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ENERGY REQUIREMENTS AND ECONOMIC ANALYSIS OF COFFEE (COFFEA SPP.) PRODUCTION IN BRGY. DAGOHOY, TALAINGOD, DAVAO DEL NORTE

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ABSTRACT

The study was conducted to trace and analyze the energy requirements for coffee production in Brgy. Dagohoy, Talaingod, Davao del Norte. The research revealed that coffee production depended on nonrenewable energy and utilized labor and water inputs for production and processing. The labor inputs show 23.26% of the energy share, followed by water with 23.25%. Also, the energy input of chemical fertilizer with 27.44% energy share, mainly nitrogen, shows remarkable inputs, followed by machinery with 15.50% energy share used. The energy ratio for coffee production is 1.02. Moreover, the benefit-cost ratio is 1.31 in their operation. On average, the nonrenewable form of energy inputs is 32.44% of the total energy used in coffee production compared to only 17.32% for the renewable forms. The use of renewable energy in the area is shallow. Furthermore, this implies that coffee production is susceptible to price changes and supply availability.

Keywords: Energy Requirements, Economic Analysis, Coffee Production, Coffee Yields

1. INTRODUCTION

Coffee is the principal genus of the family Rubiaceae, which includes some 400 genera and 500 species, primarily trees and shrubs, mainly found in the lower regions of the tropical rainforest. The family consists of some ornamentals, tannins, and some drugs, of which Cinchona spp. is the primary source of quinine (Purse-glove, 1977).

According to Graff (1986), the genus Coffee ranges from slender sprawling plants to robust trees with clean trunks and spreading heads growing 10-20 m high. Coffee belongs to the genus Coffea, with Linnaeus establishing its botanical classification in 1737. Two primary species dominate commercial coffee production: Coffea arabica, commonly known as Arabica, and Coffea canephora, known as Robusta. Both species possess distinct historical backgrounds regarding their discovery and cultivation. Murthy and Madhava Naidu (2012) proposed that Arabica coffee was first discovered in the Ethiopian highland forest. The first semi-cultivation of Robusta was on the islands of Lake Victoria and in the north of Kagera, Tanzania (Waller et al., 2007, p. 6). Ho (2018) mentioned that coffee is now cultivated in more than 60 tropical countries, most of which are developing countries and mainly carried out by smallholder farmers.

The Philippines is one of the few countries producing the four varieties of commercially viable Arabica, Robusta, Liberica, and Excelsa. Philippine Liberica is known locally as Barako/Baraco, a coffee bean that produces a distinctively robust and powerful cup (Philippine Coffee, 2016). As highlighted in the Philippine Rural Development Project (PRDP) of the Department of Agriculture, the coffee industry plays a vital role in the Philippine economy. The green coffee beans market is currently around 1.4 billion pesos. Two farm workers are directly employed for every hectare of coffee, and another two are indirectly employed.

With its extensive land area ideal for coffee cultivation, Talaingod town in Davao del Norte has been identified by the provincial government as a potential "coffee corridor" for Region 11. Barangay Dagahoy, encompassing 21,685.35 hectares (as detailed in Table 1), is a prime location within Talaingod. Efforts are underway to revitalize existing coffee plantations and establish high-quality coffee processing activities within the barangay.

The quality of coffee is greatly determined mainly by the treatment in the garden, transportation (40%), postharvest treatment (40%), and secondary processing (20%) (Musebe et al., 2007; Damanu, 2008). Expanding the coffee plantation area to the rise of market demand and coffee production increases energy utilization.

As highlighted by Alam et al. (2005), agriculture and energy share a symbiotic relationship. Agriculture acts as both a consumer and producer of energy, utilizing it for various processes while also generating bio-energy sources. This dynamic evolved in response to population growth, diminishing arable land, and the pursuit of improved living standards (Esengun et al., 2007). Across societies, these factors have driven the trend towards increased energy inputs in agriculture. This approach maximizes crop yields and minimizes labor requirements, often simultaneously (Esengun et al., 2007). Uhlin (1998) emphasizes that optimizing energy use within agriculture is a cornerstone of sustainable production practices. It offers a trifecta of benefits: economic savings, conservation of fossil fuels, and reduced air pollution.

This study aims to determine the energy input and output used in coffee production and evaluate a production cost analysis in Brgy. Dagohoy, Talaingod, Davao del Norte. The study further delves into identifying specific coffee production operations where adjustments to current practices could lead to significant energy savings. This translates to an increased energy ratio, a metric used to assess the efficiency of energy use in a system. Additionally, it proposes concrete strategies to reduce overall energy consumption within the coffee production process.

Table 1. Areas of Barangays in Talaingod, Davao del Norte.

