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IMPACT OF SUSTAINABLE VALORIZATION OF AGRO-INDUSTRIAL RESIDUES ON LOCAL CLIMATE CHANGE IN WEST AFRICA: A CASE STUDY OF CASHEW NUT WASTE IN CÔTE D'IVOIRE

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ABSTRACT

The cashew nut sector has contributed to the mitigation of local climate change by achieving in 2018 a carbon footprint of - 349,711 tCO_2eq. However, shell burning in landfills has degraded the carbon footprint of that sector, reaching an additional + 34,844 tCO_2eq of greenhouse gas emissions. This therefore justifies the study of sustainable thermochemical recovery of these agro-industrial wastes and the evaluation of the environmental potentialities. Thus, the study shows that the pyrolysis of cashew nut shells generates on average 17% shell charcoal, 81% fuel gas and 2% inorganic matter. Carbon accounting reveals that with a potential of 49,331 to 116,352 tons of shells generated annually by cashew nut shelling in Côte d'Ivoire, the local production of electricity from pyrolysis gas and the partial substitution of wood charcoal by cashew nut shell charcoal will avoid the annual release of 106,866 to about 252,055 tCO_2eq of greenhouse gases into the atmosphere, from the year 2018. That is, a potentiality of 2.166 tCO_2eq of greenhouse gases to be saved per ton of shells recovered (2.166 tCO_2eq/t). Thus, in general in West Africa, the integration of pyrolysis recovery of cashew nut shells would therefore contribute to the mitigation of local climate change.

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INTRODUCTION

According to IPCC projections, Africa, a continent with low greenhouse gas (GHG) emissions, is likely to be the most affected by the effects of climate change (Alain François and Mohamed Taabni, 2012; Marianne Tinlot, 2010). To this end, the consideration of the sectors in climate change mitigation and adaptation policies is the subject of many community reflections and decisions, including the elaboration of the African strategy on climate change by the African Union Commission in 2014 (UA, 2014). Since the end of 1990, following the increase in world cashew nut prices due in particular to a drop in Indian production, cashew nuts have become one of West Africa's most important export and cash crop products (Marianne Tinlot, 2010; RONGEAD, 2013).

For Côte d'Ivoire, the world's largest cashew nut producer and the largest processor in West Africa, the quantity processed locally has increased from 40,383 tons in 2016 to 68,515 tons in 2018, with an estimated nominal annual capacity of the installed processing units of 161,600 tons (CCA, 2019). Local processing generates very abundant waste, most of which is burnt in landfills (Etc terra- RONGEAD, 2017; Kouamé Michel *et al*., 2020). Containing an oil called CNSL (Cashew Nut Shell Liquid), the combustion of the shells generates very abundant smoke, causing environmental pollution and thus risks to human health (TAGUTCHOU Jean-Philippeand NAQUIN Pascale, 2012; Thierry Godjo *et al*., 2015). However, if biomass is valorized in a sustainable way, it can be a decentralized source of energy and contribute to the mitigation of local climate change (Sanger S.H.*et al*., 2011; Ansoumane Diedhiou *et al*., 2014). Thus, the long-term objective of this study is to propose strategies for integrating the energy recovery of cashew nuts for a better local contribution of the cashew nut sector to climate change mitigation (Marianne Tinlot, 2010; UA, 2014). Specifically, this will consist of:

- assessing the current carbon footprint of the activities carried out within the cashew nut chain. This would allow us to see if the cashew industry currently has a negative carbon footprint, allowing us to consider the CO_2 emissions that will be generated by the recovery of its waste, due to the carbon cycle, as neutral (Adrien B. *et al*., 2010; Joël Blin *et al*. 2011);
- to study the potentialities of integrating the energy recovery of cashew nut shells for a better contribution of the cashew nut sector to climate change mitigation in Côte d'Ivoire.

