	-	1	-0.079	0.857*	0.980*	0.892*	0.782*	-0.188
Excessive purge of melot	-	-	-	-	-	-	-	-	-	-	-	1	-0.258	-0.137	-0.125	-0.160	-0.213
Excessive purge of flats	-	-	-	-	-	-	-	-	-	-	-	-	1	0.814*	0.609	0.460	-0.226
Excessive purge of nodes	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.929*	0.843*	-0.224
Excessive purge of rot	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.897*	-0.094
Excessive purge of hole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.138
Rolling	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

*Significant p-value < 0.05.

Table 7. Economic loss of the logging company (in FCFA and Euro).

Responsible personnel	Causes of wood loss	EL _{SK}	EL _{FP}	TEL (SP)	AEEL (in FCFA and €)	Proportion (%)
Prospectors	Abandonment (accidental area)	16,114,902.85	1,731,699.75	45,700,319.1	274,201,914.6 (418,628.87 €)	41
	Presence of melot	820,511.90				
	Presence of holes	10,396,978.57	4,849,049.07			
	Presence of rot	9,284,681.57	1,953,891.96			
	Presence of nodes	151,652.12				
	Presence of curvature	396,951.29				
Fellers	Rolling	5,088,980.12	2,488,718.5	25,107,323.5	150,643,941 (229,990.74 €)	23
	Uprooting	275,383.36				
	Broken wood	2,831,060.29	2,288,840.83			
	Oversight	11,222,639.71				
	Causes slot/crack	287,732.95	623,967.69			
Loggers	Oversight		1,530,151.19	1,530,151.19	9,180,907.14 (14,016.65 €)	1
Buckers	Bad topping	186,401.25	1,041,990.81	5,464,356.78	32,786,140.68 (50,055.17 €)	5
	Bad stubbing	140,492.56	1,182,635.57			
	Uprooting		2,912,836.59			
Preparation cubers	Bad cutting		34,444.55	30,928,973.2	185573839.2 (283318.83 €)	28
	Inability to handle curvature		2,784,284.47			
	Excessive purge of bumps		8,467,558.71			
	Excessive purge of holes		3,098,908.76			
	Excessive purge of nodes		6,857,082.55			
	Excessive purge of rot		1,641,125.43			
	Excessive purge of flats		2,442,539.23			
	Excessive purge of melot		52,604.44			
	Presence of double heart		710,209.22			
Abandonment		4,840,215.80				
Stevedores	Oversight	2,385,933.21		2,385,933.21	14,315,599.26 (21,855.87 €)	2
Total		59,584,301.8 (86,388.24 €)	51,532,755.1 (78,675.96 €)	111,117,057 (169,644.36 €)	666,702,342 (1,017,866.17 €)	100

ELSK = Economic Loss at the Skidding Site; ELFP = Economic Loss at the Forest Park; TEL (SP) = Total Economic Loss for the study period; AEEL = Annual Estimated Economic Loss.

by loss sources and loss causes as presented in **Table 7**. The later shows that a total of 59,584,301.8 CFA francs (86,388.24 €) was recorded at the skidding sites during the time period of the study. The causes of timber losses with the highest monetary losses were abandonment with 16,114,902.85 CFA francs (24,602.9 €), followed by oversight with 13,608,572.92 CFA francs (20,776.44 €), the presence of holes with 10,396,978.57 CFA francs (15,873.24 €) and presence of rot with 9,284,681.57 CFA francs (14,175.08 €). The least costly loss cause was bad stubbing with 140,492.56 CFA francs (214.49 €).

A total of 51,532,755.1 CFA francs (78,675.96 €) was recorded at the forest parks during the time period of the study. The main loss causes included the excessive purge of bumps (8,467,558.71 CFA francs = 12,927.57 €), the excessive purge of nodes (6,857,082.55 CFA francs = 10,468.82 €), abandonment (6,571,915.55 CFA francs = 10,033.45 €) and the presence of holes (4,849,049.07 CFA francs = 7403.12 €). The lowest economic losses were mainly due to the bad cutting (34,444.55 CFA francs = 52.58 €) and excessive purge of melot (52,604.44 CFA francs = 80.31 €).

