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African Journal of Environmental Science and Technology

Full Length Research Paper

Environmental assessment of tropical African mahogany (Khaya)

John Frank Eshun

Department of Interior Design Engineering, School of Engineering, Takoradi Technical University, Takoradi, Ghana.

In this study, life cycle assessment (LCIA) was used for the assessment and evaluation of the environmental performance of the Khaya lumber manufactured by three firms in Ghana. The work mainly aims to assess all possible effects to the environment, measure the carbon footprint for Ghana Khaya lumber and offer an Environmental Product Declaration (EPD) for Ghana Khaya lumber. The results show that the average environmental effect of the Khaya lumber per cubic meter in relation to GWP was 253 kg-CO_2-Eq; AP, 3.9 kg SO_2- Eq; EP, 2.6 kg Phosphate (PO_4)-Eq; POCP, 0.56 kg Ethylene-Eq. The GWP, AP, EP and POCP match very well the results of LCIA for 1 m^3 rough-sawn, kiln dried US lumber cradle to gate for 19 diverse species and the LCA results for environmental product declaration of tropical plywood production in Malaysia and Indonesia. The EPD results give useful, confirmed and equivalent information concerning the possible environment effect of Khaya lumber manufactured by three firms in Ghana. A detailed and clear LCA for the timber industry offers industry with precise areas for making physical and economic savings to benefit the wealth of the environment and industry.

Key words: Environmental assessment, tropical timber, life cycle assessment.

INTRODUCTION

Recently, the worry concerning environmental effects is now more than counting on present national regulation as global markets are placing high demand for sound environmental products (ITTO, 2005; O'Rourke, 2014).

Several international timber certification systems give consumers alternatives to select timber products obtained from forests that have good sustainability (Brundtland, 1987). Thus, life cycle thinking is highly emphasized in environmental integrated product policy and a good incorporation of this notion in the timber segment is seen as a very successful factor for a more manageable industry (Kareiva et al., 2015; Godar et al.,

2015).

Ghana timber segment is very relevant in developing Ghana socially and economically via exporting of timber products (Eshun et al., 2010). Eshun et al. (2010) noted that manufacturing of timber in Ghana has a lot of environmental issues in areas of using of facilities and producing discharges and waste. There is no environmental incorporated product policy and its active incorporation in the timber industry. Hence, the aims of this work are to gather all the quantifiable inputs and products of the production process of Khaya lumber produced in Ghana, and do an evaluation of all possible

E-mail: jfeshun@yahoo.com or johneshun2014@gmail.com.

effects to the environment.

The work aims to be the benchmark for EPD of Khaya lumber manufactured in Ghana. The EPD will offer useful, confirmed and related information regarding the possible environmental effect of Khaya lumber in Ghana.

Life Cycle Assessment (LCA) is used for assessing the environmental impacts of Khaya lumber, and identifying the significant environment in a product chain. LCA is done usually for an output structure from the beginning to the end, by noting all the environmental effects from extraction of resource to the disposal of product using a series of LCA principles given by International Organization for Standardization (ISO): ISO 14040 and ISO 14044. The result can be utilized to identify avenues to better the environmental areas of a product at the different phases of its life cycle, decision making in industry and organization in selecting products to be used and marketed; example an environmental claim, eco-labeling plan or Environmental Products Declarations [EPD].

Aim of the study

The general aim of this work is to evaluate likely alternatives and plans to make better environmental impact of Khaya lumber from Ghana used as building materials with Life Cycle Assessment (LCA) based on ISO 14040/44. The primary aim of the work is to evaluate the cradle-to-gate environmental impact of Khaya lumber manufactured from Ghana and give reliable scientific proof to decide in aspects concerning possible environmental effect to facilitate its competiveness in the market.

Thus, the main aims of this work are to:

(1) Collate all quantifiable inputs and products of the production procedures of Ghana Khaya lumber.
(2) Collate and assess all possible performance of the environment.
(3) Evaluate the carbon footprint for Ghana Khaya lumber using the PAS2050 method.
(4) Profer an Environmental Product Declaration (EPD) for Ghana Khaya lumber

The work aims to be the benchmark for EPD of Khaya lumber manufactured in Ghana.

Scope of the study

The overall scope of the work to obtain the targeted goals is presented here. It entails identifying particular outputs to be evaluated, supporting product systems, and limit of the work.