According to some authors, the observations made on the pyrolysis of cashew nut shells suggest a reduction in atmospheric emissions because, contrary to the old practice of direct shell combustion, the fumes are practically invisible and the pungent and irritating odors to the eyes disappear (Thierry Godjo *et al*., 2015; Kouamé Michel *et al*., 2020). Taking into account the technical and environmental performances, we have therefore carried out studies on a pyrolysis furnace installed in one of the transformation units in Bouaké (Côte d'Ivoire) as part of the implementation of the AGROVALOR project.

MATERIALS AND METHODS

Biological material: Cashew nut shell sample: Raw cashew shells were sampled from a heap in a shelling unit in Bouaké. Figure 1 below shows the shell sample used for the various laboratory analyses.

Figure 1. Image of the cashew nut shell sample used for analysis

Thermochemical study material: The material is a steel construction mainly made of 3 mm thick steel sheet and refractory (Kouamé Michel *et al*., 2020). Figure 2 below shows the installation used for the different tests.

Figure 2. Example of equipment used for the thermochemical treatment of cashew nut shells (valorization of shells into pyrolysis gas for feeding a boiler)

Method for the determination of the energy performances of an industrial pyrolysis furnace: The raw cashew nut shells (fuel) are progressively admitted into the reactor (cylinder) through the hopper. The burner mounted above the pyrolysis reactor allows the combustion of the gases generated by the pyrolysis of the shells to feed the boiler used to produce steam (to embrittle the cashew nuts or to feed the turbo-alternator). After the end of the combustion flame of the pyrolysis gas, the shell charcoal is left to cool for about five hours in the furnace before its extraction(or cool it quickly with water after extraction) to prevent it from burning in contact with air. The combustion flame of the pyrolysis gas at an average internal temperature of the furnace of 450°C. For the experiment, the pyrolyzed raw shells and shell charcoals were weighed using an industrial scale to estimate the various ratios (percentage) at the end.

Methods of pyrolysis integration and fuel recovery processes: In the processing units, the fuel gas generated by the pyrolysis of the shells is used to produce steam in the nut processing process and the resulting coal is used to produce cooking heat in the locality as a substitute for wood charcoals (Thierry Godjo *et al*., 2015; Kouamé Michel *et al*., 2020). The synoptic diagram (Figure 3) below illustrates the sustainable processing of cashew nut shells using an industrial pyrolysis furnace.

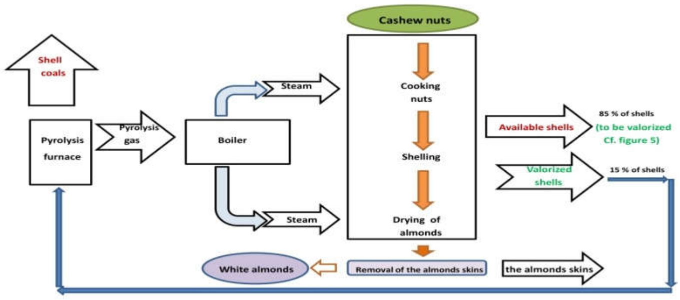

Figure 3. Synoptic diagram of the sustainable transformation process of cashew nuts using pyrolysis furnaces (Kouamé Michel *et al*., 2020).

Figure 4 illustrates the different processes adopted for the energy conversion of the 85% of cashew nut shells available after cashew nut processing.

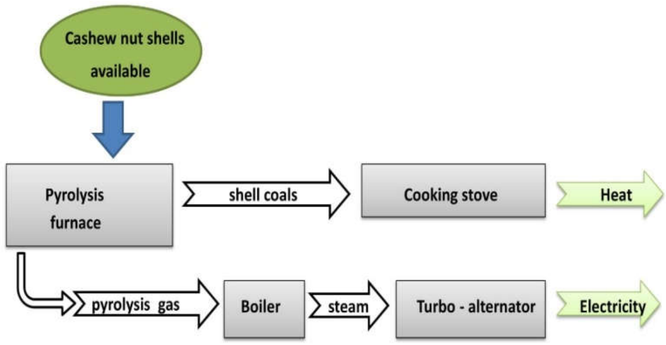

Figure 4. Synoptic diagram of the process for the sustainable energy recoveryof fuels generated by the pyrolysis of available raw cashew nut shells (Kouamé Michel et al., 2020)