The study recorded a total of 111,117,057 CFA francs (169,644.36 €) throughout the production chain during the time period of the study. The responsible personnel with the highest economic losses included prospectors (45,700,319.1 CFA francs = 69,771.47 €), preparation cubers (30,928,973.2 CFA francs = 47,219.80 €) and fellers (25,107,323.5 CFA francs = 38,331.79 €). Loggers (1,530,151.19 CFA francs = 2336.10 €), stevedores (2,385,933.21 CFA francs = 3642.64 €) and buckers (5,464,356.78 CFA francs = 8342.52 €) recorded the lowest economic losses.

The corresponding proportions were in order of importance prospectors (41%), preparation cubers (28%) and fellers (23%). Buckers, stevedores and loggers were responsible for less losses with respectively 5%, 2% and 1%. A total economic loss of 666,702,342 CFA francs (1,017,866.17 €) was annually estimated in the company.

3.2. Discussion

Timber loss sources and causes

The findings from this study show that four sources of timber loss were identified in the annual cutting plate 1.1 of the 07-004 unit, including in order of importance wood defects, unqualified personnel or less-skilled manpower, inadequate equipment and methods (Conventional logging CL) and poor work planning. The position of wood defect as the primary timber loss source in this study is in accordance with [Awasthi et al. \(2020\)](#), who mentioned that wood defect is the primary loss cause of the most commercial specie in Deurali community forest in Nepal. But is it different to the study of [Aryal et al. \(2022\)](#) in which the major causes of losses occurring in all of the three harvesting stages (felling, bucking, and sawing) of *Shorea robusta* were the use of inappropriate equipment. This is the fact that the two first major loss sources in this study are related (the second contributing to the importance

of the first), given that the personnel responsible for identifying defects on standing trees before cutting are les prospectors and fellers (both responsible of 62.54% of loss), who were less-skilled and unable to detect defects and neglecting the ergonomic conditions; and the preparation cubers (with 28.99%), unable to handle some defects or doing excessive purge of others (rot, nodes, holes, bumps, flats ...). According to Bowyer (1997), a high amount of the harvest volume (7 m³/ha) can be left behind in tropical forest after logging because skidder operators could not locate the logs.

Observations on the field showed that the methods used in this logging unit are still of CL which according to Boltz et al. (2003), are methods including unplanned, merchantable harvest of size stems, felled by fellers and transported by tractors or skid by skidders to depot; instead of Reduced Impact Logging (RIL) which is gaining more attention in recent decades due to unplanned logging practices, safety concern of less workers, and higher timber and regeneration loss (Putz et al., 2008). According to the study of Le et al. (2013), in Vietnam, conventional logging has some problems such as insufficient and unspecific mitigations of negative impacts; in-proper attention on exclusion areas; no development of proper logging evaluation of harvesting operations and its impacts; lack of well-trained workers; use of inappropriate machineries improper attention on harvesting monitoring; low rate of tops and branches utilization; and sketchy implementation of post-harvesting activities.

Concerning planning, it was noted in this study as mentioned by Jonkers et al. (2001) in the Tropenbos-Cameroon Programme in the same Rain-forest condition in the south Littoral region in Cameroon that, the planning was mostly executed at forest-camp level and is pretty much a straightforward calculation of the machines and personnel needed, based on the commercial composition of the forest (number and volume of tree to be cut per species).

The four above-mentioned loss sources induced seventeen direct loss causes, all identified at the forest park of which thirteen identified at the skidding site, with the most frequent at the skidding sites being abandonment (24.55%), oversight (18.18%), the presence of rot (11.82%) and the presence of holes (10.91%). These attest the impact of CL and the unskilled of less-skilled manpower, who are cheaper personnel usually preferred by some logging companies or imposed by local authorities to others who accept with no choice to avoid conflicts. And thus, savage harvesting practice is being observed. According to Vanderberg cited in Awasthi (2002), savage harvesting practice is the leading cause of high log damage during forest tree harvesting. The personnel related to these loss causes were prospectors and fellers responsible for higher losses (respectively 382.24 m³ and 176.24 m³) at the skidding sites. This is the fact of the above-mentioned reason. The main loss causes at the forest park were excessive purge of defects (43.6%), uprooting (16.17%) and abandonment (10.48%). Here, the preparation cubers were responsible for that with a high timber loss of 326.97 m³, due to the above-mentioned reason and also the fact that they were sometimes unable to handle the high amount of timber with defects

arriving from the forest because of the poor work of less-skilled prospectors and careless fellers. Thus, there is a strong positive Pearson correlation, close to 1 (p -value < 0.05), among most causes of loss, with the exception of rolling and excessive melot purging, which is negatively (but poorly) correlated with almost all other causes. In addition, these personnels later also work on a contract basis and are paid per felled stem. These payments are not based on indicators for the quality of their work such as the volume recovered per tree harvested.

