JEE Journal of Ecological Engineering
Volume 20, Issue 6, June 2019, pages 153–160
https://doi.org/10.12911/22998993/108637

Received: 2019.03.08
Revised: 2019.04.15
Accepted: 2019.05.06
Available online: 2019.05.20

A Study of the Smallholder Coffee Agroindustry Sustainability Condition Using the Life Cycle Assessment Approach in Bengkulu Province, Indonesia

Hamdan[1*], Anas Miftah Fauzi[2], Meika Syahbana Rusli[2], Ernan Rustiadi[3]

[1] Department of Natural Resources and Environmental Management Sciences, IPB University, West Java, Bogor, 16680, Indonesia

[2] Department of Agroindustrial Technology, Faculty of Agricultural Engineering and Technology, IPB University, West Java, Bogor, 16680, Indonesia

[3] Department of Regional Planning Sciences, Faculty of Agriculture, IPB University, Bogor, 16680, Indonesia

* Corresponding author's e-mail: hamdankasyirha@gmail.com

ABSTRACT

The management of smallholder coffee plantations in Bengkulu Province has not yet conducted according to good agricultural practices. As a result, the productivity and quality of green beans produced are also low. The efforts to improve this condition need to be made in order to maintain the economic, social, and environmental sustainability of this agribusiness. The present study aimed at identifying the life cycle of the coffee agroindustry in supporting sustainable agriculture using the Life Cycle Assessment (LCA) method. The results of the study revealed that the energy input from the use of fertilizers, herbicides, manpower, and fossil fuel was 4349.08 MJ/ha. The energy output from the green beans and coffee husks was 9763.39 MJ/ha and 13524.21 MJ/ha, respectively, so the efficiency based on the input-output ratio was 5.35. The emission values to the global warming potential, acidification, and eutrophication were 109.43 kg eqCO_2, 345.70 g SO_2eq/ha/year, and 28.54 g PO_4^{3-}eq/ha/year, respectively. The coffee agribusiness in Kepahiang Regency is categorized as organic. The coffee agribusiness was economically feasible with a Net B/C of 2.87, but the land ownership which was 1.45 ha/household and the present agribusiness conditions indicate a low sustainability rate.

Keywords: Bengkulu, green bean, husk, life cycle assessment, robusta

INTRODUCTION

The Bengkulu Province is the sixth largest coffee producer in Indonesia after South Sumatra Province, Lampung Province, Aceh Province, North Sumatra Province, and East Java Province. Bengkulu's coffee production reached 56434 tons, which were dominated by Robusta (97.35%) [Central Statistical Office, 2018]. The largest coffee producers are Kepahiang Regency and Rejang Lebong Regency. The coffee production of these two regencies amounted to 32074 tons of green beans or 56.31% of the Bengkulu Province's total production [Central Statistical Office, 2017].

Smallholder coffee plantations apply the monoculture cultivation system with shade trees. The management, which is not yet intensive, contributed to low plant productivity, reaching only 747.04 kg/ha [Central Statistical Office, 2018]. The application of cultivation technology could increase the coffee productivity, for example, fertilizing using compost and non-compost would result in productivity of 1848.35 and 1200.93 kg/ha [Kiyingi and Gwali, 2012], irrigation and fertilizing result in 960 kg/ha [Babou et al., 2017], and applying a planting distance would yield 1289.50 kg/ha [Anim-Kwapong et al., 2010].

Other challenges faced by the industry are climate change issues and the environmental impact of an unsustainable production. According to Panhuysen and Pierrot [2014], approximately 40% of the global coffee production has fulfilled

Voluntary Sustainability Standards (*VSS*) such as 4C Association, Fairtrade International, Organic, Rainforest Alliance/SAN and UTZ Certified. According to Ibnu et al., [2018] farmers and farmer groups that are certified receive a higher income than the uncertified farmers and farmer groups. Another requirement that needs to be fulfilled is the traceability of the coffee product from the original source to the consumers' pantry. Certification is related to the market access and the premium price of the coffee product, although other factors such as flavor also have an effect. The present study was conducted primarily to create the profile of the coffee cultivation environment in Bengkulu Province as the basic criterion for the coffee agribusiness sustainability. The purpose of the present study was to identify the condition of the smallholder coffee agroindustry sustainability in Bengkulu Province using the Life Cycle Assessment method.