Physical-chemical characteristics of fuels generated by cashew nut shell pyrolysis: Previous studies have shown that raw cashew nut shells, charcoal and pyrolysis gas have a Net calorific value (NCV) of 5,217 kcal/kg (21.8 MJ/kg), 6,799 kcal/kg (28.5 MJ/kg) and 4,317 kcal/kg (18 MJ/kg) respectively (Kouamé Michel *et al*., 2020).

Methods for assessing the annual mass of charcoal for cashew nut substitution: Taking into account the material and energy balance (Thierry Godjo et al., 2015), we deduce that the energy of the mass of cashew nut shell charcoal ($M_{charcoal\text{-}shell}$) to be recovered is equal to that of the mass of charcoal to be substituted. The mass of substitutable charcoal ($M_{char\text{-}wood}$) is given by the equation 1 (Kouamé Michel et al., 2020):

$$M_{charcoal\text{-}wood} \times NCV_{charcoal\text{-}wood} = NCV_{charcoal\text{-}shell} \times M_{charcoal\text{-}shell}$$

$$M_{charcoal\text{-}wood} = \frac{NCVcharcoal-shell}{NCVcharcoal-wood} \times M_{charcoal\text{-}shell} \quad \text{(eq. 1)}$$

Method for assessing the annual potential for pyrolysis gas to be converted into electricity and the rate ofcontribution to the electricity mix: The potential for electricity production (Eelect) by thedifferent devices is calculated from the equation 2 (Kouamé Michel et al., 2020):

$$E_{elect} = \eta_{elect} \times E_{gas\text{-}avail}$$
$$E_{elect}\ (GJ) = \eta_{elect} \times [(R_{gas} \times M_{shell}) \times NCVgas]$$
$$E_{elect}\ (Gwh) = \eta_{elect} \times [(R_{gas} \times M_{shell}) \times \frac{NCV\ gas}{3\ 600}] \quad \text{(eq. 2)}$$

With the mass of the shells (Mshell) expressed in tons;Rgas,the percentage of gas generated by the pyrolysis of a cashew nut shell mass and the NCV of the pyrolysis gas (NCVgas) expressed in GJ/t.

Cashew sector activities taken into account in the carbon accounting: Figure 5 below presents the cashew sector activities taken into account in carbon accounting.

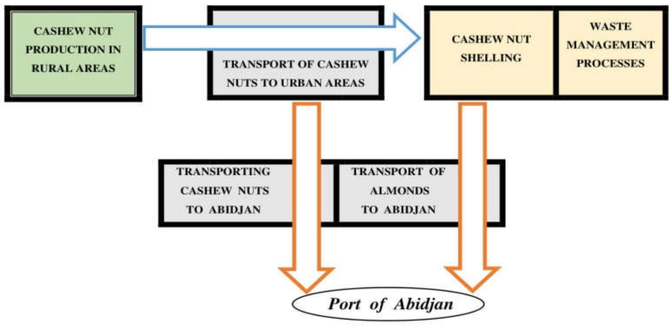

Figure 5. Synoptic diagram presenting the activities of the cashew nut sector taken into account in the carbon accounting

Assumptions and methods for assessing the carbon footprint of cashew sector activities:

- According to the cotton and cashew nut advisory data, the area occupied by cashew nut plantations since the year 2016 is estimated at about 1,250,000 hectares. Cashew nuts are produced in 19 regions, mainly in the central and northern part of the country (CCA, 2019). The distances of the different production regions from the port of Abidjan are taken from the BNETD - CI catalogue (201);
- Raw nuts and white almonds are all transported to the port of Abidjan by 50-ton trailers, consuming on average 60 liters of diesel over 100 km (field data);
- Cashew nut waste is transported to landfills outside the city by trucks with an average capacity of 10 tons, over a distance of 10 km (outward) and 10 km (return). A 10-ton vehicle consumes an average of 0.3 liters of diesel over a distance of 1 km (field data);
- according to ADEME data, the emission factor of diesel (EF_{Diesel}) at the pump is 2.52 $kgCO_{2eq}$ /liter (ADEME, 2016);
- the IPCC's soil carbon storage coefficient for perennial crops ($C_{StockSoil}$) is 0.33 tons of CO_2 per year per hectare (Marianne Tinlot, 2010; ADEME, 2016);
- the IPCC energy emission factor for the combustion of raw cashew nut shells is 0.036 tCO_2eq/GJ (Joël Blin et al., 2011).

Assumptions for the carbon assessment of cashew nut shell energy recovery:

-Taking into account the carbon cycle, carbon dioxide (CO_2) emissions due to the recovery of cashew nut waste will be considered neutral and not accounted for in the carbon balance if they do not reach the carbon sink achieved by the current cashew nut processing activities (Adrien B. Y. et al., 2010; Joël Blin et al., 2011);

- According to the MPEER's 2018 annual activity report, in 2018, the electricity sector recorded a gross production of 9,997 GWh. This production required the consumption of 1,775.7 million cubic meters of natural gas(MPEER.CI, 2019);
- According to ADEME, the electrical efficiency (ηelect) of conventional thermal power plants is estimated at 35%; the NCV of charcoal ($NCV_{wood\text{-}charcoal}$), by default, is 26 MJ/kg and the emission factor of electricity production by natural gas ($EF_{NaturalGas}$) is estimated at 406 gCO_2eq/kWh (ADEME, 2016; MPEER.CI, 2019);
- According to FAO data, GHG emissions from wood charcoal production (including from forest degradation and deforestation) are estimated at 9 $kgCO_{2eq}$ per kg wood charcoal produced (FAO, 2017).

Method and equation for the assessment of the carbon footprint of cashew nut production in Côte d'Ivoire: The evaluation of the annual carbon footprint of cashew nut production (cashew nut plants) in Côte d'Ivoire is based on the equation 3(Thiombiano Sylvain, 2010;Marianne Tinlot, 2010).

$$Q_{GHG\text{-}CarbonSink\text{-}Yr} = A_{Cashew} \times C_{StockSoil} \quad \text{(eq. 3)}$$

With A_{Cashew}, the area of cashew tree plantations, expressed in hectare and $C_{StockSoil}$, the IPCC's soil carbon storage coefficient for perennial crops.

Methodand equation of determining total truck fuel consumption: The total fuel consumption of the trucks is estimated from equation 4.

$$CONS_{totale}\ (liters) = [CONS_{Km} \times DIST_{voy}] \times [M_{produit} \times (CP_{trip})^{-1}] \quad \text{(eq. 4)}$$

With $CONS_{Km}$, the average diesel consumption of vehicles per km, expressed in l/km;$DIST_{trip}$, the average distance of a trip (round trip), expressed in kilometer (km);$M_{produit}$, the total mass of the products transported, expressed in tons and CP_{trip} is the transport capacity of the vehicles per trip, expressed in tons.

Method and equation for assessing the carbon footprint of fuels: The various expressions used to determine the annual carbon values can be summarized by the general equation 5.

$Q_{GHG(i)} = EF_{(i)} \times Value_{(i)}$(Marianne Tinlot, 2010; ADEME, 2016); (eq.5)

Where (i) is the fuel or entity being considered, $Q_{GHG(i)}$ is the quantity of greenhouse gas emitted expressed in tCO_{2eq}, EF(i) is the emission factor (mass or volume) of the fuel and Value(i) is the mass or volume value, expressed in terms of the unit of EF(i).