MATERIALS AND METHODS

Based on the standard of ISO - 14044 (2006), an LCA is made up

of four interconnected stages (Figure 1).

The first stage is 'Goal and scope definition'. This entails planning of the work in which definitions of all the detailed descriptions of the work are given such as the aim of the study, area of study; the functional unit, system boundaries, the quality of data, and the critical review process.

The second stage is the 'Life cycle inventory' involving the collation and measurement of inputs and products in all the processes. The outputs are both physical like 1 m^3 of furniture part, discharges like carbon dioxide. Here, decision is made on how to control the procedures used to produce many outputs. Inventory analysis is used to identify and quantify the resources mined and utilizations, and the environmental discharges from the processes that make up the life cycle of the products evaluated. All of these are also known as environmental interventions conveyed as measures based on units of functions. The inventory work result measures the relations between economic and environmental procedures.

The third stage is the 'life cycle impact assessment', done based on the data of the life cycle inventory. The wastes in the life cycle inventory data are categorized, meaning they are classified based on their effect. For instance, methane is a greenhouse gas and thus classified as impact category 'Global warming'. If a material donates to more than one impact group, it is allotted to all of them. After classification is characterization. Each substance is given possible impact in the impact group. A substance is given likely impact based on a dominant factor in the group; example for the global warming potential it is mainly 1 kg of CO_2 discharges. These comparative effects are then multiplied with the quantity of each release and the impact values are added up for each impact group (ISO - 14044 2006). Impact evaluation is done to have extra information for assessing a product system's LCI results to know better the environmental importance to make good decisions.

The fourth stage is interpretation. Here, the data from the inventory stage and the impact assessment stage are joined based on the aim and area of the study. Here, the decision makers draw conclusions and give recommendations; otherwise the previous stage needs to be reviewed and revised. To see more description of the LCA method, refer to ISO standard (ISO - 14044 2006).

System description

Three fundamental generic process phases consist of the cycle stage of this product.

The production stage

The production stage consists of 3 phases. Phase one entails to harvest the Khaya trees, cross-cut them into logs, extract the logs to a dumping site in the forest and transport them to sawmill. Phase two is to produce the Khaya lumber in the sawmill; phase 3 is transporting of the Khaya lumber to the manufacturers' storage before kiln drying and later to bundle or package it for shipping. The storing amenities are houses in the firm's production locations. The life cycle of the product production stage gives the greatest record for resource, power, discharge and good inflows, outflows and activities. The most environmentally consuming from the generic process stages are the extraction of the resource and production of raw materials. The usage stage and the end of life do not join the measured aspect of this Khaya lumber product life cycle assessment because it cannot be importantly conveyed by the diverse state of end use product and removal.

Use stage

The use stage of an output entails unit processes like transferring to

consumers (delivery of Khaya lumber from Ghana in boats to a buyer in Europe), manufacturing of the products, and product duration. Transferring of Khaya lumber to consumers and obtaining of building cannot be conveyed as a result of the variableness of unit processes. Product unit process duration is activity that is important to preserve it and not to decrease the quality of important parameters and material durability. The durability is based on the quality of the material and manufacturing methods, for the installation and climatic impacts. The complete durability cannot be fully conveyed.

End of life (dismantling/disposal) stage

The end phase of wood product is very hard to convey. Many works like that are assumed. LCA can be done for cradle-to-grave, cradle-to-gate or gate-to-gate. The cradle-to-grave assessment of the Khaya lumber consists of the timber harvest, extraction, processing to lumber, transportation, use stage as explained in use stage and the end of life dismantling/disposal. For a primary product like Khaya lumber produced and exported from Ghana, the use phase and final product disposal phase are not fixed. Therefore in this study, the system boundary is set for cradle-to-gate, because the use phase and end of life phase cannot be relevantly expressed (Gan and Massijaya, 2014). Use and end phases are therefore excluded.

Functional unit

A functional unit of the work gives the standard for relating the environmental inputs and outputs of a product system-ISO-14044 (2006). It explains the service of the products based on the requirements of the user and is related as the unit service for a specific given time (AHEC, 2009). The functional unit of rough sawn Khaya lumber manufactured at specified moisture content and thickness is 1 m^3 of 25 to 50 mm thickness at 12% moisture content. The functional unit (FU) measures the impact of a product system used as a standard unit. The functional unit tallies with the Product Category Rules (PCR) for solid wood products.