METHODOLOGY

The present study was conducted in Kepahiang Regency, Bengkulu Province from October to December 2018. This regency lies between 101°55'19"-103°01'29" E and 02°43"07"-03°46'48" S with an altitude of 250-1600 meter above sea level. Kepahiang Regency has a tropical climate with a precipitation rate of 3768 mm/year with up to 286 days of rain per year [Central Statistical Office, 2018]. The data were collected through in-depth interviews and questionnaires. The respondents of the present study included 110 people, consisting of farmers, the coffee mill industry, and regency-level middlemen.

The Life Cycle Assessment (LCA) method

The LCA methodology consists of four components/phases based on ISO 14040:2006, namely: goal and scope definition, life cycle inventory analysis, life cycle impact assessment, and life cycle interpretation.

Goal and scope definition

This LCA study of smallholder coffee agroindustry was conducted to discover the flow of materials, energy, and environmental impact of the green bean production process. The processing phases that were analyzed consisted of nurturing and harvesting, pulping, drying, hulling, and sorting. The energy input consisted of manpower, fertilizer, herbicides, and transport and processing fuel (gasoline and diesel).

Inventory analysis

The data collection process was the main focus of the inventory analysis. In this phase, the input and output that were related to the system of coffee agroindustry were identified and measured in function units. All the function units were converted to energy units. In this phase of inventory analysis, in addition to calculating the energy input and output, the atmospheric emission analysis was also conducted. The equation used to calculate the fuel consumption and manpower energy was as follows [Ezema, 2015]

$$E_{TM} = Q_F[LHV] \quad (1)$$

where: E_{TM} is the use of transport and processing machinery energy in megajoules (MJ);
Q_F is the amount of materials used in liters (L);
while *LHV* is the coefficient of material burning energy (MJ/L).

The LHV value used the standard established by the Ministry of Environment (KLH): solar = 36 MJ/L and premium gasoline 33 MJ [Ministry of Environment, 2012]

$$E_H = 0.75\ LT \quad (2)$$

where: E_H is manpower energy in MJ, 0.75MJ/hour is the manpower energy coefficient,
L is the number of laborers (persons), and
T is the number of work hours (hours).

The value of L in the present study was calculated as work days and the number of working hours 7 hours/day. The workday value of women was equivalent to 0.8 of men's.

$$E_{FH} = Q_{FH}\ (CF) \quad (3)$$

where: E_{FH} is the use of energy from fertilizers and herbicides (MJ/kg);
Q_{FH} is the amount of fertilizers and pesticides (kg);
CF is the fertilizer's energy conversion factor.

The CF value of urea (46% N)= 51.6 MJ/kg; TSP (46% P_2O_5)=30.25 MJ/kg; MOP (64% K_2O)=10.06 MJ/kg [Skowrońska and Filipek, 2014]; herbicides = 386 MJ/kg [Audsley et al., 2009].

The output of the coffee agroindustry includes green beans, coffee husks, and emission from the use of fertilizers, herbicides, and fuel. The energy produced from the green beans and coffee husks was 13.24 MJ/kg and 18.34 MJ /kg, respectively [Wilson et al., 2009]. The GRK emission from the burning of fuel was as follows:

$$\textit{Emission (kg/year)} = \textit{Energy Consumption (TJ/year)} \times \textit{Emission Factor (kg/TJ)} \quad (4)$$

The GRK's emission factor used the Ministry of Environment standard, 69300; 33; 3.2 kg/TJ premium gasoline, 74100; 3; 0.6 kg/TJ non-mobile diesel source, and 74100; 3.9; 3.9 kg/TJ mobile diesel source [Ministry of Environment, 2012]. The value for each gas was then converted to its equivalent in CO_2 using the BioGrace standard [2018], 23 for CH_4 and 296 for N_2O. The conversion of the emission standard of the use of fertilizers and pesticides are presented in Table 1.

Assessment of Environmental Impact (Life Cycle Impact Assessment)

The significance of the potential environmental impact of the production system based on the inventory results of the life cycle was evaluated using the LCIA. The LCIA consisted of a number of elements, classification (global warming, eutrophication, and acidification), characterization (CO_2-eq, PO_4^{3-}eq, SO_2), normalization, and weighting. Out of the four elements, normalization and weighting are considered optional, whereas the first two elements are obligatory elements in the LCIA.