Carbon footprint sign (ADEME, 2016)**:** In carbon accounting, the sources of GHG emissions are conventionally denoted as positive (with a + sign) and negative (with a - sign), the sources of carbon storage (sinks and carbon sequestration) and the sources of GHGs saved are denoted as positive (with a + sign).

RESULTS AND DISCUSSIONS

Results of the experimentation of pyrolysis cashew nut shells using an industrial furnace: The study shows that for a mass of shells (M_{shells}) admitted in the pyrolysis furnace, it produces about 17% of cashew shell charcoal (R_{coal}) and about 2% of other residues (ashes, grains of sand, ...). We deduce that the furnace valorizes in the form of gas on average 81% (R_{gas}) of the mass of treated shells. Pyrolysis therefore generates about 98% of combustible organic matter. In addition, the mass of shells used in the process represents on average

11% of the brittle nuts (precooked) and 15% of the shells generated by shelling. Figure 6 and Figure 7 present examples of the recovery of the different fuels (shell coal and pyrolysis gas).

biomass from cashew nut processing activities could be considered neutral and not accounted for in the carbon balance as long as they do not reach 349,711 tons.

Figure 6. Upgrading of shell charcoal by means of a metallic furnace

Figure 7. Feeding of a boiler by the combustion of pyrolysis gas

Table 1. Carbon accounting of cashew nut sector activities in 2018

THE DIFFERENT ACTIVITIES	QUANTITY OF FUEL OR OTHER ENTITY USED	EMISSION FACTORS (EF)	CARBON FOOTPRINT VALUES (Cf. eq. 3and eq.5)
Cashew nut production	1,250,000 hectares	$0.33tCO_2$ / hectare	- $412{,}500tCO_2$
Transport of raw cashew nuts and almonds	9,524,206 liters (Cf. eq. 4)	2.52×10^{-3} tCO_{2eq} / liter	+ 24,001 tCO_{2eq}
Transport of waste to landfills	29,106 liters (Cf. eq. 4)	2.52×10^{-3} tCO_{2eq}/ liter	+ 73 tCO_{2eq}
Shell combustion for cashew processing	49,331 tons × 10%	0.036 t CO_{2eq} /GJ × 21,8 GJ/t = 0.7848 tCO_{2eq}/t	+ 3,871 tCO_{2eq}
Shell burning in landfills	49,331 tons × 90%	0.7848 tCO_{2eq}/t	+ 34,844 tCO_{2eq}
Total value			- 349,711 tCO_{2eq}

Table 2. Results of the carbon assessment of energy recovery by pyrolysis of cashew nut shells, taking into account statistical data for the year 2018

THE DIFFERENT ENERGY RECOVERY OF THE SHELLS	FUEL MASSES TO BE GENERATED BY PYROLYSIS REACTORS	VALUES OF THE ENERGY CARRIERS TO BE PRODUCED OR SUBSTITUTED	EMISSION FACTORS (EF)	CARBON FOOTPRINT VALUES (Cf. eq. 3)
Electricity generation by pyrolysis gas	(49331 x 85%) x 81% = 33,964.39 tons of pyrolysis gas	Quantity of electricity to be produced: 0,35 x (33,964 t x18GJ/t)/3600 = 59,44 GWh (Cf. eq. 4)	406 CO_2eq/ GWh (406 gCO_2eq/ kWh)	$Q_{GHG\ -Elect}$ = 4,132.6 tCO_2eq
Energy recovery from cashew nut shell charcoal	49331 x 17% = 8,386 tons of shell charcoal	wood charcoal to be substituted: 8,386x(28,5/26) = 9,192.6 tons (Cf. eq. 5)	9 tCO_{2eq} /t	$Q_{GHG\ -Charcoal}$ = - 82,733.4 tCO_{2eq}
Total value				- 106,866tCO_2eq

Estimation of cashew nut waste availability: From field studies (visits to processing units) and calculations, we have obtained that shelling generates on average 22% almonds, 72% shells and 6% skins. In addition, about 10% of the shells generated by the units are used in the transformation process and the remaining 90%, which are not valorized, are burnt in landfills. According to the official data of the Cotton and Cashew nut Council (CCA, 2019), during the year 2018 the processing units shelled 68 515 tons. During the 2018 marketing year, nut processing therefore generated 49 331 tons of shells, 4 111 tons of skins and 15 074 tons of white almonds.