Data quality and representativeness

The work relies on the primary data obtained from survey of three companies in Ghana as well as values obtained from the literature as shown in Table 1.

Literature values gotten from IPCC 2006 were verified using main data. From the discussion of the key quality criteria, the total quality is predicted to be very good. The data quality is the best and good enough for the specific aim and scope.

Allocation

The firms were chosen to carry one product line, kiln dried Khaya lumber and thus the level of process detail was enough to prevent many product processes. Percentages were assigned to Khaya manufactured from all the sawmills' manufacturing depending on mass (density × volume) allocation.

Field study

Company survey

Sizes of companies in Ghana are classified based on their log input. The log inputs in m^3 of the firms are utilized for their identification as large, medium and small. Yearly log input in all species of timber for big firms is 25,000 m^3 and over; medium, 15,000 m^3 but below 25,000; small size, below 15,000 m^3. Three big timber companies, called A, B, C in the study were given questionnaires to give information concerning the inputs and products of the works for resources, material utilization, power necessities, and waste produced for 2013. The terms of reference (TOR) of the work needed data from three companies. The three companies were randomly selected to make data available and reliable. Extra interview was carried out for checking of the quality of the data appropriately to help the process of the LCA. The factories manufactured Khaya kiln dried lumber and they are situated at about 50, 130 and 250 km for A, B, C from log sources. Besides lumber, company A manufactures sliced and rotary veneer and plywood; company B, sliced veneer and moldings and company C, sliced veneer, moldings and square edged lumber. The power source for the factories is the national grid, and energy mix in Ghana is 50% hydropower and 50% thermal power. Hydropower is green energy and thus the environmental problem was seen as insignificant; only the thermal energy is regarded in this work.

Exporting air-dry mahogany lumber from Ghana costs money and thus 98.6% (5,843 m^3) of African mahogany exported in 2012 was kiln dried. The major Khaya species is ivorensis. Export lumber is dried from green to 10-12% moisture content according to US schedule 56(T6-D4) for thicknesses 25, 32, and 38 mm and schedule 20(T3-D3) for thickness 50 mm. Both are in line with British schedule F. 25 mm thick lumber is dried in 14 days while 50 mm thick lumber is 20 days. Companies A, B, C are big and keep accurate data to help the process of LCA. Every firm does its logging from the forest and takes the logs for processing in their factories.

Life cycle inventory (LCI)

Compiling a detailed database of life cycle inventory (LCI) is identifying the highest environmental effects producing an output (Eshun et al., 2010). LCI value is useful to evaluate an output. Most works concentrate on the ambiguity of data in Life Cycle Assessment (LCA) database. The accurateness and worth of inventory process in LCA analysis is useful to compute LCA. Also, diverse software for analyzing LCA data can share similar data name but the assessment results effects of the data differ. Thus, a selection means has to be developed to choose best data for calculating LCA. Timber companies do not have waste data inventory in Ghana. In this work, waste factors from benchmark are used for calculating wastes based on the amounts of Khaya lumber produced using Equation 1. The aim is to make the wastes local.

All raw resources and discharges were used for each of the processes making up the life cycle of the output. Inputs consist of the utilization of materials like timber, resources like petrol. They did not treat the Khaya wood with chemical when stored as it was not preserved for long prior to sawing; the lumber made after sawing was from the heartwood that lasts and cannot be impregnated if it is to be treated. Outputs are discharges released in air, water and land, including all outputs and by-products. These processes make up the life cycle system evaluated according to the system boundary. All inputs and outputs that make up the system were totaled to accumulate the life cycle inventory (LCI).

Emissions contribute to global warming, acidification, eutrophication and smog and they are Carbon dioxide CO_2, Methane CH_4, and Nitrous oxide N_2O for global warming; Sulphur dioxide SO_2 and Oxides of Nitrogen NO_X for acidification; Nitrogen Oxides (NOx) for eutrophication; CH_4, NO_X, Non-Methane volatile organic compound NMVOC, and Carbon monoxide CO for smog. Emissions that contribute to Ozone Depletion Potential (ODP) were not considered as data were not available. The emission result is written in Equations 1 and 2 in kg/m^3 of contaminant released or

Table 1. Emission factors for the calculation of the emissions from Khaya lumber production in Ghana.

