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Wood Energy as a Primary Livelihood Source and Its Impact on Forest Cover Management in the Hinterlands of Kindu and Kailo Territory, Maniema Province, DR Congo

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ABSTRACT

The present study assesses the production of wood energy as well as its socioeconomic and environmental impact in the hinterlands of the city of Kindu and the territory of Kailo, Maniema Province, DR Congo. The research employed a survey-based methodology, using Kobocollect to conduct a census of the study population. The findings identified 11 tree species exploited for wood energy, with five species—*Cynometra alexandri*, *Gilbertiodendron dewevrei*, *Xylopia aethiopica*, *Uapaca* sp. and *Acacia* sp.—being the most preferred by charcoal producers and firewood harvesters.

A total of 33920 trees are felled monthly across the two wood energy exploitation sites, averaging 18.8 stems per operator. The monthly quantities of charcoal (embers) and firewood are 2323,3 tonnes and 3369 m^3 respectively, with an average of 2.1 tonnes and 4.8 m^3.

Profit margins are proportional to the volume of production. For charcoal, profits range from 95000 FC to 1 064982,00 FC, with an average of 473915,17 FC. For firewood, profits range from 24900 FC to 99270 FC, with an average of 64476,25 FC. Financial profitability is positive for all charcoal operators and even exceeds 100% for firewood operators (700). These results indicate that wood energy production is economically viable and presents a profitable livelihood activity in the study area.

Keywords: wood energy, income, city of Kindu, Kailo territory, forest cover

INTRODUCTION

The issue of domestic energy remains a major concern worldwide, particularly in developing countries where the majority of the population uses charcoal, firewood and agricultural residues to meet their cooking needs.

Previous works are numerous, however we can cite some: Kamleu et al. (2002), Mbengele et al. (2002), Binzangi (2004), Bikumu (2005), Mbala (2007), Nazindigouba (2008), Tshimpanga (2009), Schure & Hunhyet (2014), Mbuangi (2022), Tagirabo (2023). All these researchers, each in their own country, were able to address one or the other aspect of wood energy. Most of their results were almost similar. The population of the third world mainly uses wood energy (charcoal and firewood).

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Taking into account United Nations estimates, we see that Africa is the continent whose population is growing the fastest with a rate of 2.9% per year between 1990 and 1995, compared to 1.7% for the world as a whole and 2.0% for developing countries (Gubry et al., 1994).

In the absence of the use of renewable energy sources, or even sufficient electricity, the long-term danger posed by this rapid population growth rate is that of the threat to the environment, through, among other things, the consumption of charcoal. According to Cleaver and Scheiber (1994), the heavy dependence on wood fuels, exacerbated by rapid population growth, has contributed to intensifying the pressure on natural resources.

The Democratic Republic of Congo is ranked among the African nations with the greatest potential for "clean" energy, primarily hydroelectric. Its potential is such that it could meet its own needs as well as those of all its neighbors. Paradoxically, domestic access to electricity in the DRC is estimated at around 5%, which is one of the lowest levels in the world (Aveling et al., 2004).

Maniema Province is one of the most important forest areas at the national, regional, and international levels for regulating the global climate. Vegetation maps currently still show large areas of primary forest, but also an increasing and alarming rate of deforestation and an increase in degraded forest areas (Global Forest Watch 2021). This deforestation is mainly concentrated around urban centers, such as Kindu) and along transport routes (roads, rivers) and is due to unsustainable agriculture (slash-and-burn agriculture) and a growing demand for charcoal and firewood (IUCN, 2022).

Firewood and charcoal are the main sources of cooking energy in Maniema province, where the forest provides this supply. In rural areas, firewood is the most common fuel, while in urban consumption centers and outskirts, charcoal is the most widely used. It is the most widely used fuel because it is economically the most accessible fuel for the population due to the absence, ignorance, and high price of other alternatives (IUCN, op. cit.).

It should be noted that currently, the state forestry administration does not have statistical data on the exploitation of wood energy at the provincial or territorial level, much less on the actors (producers or operators). In addition to these aspects, the exploitation sites of these products are not at all known by geolocation (Provincial Division of the Environment and Sustainable Development, abbreviated as DPEDD, 2022).

It is in this context that this study considered collecting data and information related to wood energy, in order to overcome the challenge of managing forest cover by promoting ecosystem services and seeking to highlight a model of sustainable and integrated management of wood energy resources, through the implementation, either through the practice of Agroforestry or Agroecology by farmers and establishing assisted regeneration techniques in the areas under study.