Carbon accounting of cashew sector activities in Côte d'Ivoire in 2018: The table 1 below shows the carbon accounting of cashew nut sector activities in 2018. In spite of the degradation of the carbon sink achieved by cashew plants through other activities, the cashew nut sector has contributed to the mitigation of local climate change by achieving in 2018 a carbon footprint of - 349.711 tCO2eq. However, the non-valorization of the shells (burning in landfills) has degraded the carbon footprint of the cashew sector, reaching an additional GHG emission source of + 34.844 tCO2eq. To mitigate this problem, it would be advisable to integrate in the chain the sustainable valorization of this generated biomass. Moreover, taking into account the carbon cycle (Adrien B. et al., 2010; Joël Blin et al. 2011), the carbon dioxide (CO2) emissions due to the sustainable use of the

Evaluation of the carbon footprint to be achieved by integrating the energy recovery of cashew nut shells (simulation with statistical data of the year 2018): Processing (shelling) generated 49,331 tons of shells in 2018, representing 72% of the total of 65,515 tons of shelled nuts (CCA, 2019). The transformation process by pyrolysis furnace uses 15% of the shells generated by the units, i.e. 7,399.65 tons, and the 41,931.35 tons available (85%) are used for the electricity production process. The application of equations 2, 3 and 4 gives us the carbon footprint values of the cashew nut shell energy recovery activities mentioned in Table 2. The average annual amount of additional GHG that could be saved by integrating the sustainable valorization of all the 49,331 cashew nut hulls generated by the processing units in Côte d'Ivoire during the year 2018 is estimated at 106,866 tCO_{2eq}.

Values of the carbon footprint by regions and districts of Côte d'Ivoire:

Specific case of Abidjan district: We take into account the entire amount of GHGs to be saved by producing electricity from pyrolysis gas because in Côte d'Ivoire, all the thermal power plants for centralized electricity production from natural gas are located in the district of Abidjan. Thus, the carbon assessment of the energy recovery from cashew nut shells in the Abidjan district ($Q_{GHG-ABJ-2018}$)

is made from the following relation: "The carbon assessment of the energy recovery from cashew nut shells in the Abidjan district ($Q_{GHG-ABJ-2018}$) is made from the following relation:

$$Q_{GHG-ABJ-2018} = Q_{GHG-Elect} + Q_{GHG-charcoal} \times \frac{Mreg}{68{,}515}$$

$$Q_{GHG-ABJ-2018} = -24{,}132.6\ tCO_2eq + (-82{,}733.4 \times \frac{Mreg}{68{,}515})$$

With Mreg, the total mass of cashew nuts processed in the district or region, expressed in tons.

According to the CCA report (CCA, 2019), for Abidjan district Mreg = 9,151 tons. The annual quantity of GHG that could be saved during the year 2018 ($Q_{GHG-ABJ-2018}$) by the sustainable energy recovery of cashew nut shells in Côte d'Ivoire is estimated at 35,182 tCO_{2eq}.

Case of regions or districts not producing centralized electricity : The carbon footprint of the integration of cashew nut shell energy recovery in regions without centralized electricity production is calculated from the following relation:

$$Q_{GHG-REG-2018} = Q_{GHG-charcoal} \times \frac{Mreg}{68{,}515}$$

$$Q_{GHG-REG-2018} = 82{,}733.4 \times \frac{Mreg}{68{,}515}$$

Geographic distribution of the amount of GHG emissions that can be saved in 2018: Figure 8 shows the geographical distribution of the 106,866 tCO_{2eq} of GHG that could be saved by integrating the sustainable valorization of cashew nut shells in Côte d'Ivoire in 2018.