Result interpretation (Life Cycle interpretation)

The results of the life cycle inventory analysis and assessment of life cycle impact were analyzed with consideration of various aspects such as completeness, sensitivity, and consistency. The main issues in this context could mean the key processes, materials, activities, and components or even the life cycle phase. This analysis enabled to draw a conclusions and give recommendations in relation to the environmental aspect of the product, the areas where improvements are possible or major information about the environment could be communicated to the consumer were made according to the propose of the LCA study. There are three key elements in interpreting the life cycle, as defined by ISO 14043. The first is the identification of key issues, the second is evaluation (including checking for completeness, sensitivity, and consistency), and the third is drawing conclusion, together with making recommendations.

The Economic and Social Sustainability Factor

The economic sustainability status was calculated based on the agribusiness feasibility with a profit and cost ratio approach (B/C). The social sustainability was determined by the coffee agribusiness profit ratio between the farmer household consumption per capita and job opportunity creation. The consumption per capita value was assumed to be equivalent to the poverty line in Kepahiang Regency, IDR 348,238/month [Central Statistical Office, 2018].

RESULTS AND DISCUSSION

The smallholder coffee Life Cycle

The production of green beans ranged between 120 and 2700 kg/ha with an average of 737.42 kg/ha. The difference in production was influenced by the plant characteristic, land, and plant management. The coffee processing (the drying process) was conducted naturally by sunlight. This method yields an equal amount of green beans and coffee husks, i.e. 50%, with a moisture content of approximately 21%. Similar results were reported by Chala et al. [2018], while Cruz and Crnkovic [2015] reported a ratio of 45% : 50%.

The next step involves the green bean-sorting, which is conducted by the regency-level middlemen. In this process, the results are defects in the form of husks, spoiled or damaged green beans, contaminants, and dry beans. The dry beans composition is 1% and these are re-hulled into green beans. The sorting process is conducted manually using human labor. The sorting results are also sold as raw material for the ground coffee industry in Kepahiang Regency.

The product transport begins at the plantation to the farmer's house using a motorcycle with an average distance of 27 km and a capacity of 150 kg per trip. The average number of trips with a motorcycle was 14.75 times per season and fuel consumption was 15 km/liter gasoline. After the drying process, the coffee beans are transported to the *huller* to be hulled using a pickup truck with a capacity of 2000 kg. Finally, the green beans are

Table 1. The emission conversion factor for fertilizers and pesticides per kilogram input

Type of input (kg)	Emission conversion factor (g)			Eutrophication	Acidification
	CO_2*)	CH_4*)	N_2O*)	$gPO_4^{-3}eq$**)	gSO_2eq/kg**)
N-fertilizer	2827.0	8.68	9.64	0.54	5.3
P_2O_5-fertilizer	964.9	1.33	0.05	0.74	8.1
K_2O-fertilizer	536.3	1.57	0.01	0.30	7.2
Pesticides	9886.5	25.53	1.68	-	-

Sources : [*BioGrace, 2018; ** Skowrońka and Filipek, 2014]

transported to the regency-level middlemen over an average distance of 10 km.

The coffee agroindustry inventory analysis

The inventory database development began with the phase where all the resources and materials used in the entire cycle, consisting in cultivation, transport, and process, are inventoried. The total energy input of the coffee agroindustry was 4349.08 MJ/ha or 5.90 MJ/kg green beans (Table 2). The energy input was lower than that in Brazil, i.e. 9.30-13.14 MJ/kg [Coltro et al., 2012]; 26.97 MJ/kg [Veiga et al., 2015]. The cultivation cycle used the greatest amount of energy input, 3511.48 MJ (75.01%), which originated from fertilizers and herbicides. Similar results were demonstrated in the study by Veiga et al. [2018], at 82%. The energy input for transport, process, and human labor were 404.97 MJ (9.31%), 321.42 MJ (7.39%), and 360.63 MJ (8.20%), respectively.

The low energy input from fertilizers resulted from the low usage rate and dosage. The total number of respondents who applied fertilizers was 61 people (55.88%), while the number of those who applied herbicides was 91 people (82.35%). The types of fertilizers used were urea, SP-36, and NPK-Phonska. The amount of herbicides required was between 1 and 8 liters/ha with an application frequency of three times a year.