STUDY ENVIRONMENT, MATERIALS AND METHODS

Study Environment

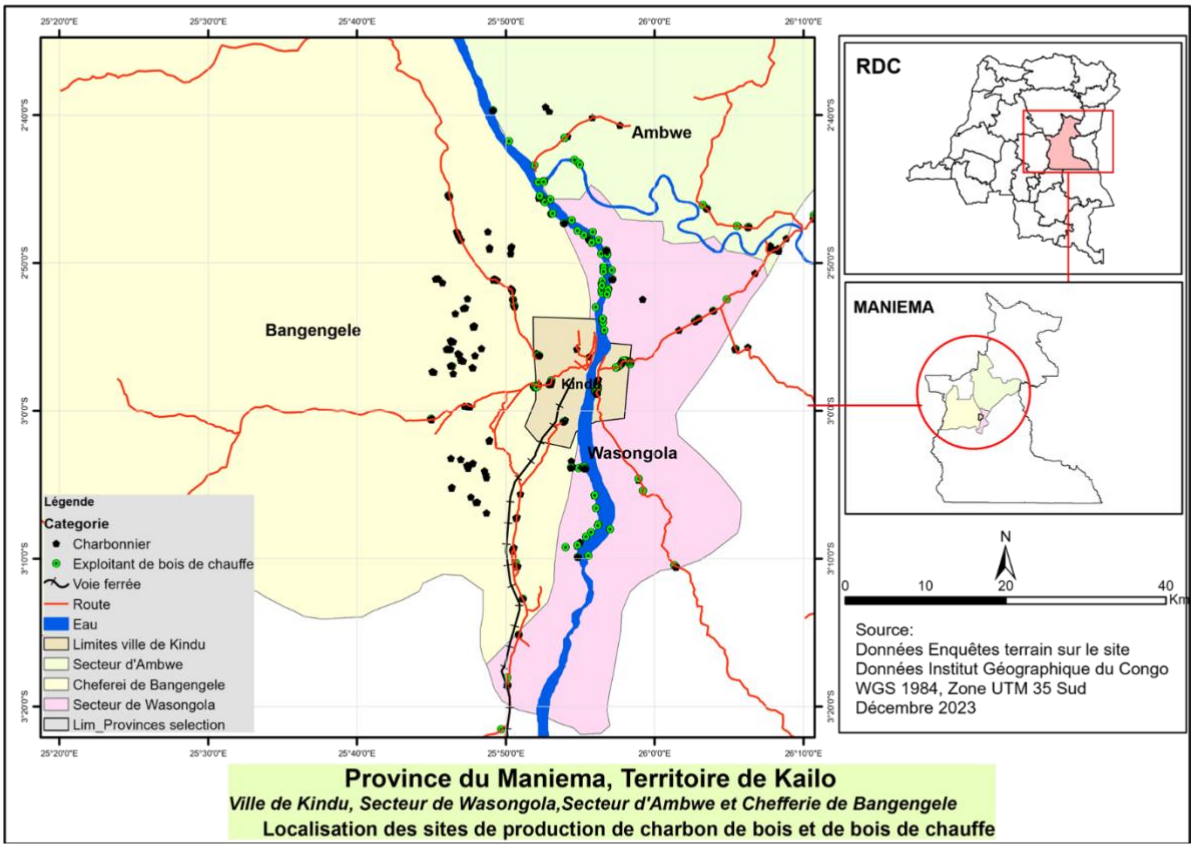

Figure 1. Location of the wood energy study area (Source: Field Survey 2023)

Materials

To achieve the objectives assigned for carrying out this research, we set ourselves the task of using two types of materials: biological and technical.

Biological Material

The biological material we used in this work is wood energy (charcoal and firewood) used in carbonization and firewood.

Technical Materials

Regarding technical equipment that contributed to the realization of this study, these include: smartphones for collecting data in the field through the Kobocollect software, QGis or ArcQGis for the production of vegetation maps and production site maps; the software maintenance guide (incorporated into the software); weighing in kg, machete, etc.

Working Methods

Pre-investigations

To select the village to be studied, a preliminary study was carried out to evaluate the different activities of collecting species for carbonization and firewood in the area under study. This pre-survey was organized among each target group under study.

We conducted an exploratory visit to each site across the various territories and hinterlands of the city of Kindu. This visit allowed us to locate the locations or areas of wood-energy exploitation and to guide the interview guide and determine the axes to be covered during data collection.