Activity area	Compound emitted	Emission factors	Unit	Reference
Forestry subsystem				
Harvesting activities (Gasoline used)	CO_2	3172.00	g/kg fuel	CORINAIR (2000)
	CO	14.07	g/kg fuel	CORINAIR (2000)
	N_2O	0.02	g/kg fuel	CORINAIR (2000)
	CH_4	7.67	g/kg fuel	CORINAIR (2000)
	NO_X	1.55	g/kg fuel	CORINAIR (2000)
	NMVOC	762.00	g/kg fuel	CORINAIR (2000)
	SO_2	0.07	g/kg fuel	CORINAIR (2000)
Harvesting activities (Diesel used)	CO_2	3150.00	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	N_2O	0.02	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	CH_4	6.91	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	NO_X	50.00	g/kg fuel	IPCC (1997)
	NMVOC	6.50	g/kg fuel	IPCC (1997)
	CO	15.00	g/kg fuel	IPCC (1997)
	SO_2	20.00	g/kg fuel	IPCC (1997)
Transportation of log to company (diesel used) + mk (Sawmill operations and internal transport diesel used)	CO_2	3180.00	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	N_2O	0.10	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	CH_4	0.20	g/kg fuel	Schwaiger and Zimmer (1995); Jawjit (2006)
	NO_X	29.80	g/kg fuel	IPCC (1997)
	NMVOC	4.70	g/kg fuel	IPCC (1997)
	CO	14.00	g/kg fuel	IPCC (1997)
	SO_2	20.00	g/kg fuel	IPCC (1997)
Electricity use fossil-fuel/Thermal energy	CO_2	77.40	ton/TJ	IPCC (2010)
	CH_4	2.00	kg/TJ	IPCC (2010)
	N_2O	0.60	kg/TJ	IPCC (2010)
	NMVOC	5.00	kg/TJ	IPCC (2010)
	CO	10.00	kg/TJ	IPCC (2010)
	NO_X	200.00	kg/TJ	IPCC(2010)
	SO_2	1194	kg/TJ	IPCC(2010)

produced from an output of Khaya lumber line. $$Emission = Activity \times Emission\ Factor \qquad (1)$$ Impact Category Indicator = Emission (inventory data) ×

Classification Factor (2)

Selecting impact assessment categories

Assessing likely methodologies

A detailed environmental performance classes were examined. The literature review revealed that the LCIA approaches are based on the environmental issues in western nations and characterization methodologies that relate how these issues are seen in the western world (Eshun et al., 2011). Several life cycle impact assessment (LCIA) methods in life cycle assessment (LCA) are established for western nations. Their LCIA methods and characterization methodologies for diverse performance classes may not be important to African environmental situations, especially not for Ghana. LCA study on timber output does not only include foreground data on timber and production procedures; other local inputs and products are also included to fully stand for the entire output system or life cycle. The evaluation of LCIA approached and characterization factors in LCA works are shown in Table 2 and Figure 1.

Characterization method used for diverse performance classes cannot be important to African tropical environmental situations (Eshun et al., 2011). Review of LCIA and characterization methods reveal that CML-2000 is the highest utilized and most accepted internationally; it is a known impact method in LCAs of timber outputs. CML-2000 utilizes mid-point signs that are apparent in the core visible modeling. This work uses the CML-2000 method for assessing this environmental performance.

Table 2 shows that the scientifically well-known CML 2000 method to Life Cycle Inventory (LCI) was examined from which the effect classes applied in this work were selected including global warming, acidification, eutrophication, and photochemical oxidant formation.

Global warming

Greenhouse gases are the major contaminants that contribute to global warming problem, and they are conveyed as Global Warming Potentials (GWP). The GWP is an index of aggregate radiative forcing between the present and some chosen later time horizon caused by a unit mass of gas released, expressed relative to the reference gas CO_2 (1 kg CO_2) (Houghton, 1996). The burning of fuels for producing Khaya lumber is the main source of these gases.

Acidification

The process of producing of Khaya lumber leads to acidifying agents. The burning of fuel in producing Khaya is the major source of NO_x discharge. Acidification is the number of protons discharged into land/marine system. The categorization factors of acidification potential (AP) are regularly given either as moles of H^+ or kilograms of SO_2 equal (Heijungs, 1992). The latter is utilized in this work.

Eutrophication

The use of these contaminants to enrich the water and soil (Nitrogen Oxides (NOx)) can result in unwanted swing in the structure of species in the ecologies, which is known as eutrophication. Many models have been used for the characterization of what life-cycle inventory data contributes to eutrophication. Heijungs et al. (1992) proposed a well-recognized model for calculating the nutrification potential (NP) of discharges

based on the reference compound PO_4^{3-}.