The biomass energy output of the coffee agroindustry was 23.29 GJ/ha, originating from the green beans and coffee husks. On the basis of the input-output of energy, the net energy was found to be 18.94 GJ/ha and the energy investment return was 5.35 times. According to Elhami et al. [2016], if the ratio between the output and the input is greater than one, then the energy use is efficient. Energy efficiency strongly affects the emission level; the higher the efficiency, the lower the environmental impact potential will be. The flow of energy and materials in the coffee agroindustry is presented in Figure 1.

Environmental impact assessment

On the basis of Table 2, the global warming potential in the on-farm coffee agroindustry loop was 109.43 kg CO_2eq/ha or 0.12 kg CO_2eq/kg of green bean. This is lower than that of coffee plantations in Costa Rica and Nicaragua, at 0.26-0.67 kg CO_2eq/kg for conventional farming and 0.12-0.52 kgCO2eq/kg for organic farming

Table 2. The Life Cycle Inventory of the coffee agribusiness per hectare in 2018 in Kepahiang Regency, Bengkulu, Indonesia

Inventory	Volume	Energy value (MJ)	Emission (kg/ha)			Global warming potential ($kgCO_2eq$)
			CO_2	CH_4	N_2O	
Labor (HOK)	68.69	360.63	-	-	-	-
Fertilizer (kg)						
- Urea	20.50	1701.71	27.82	0.13	0.15	74.14
- SP-36	1.49	412.77	1.06	1.46E-03	3.31E-04	1.19
- NPK-Phonska	38.28	90.25	3.08	3.85E-02	3.01E-04	4.05
Herbicides (L)	2.74	1 057.32	27.08	6.99E-02	4.61E-03	30.05
Transport (L)						
- Plantation (gasoline)	9.97	329.01	2.28E-5	1.09E-08	1.05E-09	2.34E-05
- Huller (diesel)	0.88	31.68	2.35E-6	3.17E-10	1.90E-11	2.36E-06
- Middlemen (diesel)	1.23	44.28	3.28E-6	1.73E-10	1.73E-10	3.34E-06
Processing machinery (L)						
- Pulping (gasoline)	1.70	56.10	3.89E-6	1.68E-10	3.37E-11	3.90E-06
- Hulling (diesel)	7.37	265.32	1.97E-5	2.65E-09	1.59E-10	1.98E-05
Total		4349.08	57.48	0.19	0.10	109.43