During this descent, we had to take measurements for certain variables such as: quantity of charcoal (embers) in kg contained in the bag and quantity of firewood in stere. This methodological approach was based on ecological and economic aspects to be able to evaluate its positive or negative impact, as well as the number of trees felled by operators;

The units used for measuring charcoal and firewood are respectively: the bag with an average weight of 56.2 kg and the stere which is equivalent to one cubic meter of firewood (1 m^3).

Surveys themselves

The field survey was carried out for one month (October 2023) where we followed the charcoal and firewood exploitation activities in 2 sites starting from the hinterlands of the city of Kindu and the territory of Kailo. A questionnaire or interview guide was submitted to the various ember manufacturers and / or firewood operators and this to allow us to acquire the realities of the environment on the aforementioned exploitation.

We had to use the entire study population producing wood energy (charcoal and/or firewood, which amounts to 1798 male/female respondents combined in the two sites including the territory of Kailo, plus the hinterland of the town of Kindu).

Table 1 gives the distribution of respondents by site and by axis.

Table 1. Distribution of respondents by site and by axis in the hinterland of the town of Kindu and the territory of Kailo

Site 1 Kindu Hinterland							Site 2 Kailo Territory			
RD	PK9	Shenge	AMF	AVF	Lwama	**Total**	Ambwe	Bangengele	Wasongola	**Total**
264	33	237	18	18	194	**764**	89	443	502	**1034**

The territory of Kailo has a large number of respondents; 1034 compared to the hinterland of the city of Kindu with 764 respondents, and the two sites together have 1798 respondents who are wood energy users.

The following variables were retained: list of species, number of tree bases felled, quantities of embers or firewood produced, cost price and financial profitability, profit margin and environmental impacts.

Statistical analyses

Statistical analysis was used to determine certain position parameters (percentage or effective), for relative frequencies, sum or averages. We used Excel software for the calculation and creation of the tables presented in this manuscript; for the calculation of Kh2, t-student and pv, we used R software.

PRESENTATION OF RESULTS AND DISCUSSION

This presentation focuses on the following variables: the list of species; number of tree bases felled, the quantity of charcoal and firewood produced, the cost price, the profit margin and the financial profitability.

List of Species Used for Wood Energy in the Hinterland of the Town of Kindu and the Kailo Territory (Sectors: Ambwe, Wsongola and Bangengele chiefdom)

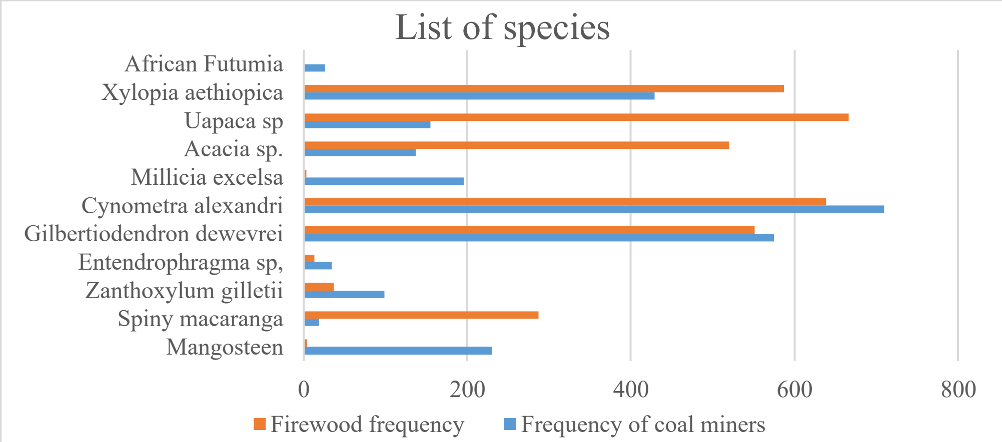

Figure 2. List of species used for wood energy

Cynometra alexandrii, Gilbertiodendron dewevrei and *Xylopia aethiopica*, followed by *Uapaca* sp. and *Acacia* sp., are the 5 species most preferred by producers under consumer demand in this work (Figure 3); This preference would be due to their dendroenergetic characteristics that consumers appreciate at the household level.

These results are similar to those of Tagirabo (2023), in Bunia who found that *Cynometra alexandrii* as well as *Gilbertiodendron dewevrei*, are among the species highly prized for carbonization in this region of the Republic; the only difference is that, depending on the phytogeographic regions, Maniema would regulate this population of species more than Bunia.