Smog

The burning of petrol when Khaya is produced and transported lead to the discharge of VOCs, CO, CH_4 and NO_x, seen as tropospheric ozone precursors. Photochemical Ozone Creation Potentials (POCPs) help in assessing comparative contribution of diverse organic compounds to tropospheric ozone creation. The classification factor value of POCPs is from Goedkoop (2000) (PReConsultants, Amersfort, the Netherlands) that created the Eco-indicator 95.

Human toxicity

In the timber sector, the discharges of particulates, SO_2, and NO_x are important contaminants contributing to human harmfulness issue. The human toxicity potential (HTP) is an index reflecting the possible damage of a unit of chemical discharged into the environment; it is related to the natural harmfulness of a compound and its likely dosage. Classification factors in this environment are obtained from CML (2002).

RESULTS AND DISCUSSION

Analysis of life cycle inventory (LCI)

The three firms gave data about the use of their resources and power needed to operate in 2013. The data obtained were changed firstly into overall yearly mean values and then related as operational unit based on their products in capacity. Discharges for the many works were obtained from literature.

Application of the selected LCIA approach for LCA study

Here, CML 2000 is applied to the LCI results of the survey for characterizing the performance classes of Global Warming, Acidification, Eutrophication, Photochemical Oxidant Formation and Human Toxicity. Table 2 shows the CML-2000 characterization factors utilized for these performance classes. Passage for acidification, another generic acidification potential was utilized which fully measures the acidifying ability in African condition, than that in CML-2000 which selects site and is European baseline method (Hauschild and Potting, 2005). Characterizing biodiversity for the timber industry is now established and thus not used in this work.

To compare the discharges in Table 2 can be hard because of the diverse units utilized for the different performance classes. But, the mean results for all the three firms were utilized as a standard to be used to compare (Figure 1). From the results, company C had the least value of GWP due to low current constituent of generating power use in comparison to companies A and B. In general, for the other performance classes

Table 2. Evaluation of LCIA methods and characterization factors in LCA studies.

Impact category	EDIP-97 (Wenzel et al., 1997)	CML baseline-2000 (Guinée et al., 2000)	Eco-indicator-95 (Goedkoop, 1995)	Eco-indicator-99 (Goedkoop and Spriensma, 2000)
Global warming	kg CO_2 eq	kg CO_2 eq	kgCO_2	DALY
Ozone layer depletion	kg CFC 11 eq	kg CFC 11eq	kg CFC 11	DALY
Acidification	kg SO_2 eq	kg SO_2 eq	kg SO_2	PAF×m^2year
	mole of H^+ eq	-	-	-
Eutrophication	kgNO_3 eq	kg PO_4 eq	kg PO_4	PAF×m^2year
Photochemical oxidant	kg C_2H_4 eq	kg C_2H_2 eq	kg C_2H_4	kg C_2H_4
Ecotoxicity	m^3 in water	kg 1,4 DB eq	PAF×m^2year	PAF×m^2year
Human toxicity	m^3 in air	kg 1,4 DB eq	-	-
Carcinogens	-	-	kg B (a) P	DALY
Respiratory organics/inorganics	-	-	DALY	DALY
Land use	-	-	-	PDF×m^2year
Solid waste	kg	-	kg	-
Abiotic resources depletion	-	kg Sb eq	-	-
Energy Resources	-	-	MJ LHV	MJ Surplus

DALY=Disability Adjusted Life Years, PDF=Potentially Disappeared Fraction, PAF=Potentially Affected Fraction.

companies A and B had higher discharge rates of AP, EP, POCP and HTP. The environmental performance linked to producing Khaya lumber in the three firms is primarily run by using fossil fuels.

Global warming potential (GWP)

An average of 253 kg CO_2-equivalents of greenhouse gas is discharged per cubic meter in kiln dried Khaya lumber produced in Ghana (Table 2). Considering the activities that produce greenhouse gases, electricity is the first (42%). The second is diesel utilized in harvesting Khaya timber, with impact of 27% next to diesel utilized in transporting Khaya timber to sawmill (21%).