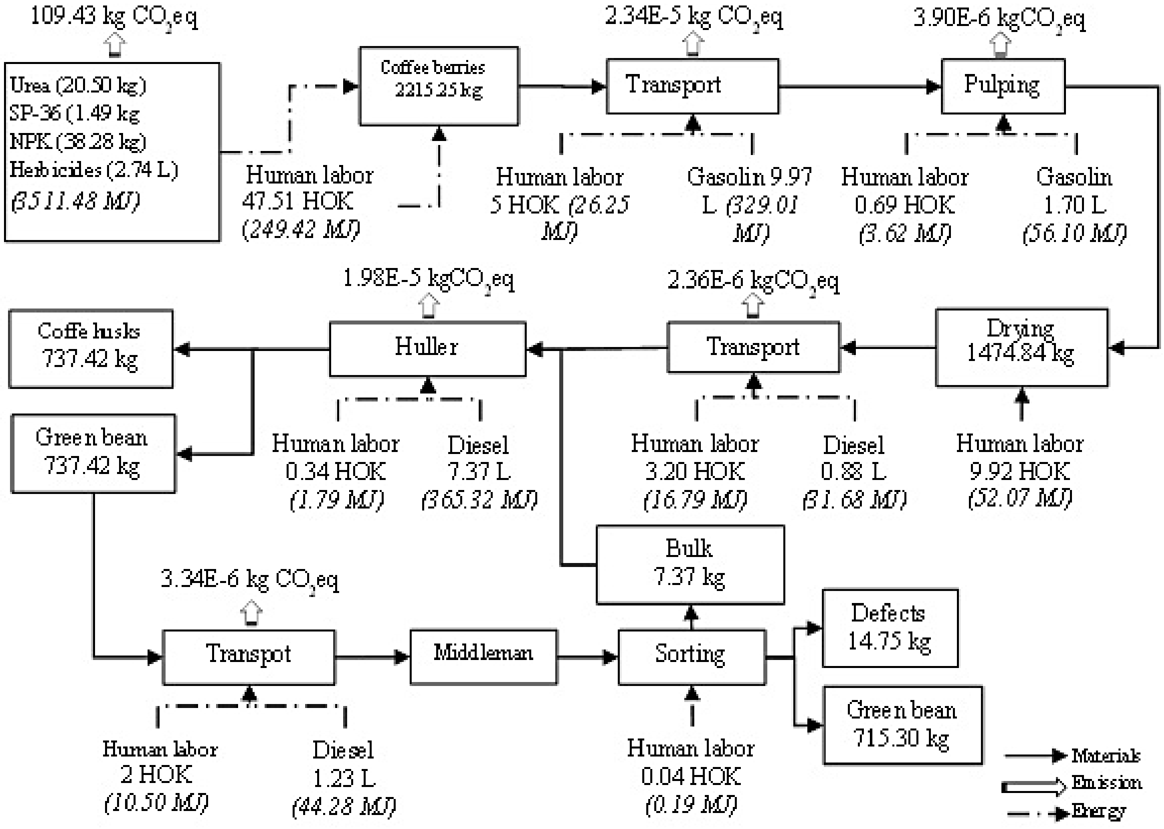

Figure 1. Life Cycle Inventory of the coffee agroindustry in Bengkulu,Indonesia

[Noponen et al., 2012]. A higher emission was reported by [Killian et al., 2013], 1.77 kg CO_2eq/kg. The main sources of emission were fertilizers and herbicides, at 79.38 kg CO_2eq/ha (72.54%) and 30.05 kg CO_2eq/ha (27.46%), respectively. Transport and processing each produced 2.91E-05 kg CO_2eq/ha/year and 2.37E-05 kg CO_2eq/ha/year GRK emission.

Another environmental impact is the acidification of water and soil; it occurs due to the emission of NH_3, NO_x, and SO_2 gases from the urea, SP-36 and NPK-Phonska fertilizers at 345.70 g SO_2eq/ha/year, whereas the leaching and over-enrichment of waters (eutrophication) was 28.54 g PO_4^{3-}eq. The potential for acidification and eutrophication from smallholder coffee plantations in Kepahiang Regency was classified as high. According to Vera-Acevedo et al., [2016] the potential for acidification and eutrophication from chemical fertilizers in conventional farming in Cauca, Argentina was 2.14 E-03 kg SO_2-eq and 9.10 E-03 kg PO_4-eq/kg of green beans, while in organic farming using compost it was 1.07E-03 kg SO_2-eq and 6.20E-02 kg PO_4-eq/kg coffee.

The potential for environmental impact from the use of urea fertilizer is high due to the loss of nitrogen through the conversion of nitrate into gaseous form (de-nitrification) and the change from ammonium into ammonia gas (volatilization). According to Borbos-cordova et al. [2006], the loss of N due to de-nitrification is 25% and due to volatilization – 20%. The application of fertilizers by spreading onto the surface of the soil and the lack of any efforts to improve the physical and chemical characteristics of the soil by applying organic fertilizer would increase the potential for environmental contamination.

The management of coffee husks in the hulling industry is another source of emission in the processing phase, because piled up coffee husks are usually burned or thrown into rivers. The low utilization of coffee husk waste is also an issue for the coffee producing countries, as reported by Pauline et al. [2010], who stated that the coffee husks from smallholder coffee plantations in Cameroon were accumulated at mill level and had contaminated groundwater, caused ecological imbalance, and fires.

Reducing the environmental impact

Inorganic fertilizers and herbicides are the main sources of emission in the smallholder coffee agroindustry. The application of inorganic fertilizer by spreading it on the surface of the soil without any cover causes a large amount of nutrient loss. Improvement of the effectiveness of nutrient absorption and the physical and chemical condition of the soil could be done by using organic fertilizer from coffee husks. According to Baon and Wibawa [2005], an increase in the organic content of soil could maintain the productivity and production sustainability. A study by Falahuddin et al. [2016] revealed that the organic fertilizer from coffee husks contributed to maximum growth in coffee plants.

The coffee cultivation using the shade system requires a very small amount of nitrogen from fertilizers, it could even be considered negligible because the plant roots can absorb it directly from the air. Ecosystem balance is the key to the natural cycle in coffee plantations. Stable environmental conditions would create a haven for natural predators of pests and diseases such as birds, frogs, and reptiles. Mechanic weed control needs to be introduced to reduce the use of herbicides. Many farmers use herbicides with paraquat as the active ingredient, even though this chemical has been banned in the USA since 1970. The World Health Organization classified paraquat as a fairly dangerous herbicide and class II poison for acute toxicity [World Health Organization, 2009].