Also, Tshimpanga (2009), in his study in Kisangani, states that: Among all the species exploited, *Gilbertiodendron dewevrei* (Limbali) in commercial name occupies the first position, i.e. 65%; followed by *Cynometra sessiliflora* (Botuna) with 50% and finally, the last place goes to *Uapaca guineensis* with 5% of the entire production. These results partly confirm our first specific hypothesis of the postulate. For their dendroenergetic qualities, several species are exploited for wood energy in the hinterland of the town of Kindu and in the territory of Kailo.

Number of Trees Felled per Month by Wood Energy Operators

Table 2 provides information on the number of stems felled monthly by farmers in the hinterland of the town of Kindu and the territory of Kailo.

Table 2. Number of stems felled monthly by operators

	Site 1. Kindu Hinterland								Site 2. Kailo Territory						
Category	RD	pK9	Sh	AMF	avf	lM	**NTE**	**ETA**	aM	bAn	wS	NTE	ETA	Kh2	**pv**
≤ 10	14	14	8	5	6	2	**49**	**490**	70	343	375	**788**	**7880**	**16299.1**	**2.2e_16**
≤ 20	48	0	55	3	3	56	**165**	**3300**	12	78	75	**165**	**3300**	-	-
≤ 30	202	19	174	10	9	136	**550**	**16500**	7	22	52	**81**	**2430**	-	-
Total	264	33	237	18	18	194	**764**	**20290**	89	443	502	**1034**	**13610**	-	-

Legend: ETA: number of felled stems, NTE: total number surveyed. Category ≤10 stems ≤= 20 stems and≤30 stems, rD: right bank, pk9: kilometer point 9 rail, sh: shenge, aM F: upstream of the river, avF: downstream of the river, lM: lwama, aM: ambwe, bAN: bangengele, Ws: wasongola.

In Table 2 above, the total number of felled stems is 33,920 of all categories with an average of 19 stems per person per month. For both sites, the difference between the felled trees is significant because the alpha angle is less than 5%.

The distribution of felled trees per month reveals significant differences in felling practices between operators and sites. From the above, for the categories of felled stems, there is a varied pressure on forest resources, with higher concentrations for certain axes, in the hinterland of the city of Kindu. This could be explained by the fact that the city's hinterland is the gateway to wood energy where demand is higher following a galloping population and the absence of other sustained energy sources, and to satisfy their dendroenergy needs (Baking bricks, soaps, breads, etc.). Given the results related to excessive felling, there is a need to suggest appropriate management and conservation strategies to protect forest resources while supporting the needs of local communities, by integrating agroforestry practices.

Also, all things being equal, the importance of wood cutting, for charcoal and firewood in the hinterland of the town of Kindu and territory of Kailo, as well as the consumption of wood energy by households in Kindu, is so great that its exploitation deserves to be supported, instead of considering its cessation due to the expansion of the town.

From these results the first specific hypothesis is also partly confirmed.; according to which the number of felled timber vary from one species to another.

Quantity of Charcoal (Embers) Produced by Operators

Table X shows the quantity of charcoal (embers) produced by farmers in the study sites.

Table 3. Quantity of charcoal (embers) produced by operators

	Site 1 HK									Site 2 TK							
Qty/BM	rd	pK 9	Sh	AMF	AMF	lM	NTE	NS	Kg	aM	bAn	wS	NTE	NS	Kg	t	pv
≤20 S	24	0	13	0	0	15	52	1040	58448	32	211	157	400	8000	449600	-0.44569	0.666
≥50 S	75	0	152	0	0	113	340	17000	955400	17	213	76	306	15300	859860		
∑	99	0	165	0	0	128	392	18040	1E+06	49	424	233	706	23300	1309460		
χof 20S							20		1124				20		1124		
χof 50S							50		2810						2810		

Legend: NTE: total number of respondents, NS: number of bags and Kg: Kilogram (weight of embers), Qty/BM: Quantity of embers per month, S: 56.2 kg bag. rD: right bank, pk9: kilometer point 9 railk, sh: shenge, aM F: upstream of the river, avF: downstream of the river, lM: lwama, aM: ambwe, bAN: bangengele, Ws: wasongola

The quantity of charcoal produced in the two sites, in Table 3 above, shows that it is the territory of Kailo (site 2) which has a high number of charcoal producers (embers) with 706 respondents providing 23,300 bags of charcoal monthly, compared to the hinterland of the city of Kindu, which has 392 respondents for 18,040 bags of charcoal. This situation could be explained by the fact that it is in Kailo that we still find the forest massifs which abound with a good number of trees compared to the hinterland of the city of Kindu.