Barangays		Area (has)
Talaingod		
Barangay Dagohoy		21,685.35
Barangay Palma Gil		15,830.48
Barangay Sto. Niño		37,182.01
	TOTAL	**74,697.84**

Note: Data are retrieved from Talaingod website.

2. MATERIALS AND METHODS

The study is carried out in Brgy. Dagohoy, Talaingod, Davao del Norte, is approximately 7.6548, 125.6331. Data are collected from the growers using a survey questionnaire, as shown in the Table of Appendix. The secondary material used in this study is collected from previous studies and publications.

The energy ratio between output and input evaluates the energy efficiency of the agricultural system. Human labor machinery, diesel oil, fertilizer, pesticides, seed amounts, and output yield values of coffee have been used to estimate the energy ratio. Energy equivalents shown in Table 2 are used for estimation. The study focuses on mechanical energy sources employed on the selected farms, including tractors and diesel fuel. Mechanical energy consumption is calculated based on the total fuel consumption per hectare (L/ha) across various coffee production operations. The conversion factor of 1 liter of diesel equating to 56.31 MJ (Megajoules) is used to convert fuel consumption into energy units (MJ/ha) (Tsatsarelis, 1991). Microsoft Excel spreadsheets compile basic data on energy inputs (e.g., fuel) and coffee yields. Key energy use metrics are then calculated by leveraging energy equivalent values for inputs and outputs presented in Table 1. These metrics include the energy ratio (energy use efficiency), energy productivity, and specific energy (Demicran et al., 2006; Sartori et al., 2005).

$$\text{Energy use efficiency} = \frac{\text{Energy Output}\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Energy Input}\left(\frac{\text{MJ}}{\text{ha}}\right)} \text{ x } 100\% \qquad [1]$$

$$\text{Energy productivity} = \frac{\text{Grain output}\left(\frac{\text{kg}}{\text{ha}}\right)}{\text{Energy Input}\left(\frac{\text{MJ}}{\text{ha}}\right)} \qquad [2]$$

$$\text{Specific Energy} = \frac{\text{Energy Input}\left(\frac{\text{MJ}}{\text{ha}}\right)}{\text{Grain output}\left(\frac{\text{kg}}{\text{ha}}\right)} \qquad [3]$$

$$\text{Net Energy} = \text{Energy Output}\left(\frac{\text{MJ}}{\text{ha}}\right) - \text{Energy Input}\left(\frac{\text{MJ}}{\text{ha}}\right) \qquad [4]$$

Indirect energy includes the energy embodied in seeds, fertilizers, manure, chemicals, and machinery, while direct energy covers human labor, and diesel is used in coffee production. Nonrenewable energy includes diesel, chemicals, fertilizers, and machinery, while renewable energy consists of human labor, seeds, and manure are considered. The production cost analysis of coffee production was observed, including the net profit and benefit-cost ratio. Net return per hectare was determined by subtracting the total production cost from the gross production value. The benefit-cost ratio was calculated to evaluate coffee production's economic viability. This ratio is obtained by dividing the gross value of production per hectare by the total cost of production per hectare (Demircan et al., 2006; Ozkan et al., 2004). This metric provides a clear picture of the economic benefit generated for every unit of cost invested in coffee production. There is a lag time in production, considering the wait from the cultivation to the harvest of fresh coffee cherries. This study collects all the energy involved to assess the overall production.

Table 2. Energy equivalent of inputs and outputs in coffee production.

Particulars	Unit	Energy Equivalent (MJ/unit)	References
A. Inputs			
1. Human Labor	hr	1.96	(Singh *et al*., 2002)
2. Machinery	hr	62.70	(Erdal *et al*., 2007; Singh *et al*., 2002; Singh, 2002)
3. Diesel fuel	L	38.19	(Staffell, 2011)
4. Gasoline fuel	L	34.77	(Staffell, 2011)
5. Chemical Fertilizers	kg		
(a) Nitrogen, N		66.14	(Esengun *et al*., 2007; Yilmaz *et al*., 2005)
(b) Phosphate, P_2O_5		12.44	(Esengun *et al*., 2007; Yilmaz *et al*., 2005)
(c) Potassium, K_2O		11.15	(Esengun *et al*., 2007; Yilmaz *et al*., 2005)
(d) Calcium Dolomite, $CaMg(CO_3)_2$		0.31	(Alsharhan, A. S., & Nairn, A. E. M., 2003)
6. Farmyard manure/ compost mix	kg	0.30	(Demircan *et al*., 2006; Ozkan *et al*., 2004; Singh *et al*., 2002)
7. Chemicals	kg	120.00	(Canakci *et al*., 2006; Mandal *et al*., 2004; Singh, 2002)
8. Water for irrigation	cu.m	1.02	(Acaroglu, 1998; Acaroglu and Aksoy, 2005)
9. Electricity	kWh	11.93	(Singh *et al*., 2002)
B. Outputs			
1. Coffee cherries	kg	1.93	(Cardoso *et al*., 2018)
2. Coffee (bean/ ground)	kg	1.25	(Cardoso *et al*., 2018)

3. RESULTS AND DISCUSSION

The research results cover the energy requirements during coffee management and production, energy input-output relationships, and energy and economic analysis of producing coffee. The results of this study are presented as follows.