Future projection of the carbon footprint of the cashew sector and the pyrolysis valorization of cashew shells in Côte d'Ivoire: According to the CCA report (CCA, 2019), the nominal annual cashew nut shelling capacity of the processing units installed in Côte d'Ivoire is estimated at 161,600 tons of cashew nuts, about 2.36 times the quantity processed in 2018. In the absence of sustainable valorization, burning of shells in landfills could therefore degrade the carbon footprint of the cashew nut sector from + 34,844 tCO2eq to + 82,183 tCO2eq, starting in 2018. Conversely, the carbon footprint of the energy conversion of this biomass using pyrolysis furnaces could change from - 106,866 to around - 252,055 tCO2eq/year. Thus, from the year 2018, in case of integration of the energy recovery of all the shells by pyrolysis, the cashew nut sector in Côte d'Ivoire could thus improve its contribution in the local climate change mitigation strategy by avoiding the release of 106,866 to 252,055 tCO2eq/year of additional greenhouse gases into the atmosphere. The various calculations for estimating the amount of GHGs to be saved by region and district were made using data for the year 2018 and the total nominal capacity of the processing units.

$$Q_{GHG-Elect-nominal-national} = Q_{GHG-Elect-2018} \times \frac{161{,}600}{68{,}515}$$

$$Q_{GHG-Elect-nominal-national} = 56{,}919.333\ tCO_{2eq}/_{year}$$

$$Q_{GHG-charcoal-nominal-national} = Q_{GES-charcoal-2018} \times \frac{161{,}600}{68{,}515}$$

$$Q_{GHG-charcoal-nominal-national} = 195{,}135.626\ tCO_{2eq}/_{year}$$

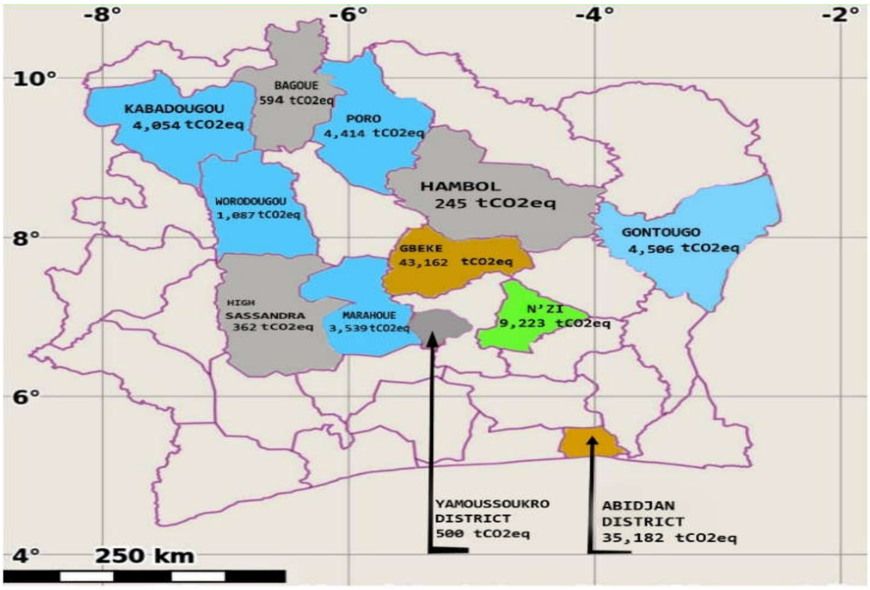

Figure 8. Geographical distribution of GHG emissions that can be saved by the energy recovery of fuels to be generated by cashew nut shell pyrolysis, for the year 2018

Table 3. Nominal values of the quantities of cashew nut shells potentially recoverable by pyrolysis and GHGs that can be saved by region and district