The result of charcoal production, reported for the two sites, is 2,323,308 kg or 2,323.30 tonnes with an average of 2.1 tonnes, which are significantly higher than Mbuangi (2022) and Tagirabo (2023) which found respectively, in Boma Province of (Central Congo) an annual consumption at the household level, 25,719,600 kg, or 635,052 bags with an average weight of 40.5 kg of charcoal and in Bunia Province of (Ituri), 70,700.28 kg.

This could be explained by the fact that their samples are also significantly smaller than the present study, which attempted to take stock of charcoal production among producers at production sites before delivery to consumption centres.

Thus, the proposed interventions, such as raising awareness of more sustainable practices and monitoring production, could help to promote more responsible exploitation of forest resources and reduce pressure on forest cover in these forest areas, as this exploitation contributes negatively, in terms of climate change, to maintaining the balance of forest ecosystems.

Quantity of Firewood Produced by Operators per Site

Table 4 below illustrates the quantity of firewood produced by operators in both (Hinterland of the city of Kindu and Territory of Kailo).

Table 4. Quantity of firewood produced by operators in the two sites

	Site 1. Hinterland of the town of Kindu								Site 2. Kailo Territory						
Qty Bc /m³	RD	Pk9	Sh	Amf	avf	lM	NTE	**m3**	aM	bAn	Ws	NTE	**m3**	t	pv
3 m³	9	8	9	0	0	6	32	**96**	14	17	226	257	**771**	0.17975	0.8603
6 m³	156	25	63	18	18	60	340	**2040**	26	2	43	71	**426**		
Total	165	33	72	18	18	66	372	**2136**	40	19	269	328	**1197**		
X								**213.6**					**199.3**		

Legend: HK: Kindu Hinterland; TK: Kailo Territory Qty Bc/M: quantity of firewood per month, m3: cubic meter, rD: right bank, pk9: kilometer point 9 railk, sh: shenge, aM F: upstream of the river, avF: downstream of the river, lM: lwama, aM: ambwe, bAN: bangengele, Ws: wasongom

Reading Table 4 shows that, for a period of one month, comparing the two sites, on the production of firewood, the hinterland of the town of Kindu, comes first, both in number of producers and in quantity of firewood produced, (372 respondents, 2,136 m3) against (328 respondents, 1,197 m3) of firewood, in the territory of Kailo, the sum being 3,369 m3 of wood. Comparing this production, the difference is not significant.

The results in relation to the production of firewood are significantly higher than those of Tagirabo (2023), in Bunia, Ituri Province, which converted the quantity of charcoal into wood equivalent, for a period of one year of 989.8m3. Although the difference between the two sites is not statistically significant, the sustainable management of this resource remains essential. Recommendations include the promotion of sustainable logging practices and the exploration of energy alternatives to alleviate pressure on forest resources, through the use of "Green Charcoal". As well as the quantity of charcoal, firewood, their quantities vary from one species to another, from one operator to another and from one site to another; which confirms the first specific hypothesis of this study.

Calculation of Profit Margin and Financial Profitability of Charcoal

Table 5 shows the situation in relation to the profit margin and financial profitability (FR) of coal miners.