The problem in utilizing coffee husks as a fertilizer is the considerable distance between the coffee huller and the plantations . Most hullers are located close to settlements, so transporting coffee husks is a financial burden for farmers. In addition, emission from the burning of coffee in most hullers and the small particles (particulate matter) produced could be hazardous for the health of adjacent communities. Building hullers closer to coffee plantations needs to be considered for the sustainability of the agribusiness.

The coffee agroindustry economic and social sustainability

The coffee plantations are replanted using a replanting system, where the plants are rejuvenated every four years known as the "kapak kulai" system. This method is chosen because during the replanting process the plants can still produce. Agribusiness production and income are presented in Table 3.

On the basis of Table 3, the agribusiness income originated from the sales of green beans at an average price of IDR 19,969/kg. The cost structure of the agribusiness consisted of labor at 2.87 million/ha (70.90%), fertilizers and herbicides at 0.60 million/ha (14.46%), processing at 0.37 million/ha (9.10%), and transport at 0.21 million/ha (5.14%). The requirement of labor was 68.69 workdays/ha, especially those from the household and non-family members at 59.27 workdays (86.29%) and 9.42 workdays (13.71%), respectively. The wages for farmhands was IDR 75,000/day in the form of cash and lunch money. The benefit-cost ratio (B/C) of the coffee agribusiness was 2.87 at a reference interest rate of 5.75%. This means that the coffee agribusiness is feasible because it could be profitable in the future.

On the basis of the average land ownership which was 1.45 ha/household, the consumption which was IDR 348,238/capita/month, and the number of household members which was 4, the coffee agribusiness fulfilled 95.21% of the farmer household's basic needs. However, if the family member labor is not included in the calculations, the income from the agribusiness could fulfill 111% of the consumption needs. Increasing the farmers' welfare could be done by increasing the size of the plantations to 1.52 ha/household. Another scenario to improve farmer welfare is by increasing production by 50% to reach 1106.12 kg/ha, so that it could fulfill 103% of the farmer household needs.

Table 3. The production (kg/ha), revenue, cost, and benefit (Million IDR/ha) of the coffee agribusiness in 2018 in Kepahiang Regency, Bengkulu Indonesia

Year	Production	Revenue	Cost	Benefit	B/C
1	233.73	4.72	2.16	2.55	1.18
2	571.63	11.60	3.14	8.45	2.69
3	785.61	15.89	3.79	12.11	3.20
4	1338.69	26.69	5.89	20.80	3.53
Average	737.42	14.73	3.75	10.98	2.65

There are two scenarios that could be implemented to improve the farmer's welfare. The first is increasing production. The gap between coffee potential and coffee production is still wide, reaching approximately 60% [Wahyudi and Jati, 2012]. Moreover, the results of the study by Hareesh et al. [2017]; Isaac and Gwali [2012] revealed higher productivity with organic fertilizers, 1101 kg/ha and 1848.35 kg/ha. The scenario that could be implemented is improving the quality of the plants by grafting using superior scions. Bengkulu Province has 11 superior coffee clones with a productivity of 1073.3-1871 kg/ha [Halupi, 2012]; four of which have been launched as superior varieties: Sehasence, Sintaro 1, Sintaro 2, and Sintaro 4 [Oetami, 2017].

The second solution is to improve the coffee quality. This is done through the selection of superior clones, soil conservation, plant maintenance, harvesting red coffee berries, and wet-processing to produce premium coffee. The issue faced by farmers in the production of premium coffee is the lack of market access. Therefore, an effort to receive certifications such as the fair trade or organic certifications needs to be made so that the green beans produced could be exported for a better price. According to Valkila [2009], the production of fair trade-certified organic coffee could increase the farmers' income.

CONCLUSION

The coffee agroindustry in Kepahiang Regency is classified as an export-oriented production system. This influenced the life cycle of the coffee product, which commonly consists of cultivation, process, and transport. The cultivation loop used most of the energy input which originated from fertilizers and herbicides, followed by the transport and process loop in which the energy is obtained from the fossil fuels combustion. The potential for environmental impact due to the GRK emission was lower than that of other coffee-producing countries, while acidification and eutrophication were higher because of the inappropriate use of fertilizers and excessive use of herbicides. The coffee agribusiness was not yet able to fulfill the farmer household's basic needs, even though it fulfilled the criteria for economic feasibility. Improving the welfare of farmer households can be done by increasing the coffee production and enhancing the quality of certified coffee.