Regions and districts of Cote D'Ivoire	THE DIFFERENT NOMINAL VALUES		
	Mreg : Mass of quantity of cashew nuts to be processed, in tons/year	Mass of the quantity of shells to be recovered (Mreg * 72 %), in tons/year	Quantity of GHGs to be saved, in tCO_{2eq}/year (Cf. eq. 6 and eq. 7)
Abidjan	38 000	27 360	102 805
Gbeke	50 300	36 216	60 738
Yamoussoukro	1 300	936	1 570
N'zi	12 000	8 640	14 490
Kabadougou	13 500	9 720	16 302
Poro	16 000	11 520	19 320
Sassandra	5 000	3 600	6 038
Worodougou	6 000	4 320	7 245
Hambol	3 500	2 520	4 226
Bagoue	3 000	2160	3 623
Marahoue	3 000	2160	3 623
Gontougo	10 000	7 200	12 075
NATIONAL VALUES	161 600 tons /year	116 352 tons / year	252 055 tCO_{2eq}/year

We therefore deduce that:

$$Q_{GHG\text{-Abidjan-nominal}} = 56{,}919.333+195{,}135.626 \times \frac{\text{Mreg}}{161{,}600} \text{(eq. 6)}$$

$$Q_{GHG\text{- Region -nominal}} = 195{,}135.626 \times \frac{\text{Mreg}}{161{,}600} \text{(eq. 7)}$$

Table 3 shows the nominal values of the quantities of potentially recoverable cashew nut shells as well as the quantities of GHGs that could be saved by region and district if pyrolysis furnaces are used for cashew processing and for the energy valorization of available cashew nut shells after shelling. Figure 9 below shows the nominal annual amount of GHG that could be saved per region and district by integrating the pyrolysis recovery of cashew nut shells in Côted'Ivoire.

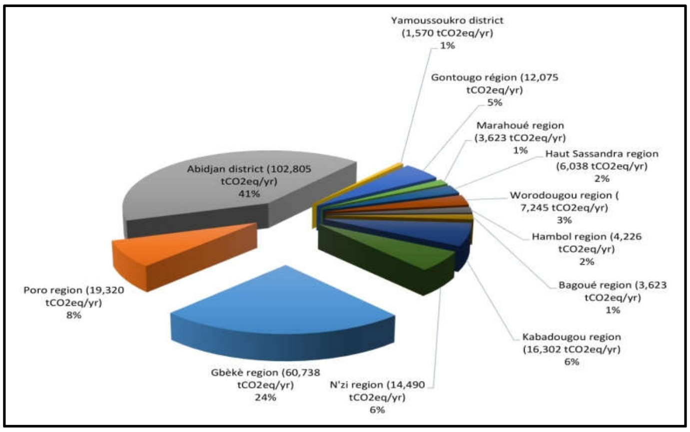

Figure 9. Regional distribution of GHG emissions that can be saved by integrating the pyrolysis recovery of cashew nut shells in Côte d'Ivoire

CONCLUSION

From the results obtained, we note that the use of pyrolysis furnaces for the valorization of the shells into electricity in the cashew nut processing localities in Côte d'Ivoire and the partial substitution of wood charcoals by shell charcoals to be generated, can save annually the release of 106,866 tCO_2eq to 252,055 tCO_2eq of additional greenhouse gases into the atmosphere. That is, a potentiality of 2.166 tCO2eq of greenhouse gases to be saved per ton of shells recovered (2.166 tCO2eq/t). The conversion into sustainable energy of shells generated by cashew nut processing is therefore a privileged means to improve the contribution of the cashew nut sector in the local climate change mitigation strategy. In sum, the results of the study thus raise interest in developing sustainable energy recovery from cashew nut residues wherever processing units exist in West Africa, in order to enable the cashew nut sector to contribute as much as possible to the fight against local climate change, and even global warming.

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