Table 5. Calculation of profit margin and financial profitability of charcoal

SITE 1												
Rive droire	Nombre de pr	Accès aux Bois	Alimentation	Materiels	Transport	Mains d'œuvre de la production	Taxes/Impots	Prix par sac	Coût total/Dépense	Prix de vente Total	Marge bénéficaire	RF%
20 sacs	24,00	60 000,00	25 000,00	35 000,00	40 000,00	60 000,00	40 000,00	30 000,00	260 000,00	600 000,00	340 000,00	130,77
50 sacs	75,00	150 000,00	50 000,00	35 000,00	100 000,00	150 000,00	100 000,00	30 000,00	585 000,00	1 500 000,00	915 000,00	156,41
AXE SHENGE												
20 sacs	13,00	70 000,00	40 000,00	39 000,00	40 000,00	140 000,00	40 000,00	35 000,00	369 000,00	700000	331 000,00	89,70
50 sacs	152,00	175 000,00	80 000,00	39 000,00	100 000,00	350 000,00	100 000,00	35 000,00	844 000,00	1750000	906 000,00	107,35
AXE Lwama												
20 sacs	15,00	70 000,00	40 000,00	40 000,00	40 000,00	140 000,00	40 000,00	35 000,00	370 000,00	700 000,00	330 000,00	89,19
50 sacs	113,00	175 000,00	80 000,00	55 000,00	100 000,00	350 000,00	100 000,00	35 000,00	685 018,00	1750000	1 064 982,00	155,47
SITE 2												
Wasongola												
20 sacs	157,00	50 000,00	30 000,00	45 000,00	70 000,00	100 000,00	40 000,00	25 000,00	335 000,00	500000	165 000,00	49,25
50 sacs	76,00	125 000,00	55 000,00	65 000,00	175 000,00	250 000,00	100 000,00	25 000,00	770 000,00	1250000	480 000,00	62,34
Bangengele												
20 sacs	211,00	60 000,00	30 000,00	45 000,00	80 000,00	140 000,00	40 000,00	30 000,00	395 000,00	600000	205 000,00	51,90
50 sacs	213,00	150 000,00	75 000,00	60 000,00	200 000,00	350 000,00	100 000,00	30 000,00	935 000,00	1 500 000,00	565 000,00	60,43
Axe Ambwe												
20 sacs	32,00	40 000,00	25 000,00	50 000,00	70 000,00	80 000,00	40 000,00	20 000,00	305 000,00	400 000,00	95 000,00	31,14754098
50 sacs	17,00	100 000,00	60 000,00	75 000,00	175 000,00	200 000,00	100 000,00	20 000,00	710 000,00	1000000	290 000,00	40,84507042
∑	1 098,00	1 225 000,00	590 000,00	583 000,00	1 190 000,00	2 310 000,00	840 000,00	350 000,00	6 563 018,00	12 250 000,00	5 686 982,00	917,45
$\bar{x}$		102 083,33	49 166,67	48 583,33	99 166,67	192 500,00	70 000,00	29 166,67	546 918,17	1 020 833,33	473 915,17	0

Calculation of Profit Margin and Financial Profitability of Firewood

Table 6 provides information on the profit margin and financial profitability of firewood.

Table 6. Profit margin and financial profitability of firewood

Site 1													
Rive roite		Accès aux Bois	Alimentation	Materiels	Transport	la production	Taxes/Impots	Prix par stère (m3)	total/Dépense	Prix de vente Total	Marge bénéficaire	R F%
3 m^3	9,00	9 000,00	12 000,00	5 000,00	15 000,00	10 000,00	3 000,00	30 000,00	54 000,00	90 000,00	36 000,00	66,66666667
6 m^3	156,00	21 000,00	25 000,00	12 000,00	30 000,00	20 000,00	6 000,00	35 000,00	114 000,00	210000	96 000,00	84,21
PK9												
3 m^3	8,00	9 000,00	9 000,00	5 000,00	15 000,00	10 000,00	3 000,00	30 000,00	51 000,00	90 000,00	39 000,00	76,47058824
6 m^3	25,00	21 000,00	25 000,00	12 000,00	30 000,00	20 000,00	6 000,00	35 000,00	114 000,00	210 000,00	96 000,00	84,21052632
SHENGE												
3 m^3	9,00	1 500,00	5 000,00	5 000,00	18 000,00	5 000,00	3 000,00	35 000,00	37 500,00	105 000,00	67 500,00	180
6 m^3	63,00	21 000,00	25 000,00	12 000,00	50 000,00	20 000,00	6 000,00	35 000,00	134 000,00	210 000,00	76 000,00	56,71641791
fleuve								-				
3 m^3	-	-										
6 m^3	18,00	21 000,00	15 000,00	15 000,00	50 000,00	15 000,00	6 000,00	35 000,00	122 000,00	210 000,00	88 000,00	72,13114754
Avardu												
3 m^3	-											
6 m^3	18,00	21 000,00	15 000,00	15 000,00	50 000,00	15 000,00	6 000,00	35 000,00	122 000,00	210 000,00	88 000,00	72,13114754
Lwama												
3 m^3	6,00	7 450,00	10 000,00	15 000,00	18 000,00	15 000,00	3 000,00	35 000,00	68 450,00	105 000,00	36 550,00	53,40
6 m^3	60,00	12 300,00	11 430,00	15 000,00	36 000,00	30 000,00	6 000,00	35 000,00	110 730,00	210 000,00	99 270,00	89,65
SITE 2												
Wasongola												
3 m^3	226,00	8 100,00	5 000,00	25 000,00	9 000,00	6 000,00	3 000,00	27 000,00	56 100,00	81 000,00	24 900,00	44,38502674
6 m^3	44,00	16 200,00	10 000,00	35 000,00	15 000,00	10 000,00	6 000,00	27 000,00	92 200,00	162 000,00	69 800,00	75,70498915
Bangengele								-				
3 m^3	17,00	8 700,00	5 000,00	25 000,00	9 000,00	6 000,00	3 000,00	29 000,00	56 700,00	87 000,00	30 300,00	53,43915344
6 m^3	6,00	17 400,00	10 000,00	35 000,00	15 000,00	10 000,00	6 000,00	29 000,00	93 400,00	174 000,00	80 600,00	86,29550321
Ambwe												
3 m^3	14,00	8 100,00	5 000,00	25 000,00	9 000,00	6 000,00	3 000,00	27 000,00	47 100,00	81 000,00	33 900,00	71,97452229
6 m^3	21,00	16 200,00	10 000,00	35 000,00	15 000,00	10 000,00	6 000,00	27 000,00	92 200,00	162 000,00	69 800,00	75,70498915
$\sum$	700,00	218 950,00	197 430,00	291 000,00	384 000,00	193 000,00	75 000,00	506 000,00	1 365 380,00	2 397 000,00	1 031 620,00	1 243,09
$\bar{x}$		13 684,38	12339,375	18 187,50	24000	12062,5	4687,5	31625	85336,25	149 812,50	64476,25	77,6930216