Lost timber volume

The high loss (586.36 m³) recorded at the skidding sites is in accordance with [McKeever \(2004\)](#) who also mentioned that a high amount of timber loss occurs during timber extraction, including tree felling in forest. It is the same observation as [Delvingt \(1994\)](#), who mentioned that up to 30% of the logs are abandoned in the forest for technological reasons (not compliant) or by omission, in the ECOFAC project around the Dja reserve in the eastern Cameroon. According to [Jonkers et al. \(2001\)](#) in the Tropenbos-Cameroon Programme in the same Rain-forest condition in the south Littoral region in Cameroon, about 20% of the skidding damage could have been avoided, and was caused by:

- Rain and unstable, water saturated ground conditions. Skidding continues in bad weather until the output is almost zero.
- Lack of supervision. Machine operators can set their own standards of work. As long as they produce enough logs, their supervisors remain on the landing and inspect only logs that reach there.
- Lack of environmental awareness among operators and supervisors. Few operators see a need for damage reduction, and most feel that the forest will recover anyway.

A lesser rate (15.58%) was observed at the skidding sites in this study, and may be due to the relatively short period of data collection. The loss rate of 14.37% of felled trees observed at the forest parks, is less than what observed [Forni \(1994\)](#) in the sale cutting plate 1112 and 1179 in Dimako, eastern Cameroon were about 25% of the volume cut was abandoned on park, all species. These lesser rates observed in this study could be the due to short data collection period. Interview with some staff highlighted the fact that another loss source is the log dimensions imposed by buyers. Furthermore, at landings, another loss occurred, mainly due to cutting off both log ends to give the timber a better appearance ([Jonkers & van Leersum, 2000](#)). According to [Agom \(1994\)](#) in Nigeria, a large amount of useful wood is left in the forest because of the adherence of the dealers and buyers to specific flitch dimensions.

More than 50% of the species were concerned by loss of volume above 50 m³; the higher the number of trees felled, the greater the losses in volume of wood. The total rate obtained in this study (29.69%) is near to that obtained by [Eshun \(2000\)](#) in Ghana and different from what has been observed in similar climatic areas where more variations in tree harvesting loss rate can be seen ([Table 8](#)). But these results could have been minimized given the small sampling rate (1%) due to the short period of data collection and the difficulty of access to certain sites. But the daily

reports of the company including the yield, were consulted to consolidate the collected data. It is quite conceivable that the losses will be slightly higher if this sampling rate is increased.

Table 8. Tree harvesting loss rate in similar studies.

Study area	Loss rate	Authors
Nepal	19.8% (left over)	Poudyal et al. (2019)
Nepal	27%	Meilby et al. (2014)
Gabon	25%	Carlson et al. (2017)
Ghana	30%	Eshun (2000)
Latin America	44%	Poudyal et al. (2019)
Africa	46%	Poudyal et al. (2019)
Sarawak Malaysia	46%	Poudyal et al. (2019)
Australia	47.20%	Poudyal et al. (2019)
Asia	50% (1:1 ratio)	Butarbutar et al. (2016)
STropical Region (Avg.)	50%	Poudyal et al. (2019)
Asia-Pacific	54%	Poudyal et al. (2019)
The Philippines	60%	Lasco et al. (2006)
Brazilian Amazon	66% (1:2 ratio)	Numazawa et al. (2017)
Terai <i>Horea robusta</i> Forest, Nepal	21.59%	Aryal et al. (2022)
Littoral, Cameron Rain Forest	29.69%	This study

All authors cited in [Aryal et al. \(2022\)](#).

The loss of 540.95 m³ corresponding to 14.37% of felled trees, observe at the forest parks, is less than what observed [Forni \(1994\)](#) in the sale cutting plate 1112 and 1179 in Dimako, eastern Cameroon were about 25% of the volume cut was abandoned on park, all species.