According to these data, it is obvious that the global warming potential (GWP) is highly linked to using fossil fuel (Figure 1). Electricity utilized to generate current, harvest Khaya timber and transport logs over long distances, bad roads and poor haulage trucks in Ghana cause the use of high diesel. The best environment for reducing high diesel use is the use of green energy technology like solar, wind and hydropower, while re-locating factories near forest source of timber or conveying the timber by rail.

Acidification potential (AP)

The mean potential acidification impact from Khaya lumber produced in Ghana is 3.9 kg SO_2-eq for a cubic meter (Table 2). Considering the contributors of the overall acidifying discharge, diesel used to generate power contributed 46%, the largest amount next to diesel used for harvesting Khaya timber (30%) (Figure 1).

Eutrophication potential (EP)

The average eutrophying impact was up to 2.6 kg PO_4-eq for a cubic meter (Table 2). Of all the eutrophying compounds NO_X contaminants released when Khaya timber is harvested using diesel contributed 52%, next to diesel used for transporting Khaya timber to sawmill (24%) (Figure 1).
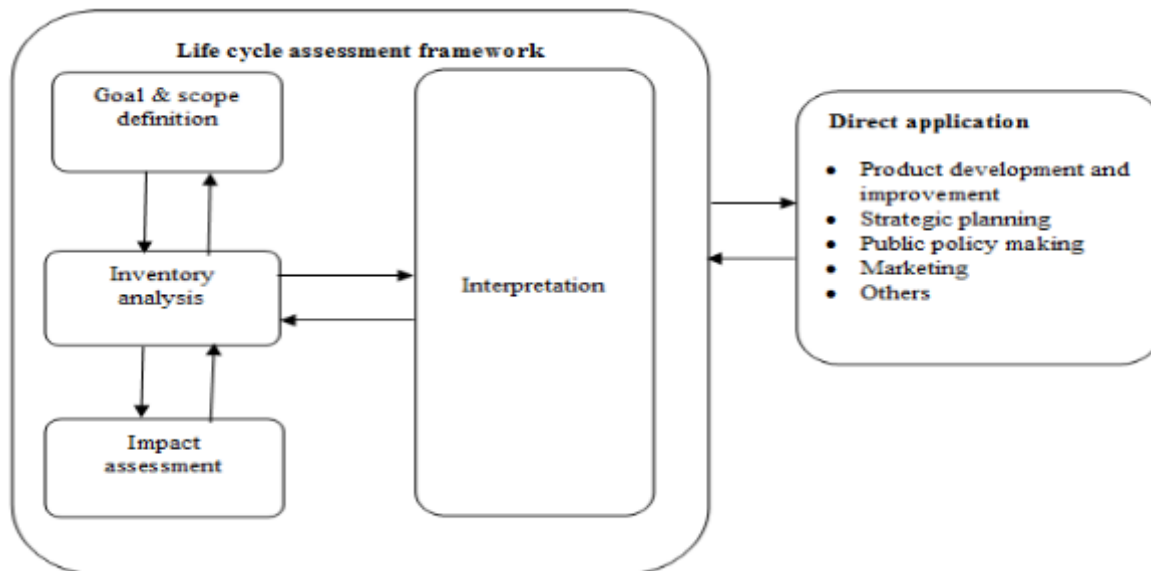
Figure 1. The phases of an LCA according to ISO 14044 (2006).

Photochemical ozone creation potential (POCP)

The potential impact of tropospheric ozone precursor compounds is 0.56 kg ethylene-eq for a cubic meter (Table 2). The smog problem had two main important sources: gasoline used to harvest Khaya timber and diesel used to harvest Khaya timber. Gasoline for harvesting Khaya timber came first (68%). The second is the diesel used to harvest Khaya timber having comparative discharge of 17%.

Human toxicity (HT)

The possible human harmfulness effect is 2.6 kg $C_6H_4Cl_2$-eq per a cubic meter. The diesel used in harvesting Khaya timber which is the main source of human toxicity compound constitutes 49%, next to diesel used to transport Khaya timber to sawmill (24%).

Assessing the carbon footprint for Ghanaian Khaya lumber in line with the PAS2050 methodology

Carbon footprint is a new concept for global warming potential and is referred to the overall greenhouse gas discharges linked to a product or service (Chaplin-Kramer et al., 2015).

Discharges of diverse separate greenhouses gases are changed to global warming potential and related in the common unit of CO_2-equivalents. The CO_2 discharge to determine the carbon footprint of product can be got from a complete LCA work. In Table 2, the mean GWP of 253 kg CO_2- equivalent can be considered as the carbon footprint for one cubic meter of Khaya lumber manufactured in Ghana.