Referring to the profit margin calculations, see (Table 5 and 6) above; it is proportional to the quantity of charcoal produced and depending on the axes and production sites, it varies from 95000 FC to 1064982,00 FC with an average of 473915,17 FC; and for firewood 24900 FC to 99270 FC with an average of 64476,25 FC.

As for financial profitability, it is positive for all charcoal producers (1098) and even goes beyond 100% for some, in the production axes and sites. The same situation is also observed for all firewood producers (700); their profit margins and financial profitability are a function of the capital invested, the more you invest, the more sufficient profit you have and the less you invest, the less profit you will have.

By comparing the profit margin and financial profitability with those of other researchers in other countries in particular; Tagirabo (2023), Mbuangi (2022), Tshimpanga (2009), we had to find the positive profit margin and financial profitability in their respective results.

The production of charcoal and firewood provides monetary income, producers acquire important assets (furniture, plots of land, livestock, motorcycles, work tools, clothes, telephones, radio and bicycle). The resources obtained are also allocated to the schooling of children, the construction of houses and health care. The charcoal makers and firewood harvesters in the hinterland of the city of Kindu and the territory of Kailo; have even purchased land (for the construction of houses). The hypothesis related to the profit margin and profitability is confirmed

Impact from the Exploitation of Wood Energy in the Hinterland of the City of Kindu and Kailo Territory

Table 7 illustrates the impact of wood energy exploitation in the hinterland of the town of Kindu and the territory of Kailo.

Table 7. Social, economic and environmental impact of wood energy exploitation

Plan	Level	Impacts	
		Positives	**Negatives**
Social	Production	Source of job creation; maintaining employability as long as the forest exists;	Sources of conflicts between community members and local authorities over resource access rights revenues
	Marketing	Existence of permanent jobs	Some epidemics
	Consumption	permanent source of energy; generates other intermediate jobs	Causes fires
Economic	Production	Improved living conditions and income; and social well-being	Tax Payment Problem
	Marketing	Acquisition of permanent revenue	Multiplication of state services
	Consumption		Additional monetary expenditure
Environmental /Ecological	Production		Deforestation, Disappearance of animals, Fire (bush fire), Soil degradation, Step back from the dense forest, Climate disruption or climate change