The total loss volume (1127.67 m³) observed in this study is closed to that (1278.129 m³) obtained by “*La Côtère Forestière et Industrielle de la Doumé (SFID)*” in its forest management unit 10-065 in the Integrated Pilot Development Project (IPDP) of Dimako in the East region, mentioned by [CIRAD \(1998\)](#). This may be the fact that the CSIWE and SFID are both using CL practices. On the other hand, the Rougier group at its Djoum site in southern Cameroon, estimated a total volume loss of 603.729 m³ throughout the production chain, and this is because the group has a very experienced team and uses work procedures that take into account RIL standards.

Monetary loss

The study recorded a total of 111,117,057 CFA francs (169,644.36 €) throughout the production chain during the time period of the study. An estimated annual economic loss of 666,702,342 CFA francs (1,017,866.17 €). Prospectors (41%), preparation cubers (28%) and fellers (23%) are the personnel responsible for the highest economic loss. And it is the fact of the quality of the loss. According to Gillian (2013), the quality loss in log leads to monetary loss of the timber. It is a matching logic with our research findings, as the most concerned loss were whole stems with defects or good ones felled in accidental areas, abandoned in the skidding sites after felling. The loss rate of 29.69% is close to that observed by Sah et al. (2004) who stated that the timber loss and its monetary value was about 30% less in total. Another study of Vanderberg cited in Awasthi et al. (2020) shows that 10% - 15% timber losses were caused by defects at felling sites which ultimately result to monetary loss (Lowell et al., 2010; Nordmark, 2005). Furthermore, study done by Donovan and Nicholls (2003) stated that defects resulted to affect diameter, length, width and thickness of the log, which were the chain effect to reduce the overall timber quality and quantity.

4. Conclusion

The study permitted to identify and highlight the main sources of timber loss in the logging company applying in the annual cutting plate 1.1 of the 07-004 unit in the dense rain forest in Cameroon. This loss of timber is due to the use of conventional logging methods by the company. The loss sources include poor work planning, unqualified personnel, wood defects and inadequate equipment and methods. Considered as indirect, these loss sources induced seventeen direct causes of timber losses, with uprooting and excessive purge of bumps being the most frequent at the skidding sites and abandonment and oversight the most frequent at forest parks. There is a strong positive correlation between most of these loss causes, with the exception of the rolling and the excessive purging of melot, whose correlation is negative with almost all others. So, the null hypothesis fixed in this study is rejected. For the target species, more than 50% of them were concerned by loss of volume above 50 m³. It was noted that the higher the number of trees felled, the greater the losses in volume of wood. *Julbernardia pellegriniana* recorded the highest loss volumes during harvest and shaping. A high volume (1127.61 m³) of timber losses was recorded, corresponding to a considerable monetary loss of 111,117,057 FCFA (169,644.36 €), for an estimated annual loss of 666,702,342 FCFA (1,017,866.17 €). These results could have been minimized given the small sampling rate (1%) due to the short period of data collection and the difficulty of access to certain sites. It is quite conceivable that the losses could be slightly higher if this sampling rate is increased. In any way, limiting timber losses could reduce harvested forest areas while increasing yield and monetary benefits. This could be effective by the use of the RIL methods, and also if monitoring and capac-

ity-building processes are undertaken by both logging companies and the forest administration.

5. Recommendations

Interviews with staff and field laborers highlighted some strategic points of “*close-to-best practice*” (Table 9), which could be implemented to reduce timber and monetary losses.

Table 9. Somme strategical points to implement to reduce losses.

Strategic points	Activities	Indicators	Responsible staff
Better planning of field work	Reorganization of work teams	Integration of a management and planning unit	Manager/Chief Operating Officer
	Development of strict work instructions	Manual of Procedures and work Instructions	
The setting up of qualified teams	Training/capacity building of staff and laborers on RIL techniques	Training/capacity-building certificate, Improvement of volume and monetary yields	Accredited RIL Training Organization
Better communication and reporting	Organization of real-time communication platforms, Intensification of communication between forest operations	Information available in real time, between office and forest camp	Site Manager/Chief Operating Officer
Monitoring and evaluation of operations	Ongoing control of field operations	Compliance with work instructions	Site Manager/Chief Operating Officer
Implementation of a system for recovering abandoned wood in the forest and waste wood in landings	Sawing boards for the local market or recovery of defects wood and abandoned by local populations for fuelwood	Planks/fuelwood	Partners
	Alternative energy production to fossil fuels, from logs with defects abandoned in forest and wood waste in forest parks	Ecological source of energy	

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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