Acknowledgments

The author would like to thank the Indonesia Agency for Agricultural Research and Development Ministry of Agriculture that had provided a scholarship. Deepest gratitude is also conveyed to all the respondents in Kepahiang Regency who were involved in the present study.

REFERENCES

1. Anim-Kwapong G.J., Anim-Kwapong E., Oppong F.K. 2010. Evaluation of some robusta coffee (Coffea canephora pierre ex a. Froehner) clones for optimal density planting in Ghana. African Journal of Agricultural Research, 5(1), 84–89. https://academicjournals.org/article/article1380800006_Anim-Kwapong%20et%20al.pdf
2. Audsley E., Stacey K., Parsons D., Williams A. 2009. Estimation Of The Greenhouse Gas Emissions From Agricultural Pesticide Manufacture And Use. Inggris: Cranfield University.
3. Babou C., Rudragouda D.S., Mukharib K., Mote N., Gokavi R., Manjunath A.N., Raghuramulu Y. 2017. Influence of micro irrigation and drip fertigation practices on yield and quality parameters of robusta coffee (Coffea canephora). International Journal of Current Microbiology and Applied Sciences, 6(2),701–706. https://doi.org/10.20546/ijcmas.2017.602.079
4. Baon J.B., Wibawa A. 2005. Kandungan bahan organik dan lengas tanah serta produksi kopi pada budi daya ganda dengan tanaman sumber bahan organik. Pelita Perkebunan 21(1), 43–54. https://anzdoc.com/kandungan-bahan-organik-dan-lengas-tanah-serta-produksi-kopi.html
5. Borbor-cordova M.J., Boyer E.W., Mcdowell W.H., Hall C.A. 2006. Nitrogen and phosphorus budgets for a tropical watershed impacted by agricultural land use : Guayas , Ecuador. Biogeochemistry, 79 (1-2), 135–161. https://doi.org/10.1007/s10533-006-9009-7
6. [BPS] Badan Pusat Statistik. 2018. Provinsi Bengkulu Dalam Angka. Bengkulu (ID): Badan Pusat Statistik (in Indonesian).
7. [BPS] Badan Pusat Statistik. 2017. Provinsi Bengkulu Dalam Angka. Bengkulu (ID): Badan Pusat Statistik (in Indonesian).
8. Chala B., Oechsner H., Latif S., Müller J. 2018. Biogas potential of coffee processing waste in Ethiopia. Sustainability, 10(8),1–14. https://doi.org/10.3390/su10082678.
9. Coltro L., Mourad A.L., de Oliveira P.P.L.V., Andrade J.P.B.O. 2012. Regional differences of coffee cultivation in Brazil. Coffee Science, 7(1), 31–41.http://taurus.unicamp.br/bitstream/REPOSIP/90250/1/2-s2.0-84864363281.pdf