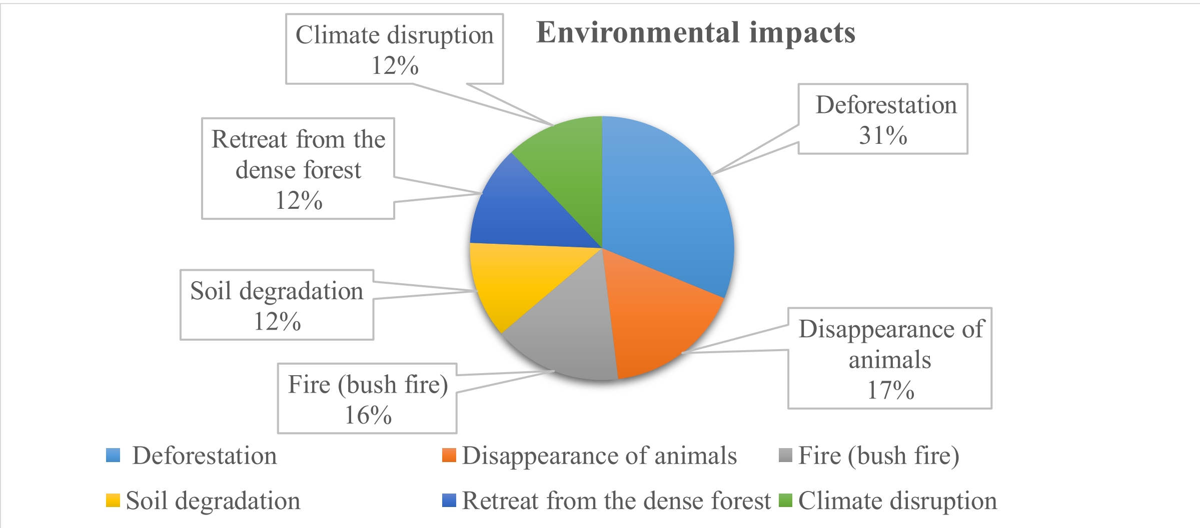

Figure 3. Environmental impact of wood energy exploitation

The impact of wood energy exploitation in the area under study is considered on two levels: positive and negative. On the positive side, the exploitation of wood energy creates employment opportunities, this is the (social) aspect and improves living conditions, source of income (economic aspect) see (Table 7) above.

The result of (Table 4) shows that the exploitation of wood energy in the hinterland of the city of Kindu and territory of Kailo, offers employment to 1098 charcoal burners, or 61.0% against 700 firewood exploiters who represent 38.0% in the two sites. By comparing our results with those of other researchers (Tagirabo, 2023; Mbuangi, 2022; Schure & Hunhyet 2014; Tshimpanga, 2009; Ouédraogo, 2007), to name but a few; all their results sufficiently demonstrate that the wood energy sector is a source of informal job creation and also a source of household income.

At the negative level, the environmental impacts that the respondents were able to recognize in their environments for the present study, see (Figure 3) above, are in particular:

deforestation (31%) which comes first, disappearance of animals (17%), fire (16% bush fire), soil degradation, retreat of dense forest and climate change respectively, with (12%) each.

The same authors cited above, regarding the positive impact of wood energy exploitation, recognized almost the same effects on the negative level of environmental impacts on wood energy exploitation, each in their respective study environment.

From all the above, in view of the partial discussion and starting from the hypothesis of this study which stipulates that: economically, wood energy offers financial profitability with a significant profit margin; informal jobs (reduction of unemployment); ensures the coverage of household wood energy needs. Ecologically, it impoverishes forest ecosystems through the non-selective exploitation of populations of energy wood species.

CONCLUSION

A study has just been conducted in the hinterlands of Kindu's city and Kailo territory, focusing on wood energy – the main source of household income: a challenge for the management of forest cover in Maniema province. Wood energy exploitation in Kindu hinterlands and Kailo territory presents significant challenges in terms of environmental sustainability and social justice. Although the activity is economically profitable, its negative impacts on the environment and the living conditions of loggers highlight the urgent need for reforms to ensure sustainable management of forest resources and improve the working and living conditions of local communities.

The results address the three specific questions of the study, which collaborate with the three specific objectives in relation to the verification of three specific hypotheses as well. It should be noted that:

- Out of 11 identified species: 5 are more preferred by charcoal burners and firewood users which are: *Cynometra alexandrii, Gilbertiodendron dewevrei* and *Xylopia aethiopica* followed by *Uapaca* sp. and *Acacia* sp.;
- the number of trees felled per month is significantly higher, i.e. a total of 33920 stems with an average of (18.8 stems) in the two wood-energy exploitation sites as well as the quantities of charcoal (embers) and firewood which are respectively 2323;3 tones' and 3369m^3; with an average of 2.1 tunes and 4.8 m^3;
- in relation to the total cost of production; it varies from 260000 FC to 935000 FC with an average of 546 918,70 FC for carbonization and from 37500 FC to 134000 FC with an average of 85386,25 FC for firewood and proportional to the quantity produced;
- regarding profit margin calculations, this is also proportional to the quantity of charcoal produced, and varies from 95 000 FC to 1 064982,00 with an average of 473915,17 FC for charcoal and for firewood it varies from 24900 FC to 99270 FC with an average of 64476,25 FC;
- As for financial profitability, it is positive for all charcoal burners (1098) and even goes beyond 100% and the same for firewood operators (700); the activity is therefore declared profitable overall.
- on the environmental impacts we were able to collect six elements: deforestation (31%); disappearance of animals (17%); fire (bush fire) (16%); soil degradation (12%); retreat of dense forest (12%) and climate disruption or climate change (12%).

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