Environmental product declaration (EPD) for Ghana Khaya lumber

Environmental product declarations are standard documents for communicating the environmental impact of a specific output using LCA. In Table 2, the mean environmental performance of Khaya lumber made in Ghana per cubic meter based on GWP was 253 kg-CO_2-Eq; AP, 3.9 kg SO_2-Eq; EP, 2.6 kg Phosphate (PO_4)-Eq; POCP, 0.56 kg Ethylene-Eq, and 2.65 kg $C_6H_4Cl_2$.Eq. GWP, AP, EP and POCP were in line with the Life Cycle Impact Assessment (LCIA) results for 1 m^3 rough-sawn, kiln dried US lumber cradle to gate for 19 different species including the LCA results for environmental product declaration of tropical plywood produced in Malaysia and Indonesia (AHEC, 2009; Gan and Massijaya, 2014).

Based on all the possible environmental signs noted in this LCA work of Khaya lumber manufactured in Ghana, it can be said that Khaya lumber output controlled from a viable tropical natural forest does better in Ghana environmentally.

Limitations

The main limitation in this work was time and budget. This assessment results are to be utilized based on the set goal and area of this work. Omitting some life cycle impact classes can lead to unfinished picture of the total

performance of the products. For instance, biodiversity and potential of ozone depletion were not studied in this LCA works because there is no advanced and steady method in Africa and precisely in Ghana. Biodiversity and Ozone Depletion Potential and Biodiversity performance of hardwood production need to be studied again as novel and dependable methodologies exist. The categories factors utilized like global warming potentials (GWPs), acidifying and eutrophying potentials are not certain as these values were not created in Ghana or on Ghanaian-based data, though GWPs are mostly utilized and accepted as category factor for greenhouse gases (IPCC, 1997). The category factors utilized to calculate the PO_4-equivalents of eutrophying discharges are less utilized and depend on many suppositions (Heijungs et al., 1992). PO_4-equivalents are widely utilized in LCA work to note the gross impact of eutrophication despite the site of the discharges. Eutrophication is an environmental issue with mainly local impacts, and the eutrophication potentials can vary when eutrophication is taken as a local issue. Discharges that contribute to OPD were not looked into because there are no data in Ghana. Irrespective of the constraints, the predicted discharge and possible environmental effect shown here is the best available now and, thus served the aim of this work.

Conclusions

Life cycle assessment was utilized for the assessment and evaluation of the environmental impact of the Khaya lumber made in Ghana. Based on the results, the mean environmental performance of Khaya lumber made by three (3) firms in Ghana per cubic meter regarding GWP was 253 kg-CO_2-Eq; AP, 3.9kg SO_2-Eq; EP, 2.6 kg Phosphate (PO_4)-Eq; POCP, 0.56 kg Ethylene-Eq. The GWP, AP, EP and POCP were in line with the results of LCIA for 1 m^3 rough-sawn, kiln dried US lumber cradle to gate for 19 diverse species including the LCA results for environmental product declaration of tropical plywood produced in Malaysia and Indonesia. The results show that the environmental performance linked to Khaya lumber produced in Ghana is mostly caused by using fossil fuels. Using renewable energy sources for generating power is an alternative with good prospects against using fuel, forest activities and transporting of timber. The high return of power in timber unlike energy use in forest management makes timber a very interesting energy carrier (Lindholm and Berg, 2005). Also, to make better the environmental impact of Khaya lumber produced in Ghana, firms can decrease diesel use by trucks and improving transport systems like rail system and material flow in the production process to decrease internal transport (Kätelhön et al., 2015).

Wood drying using solar energy powered with high frequency inverter is also a better environmental improvement for kiln drying of Khaya lumber. Wood waste is a serious matter and needs fast consideration.

This can be altered to Environmental Product Declaration use in terms of the selected scheme or Product Category Rules. It is concluded that Khaya lumber made in Ghana which is managed from a sustainable tropical natural forest does better environmentally. All data utilized in this work to measure the discharges and possible environmental effect is taken as the best data now and, thus served the aim of the work.

This work gave excellent primary data distinctive for LCA research in Africa. This can facilitate LCA methods in Ghana, and help to identify the core environmental stresses and their major contributing processes in the timber sector.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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