10. Cruz G, Crnkovic PM. 2015. Evaluation of the combustion process of coffee husk samples in a drop tube furnace (DTF). Engenharia Térmica (Thermal Engineering), 14(2):53–62. https://doi.org/10.13140/2.1.2139.8086
11. Elhami B., Akram A., Khanali M. 2016. Optimization of energy consumption and environmental impacts of chickpea production using data envelopment analysis (DEA) and multi objective genetic algorithm (MOGA) approaches. Information Processing in Agriculture, 3(3), 190–205. https://doi.org/10.1016/j.inpa.2016.07.002.
12. Ezema IC. 2015. Estimating Embodied Energy in Residential Buildings in a Nigerian Context. International Journal of Applied Engineering Research, 10(24), 44140–44149. https://doi.org/10(24):44140–44149
13. Falahuddin I, Raharjeng ARP, Harmeni L. 2016. Pengaruh pupuk organik limbah kulit kopi (Coffea Arabica L.) terhadap pertumbuhan bibit kopi. Bioilmi: Jurnal Pendidikan, 2(2), 108–120. http://jurnal.radenfatah.ac.id/index.php/bioilmi/article/view/1135/953
14. Hareesh S.B., Jayarama, D'Souza M.V., Keshavayya J. 2017. The biochemical status of Robusta coffee (Coffea canephora) influenced by organic and integrated nutrient management practices. International Journal of Current Microbiology and Applied Sciences, 6(4), 232–239. https://doi.org/10.20546/ijcmas.2017.604.027
15. Hulupi R. 2012. Prospek klon-klon lokal kopi Robusta asal Bengkulu. Warta, 24(2), 6–12. https://iccri.net/download/warta_puslit_koka/Warta%20Puslitkoka%20Vol.%2024%20No.%202%20Juni%202012/2.RHL3_6-12.pdf
16. Ibnu M., Offermans A., Glasbergen P. 2018. Certification and farmer organisation : Indonesian smallholder perceptions of benefits.Bulletin of Indonesian economic studies, 54(3), 387–415. https://doi.org/10.1080/00074918.2018.1506093
17. Kiyingi I., Gwali S. 2012. Productivity and profitability of robusta coffee agroforestry systems in central Uganda. Uganda Journal of Agricultural Sciences, 13(1), 85–93. https://www.ajol.info/index.php/ujas/article/view/126117/115645
18. Killian B., Rivera L., Soto M., Navichoc D. 2013. Carbon footprint across the coffee supply chain : The case of Costa Rican Coffee. Journal of Agricultural Science and Technology 3(3), 151–170. http://www.mag.go.cr/informacion/prog-nac-cafe-Carbon-Footprint.pdf
19. [KLH] Kementerian Lingkungan Hidup. 2012. Pedoman Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional. Jakarta (ID): Kementerian Lingkungan Hidup (in Indonesian).
20. Mhilu C.F. 2014. Analysis of Energy Characteristics of Rice and Coffee Husks Blends. ISRN Chemical Engineering, 1–6. https://doi.org/10.1155/2014/196103
21. Noponen M.R.A., Edwards-jones G., Haggar J.P, Soto G., Attarzadeh N., Healey J.R. 2012. Greenhouse gas emissions in coffee grown with differing input levels under conventional and organic management. Agriculture, Ecosystems & Environment, 151, 6–15. https://doi.org/10.1016/j.agee.2012.01.019.
22. Oetami R.F. 2017. Perbanyakan In-Vitro Klon-Klon Unggul Lokal Kopi Bengkulu. Warta, 29(1), 6–10.
23. Panhuysen S., Pierrot J. 2014. Coffee Barometer 2014. Hivos, IUCN Nederland, Oxfam, Novib, Solidaridad, WWF.
24. Pauline M., Mama N., Justin F. 2010. Development of a method for the mineralization of coffee husk (Coffea canephora P.) to obtain raw material for soap factories. African Journal of Biotechnology, 9(49), 8362–8364. https://doi.org/10.5897/AJB07.051.
25. Skowrońska M., Filipek T. 2014. Life cycle assessment of fertilizers : a review. International Agrophysics, 28, 101–110. https://doi.org/10.2478/intag-2013-0032.
26. Valkila J. 2009. Fair Trade organic coffee production in Nicaragua — Sustainable development or a poverty trap ? Ecological Economics, 68(12), 3018-3025. https://doi.org/10.1016/j.ecolecon.2009.07.002.
27. Veiga J.P.S., Romanelli T.L., Gimenez L.M., Busato P., Milan M. 2015. Energy embodiment in Brazilian agriculture : an overview of 23 crops. Scientia Agricola, 72(6), 471–477. https://doi.org/10.1590/0103-9016-2015-0188
28. Vera-Acevedo L.D., Vélez-Henao J.A., Marulanda-Grisales N. 2016. Assessment of the environmental impact of three types of fertilizers on the cultivation of coffee at the Las Delicias indigenous reservation (Cauca). Revista Facultad de Ingenieria, (81), 93–101. https://doi.org/10.17533/udea.redin.n81a09.
29. Wahyudi T., Jati M. 2012. Challenges of sustainable coffee certification in Indonesia. In Seminar on the Economic, Social and Environmental Impact of Sertification on the Coffee Supply Chain, International Coffee Council 109th Session, London, United Kingdom 25th September 2012, pp. 1–14.
30. [WHO] World Health Organization. 2009. The WHO Recommended Classification Of Pesticides By Hazard And Guidelines To Classification 2009. Geneva (CH): World Health Organization.
31. Wilson L., John G.R., Mhilu C.F., Yang W., Blasiak W. 2010. Coffee husks gasi fi cation using high temperature air / steam agent. Fuel Processing Technology, 91(10), 1330–1337. https://doi.org/10.1016/j.fuproc.2010.05.003.