3.1 Energy requirements and input-output relationships of coffee

Table 3 presents the practices and operations during the production of fresh coffee cherries and the processing of coffee beans. The research area planted two types of coffee beans: Robusta and Arabica. They prepare the using hand equipment as the location is not feasible for the machinery. The fertilizer used is complete, calcium dolomite, and compost mix. The water for irrigation is collected and delivered to the site. This consumed energy in human labor and transportation. Weeding and harvesting are done manually by the personnel.

Table 3. Management Practices and Production of Coffee Beans.

Particulars	Practices/ Operations
Names of Varieties	Arabica/ Robusta
For production of fresh coffee cherries	
Land preparation	Use hand equipment
Planting	Utilize some of its family members and hired workers for labor
Fertilizer Management	Apply chemical fertilizer: bag of 14-14-14, calcium dolomite, and compost mix: depending on the soil analysis
Irrigation	Waters newly planted seedling, at least twice a week. For established trees, when only necessary, particularly during dry season
Weeding	Regular manual weeding
Harvesting	Harvesting of matured coffee berries is done for 2-3 times a month
For production of processed coffee beans*	

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Particulars	Practices/ Operations
Floatation	Separate ripe coffee berries or good beans from unripe and damage coffee berries.
Depulping	Open pulp to make the drying faster.
Fermentation	Facilitate the removal of the mucilage.
Drying	Reduce moisture content to about 13% to 14%.
Dehulling	Remove the outer covering, also called as parchment, of a coffee bean.
Testing for Moisture Content	Test the moisture content of green coffee beans is 9 percent and not to exceed 12 percent.
Grading	Grade green coffee beans based on the percentage of defects contained in a 300 -gram sample
Roasting	Heat the coffee beans between 370 degrees and 540 degrees for 8 to 15 minutes, depending on degree of roast required
Grinding	Ground the roasted coffee beans
Packing, Weighing and Labeling	Pack coffee beans new and clean sacks made of natural fibers such as jute, kenaf, sisal, and hemp.
Storage	Store in clean, dry and cool conditions that are free from pest.

Note: *Using wet method of processing coffee beans

They are used in drums as floatation equipment for sorting good coffee cherries on site. They utilized machines from their association for de-pulping, dehulling, roasting, and grinding. The barangay performs fermentation to facilitate the removal of mucilage. They used sun drying on their operation to achieve the moisture needed for the coffee beans. Trained staff were assigned to test the moisture and grading of coffee beans. All members pack, weigh, label, and store processed coffee beans.

The inputs used in coffee production and their energy equivalents, output energy equivalents, and energy ratio are illustrated in Table 3. The results revealed that 1176.04 hrs. of labor and 24.51 hrs. of machinery power per hectare are needed to produce coffee in the area, including cultivation and processing. Labor has the most significant share, amounting to 23.26%, on which their operation relies. The same is true with water for irrigation, which has little difference in labor energy, with a share of 23.25% as they used the wet method in processing coffee beans.

Table 4. Amounts of inputs and outputs in Coffee production.

Quantities (Inputs and Outputs)	Quantity per unit area (ha)	Total Energy equivalent (MJ/unit)	Percentage of the Total Energy Input (%)
A. Inputs			
1. Human Labor (hr)	1176.04	2305.04	23.26%
2. Machinery (hr)	24.51	1536.46	15.50%
3. Diesel fuel (L)	8.00	305.52	3.08%
3. Gasoline fuel (L)	7.00	243.39	2.46%
4. Chemical Fertilizers (kg)			
(a) Nitrogen, N	30.00	1984.20	20.02%
(b) Phospahte, P_2O_5	30.00	373.20	3.77%
(c) Potassium, K_2O	30.00	334.50	3.37%
(d) Calcium Dolomite, $CaMg(CO_3)_2$	90.00	27.99	0.28%
5. Farmyard manure/ Compost mix (kg)	750.00	225.00	2.27%
6. Chemicals (kg)	1.70	204.00	2.06%
7. Water for irrigation (cu.m)	2258.75	2303.93	23.25%
8. Electricity (kWh)	5.72	68.24	0.69%
Total Energy Input (MJ)		**9911.47**	**100%**
B. Outputs			
1. Coffee cherries (kg)	4517.50	8718.78	86.06%
2. Coffee processed (kg)	1129.38	1411.73	13.94%
bean	734.10	917.62	
ground	395.28	494.10	
Total Energy Output (MJ)		**10130.50**	**100%**

Chemical fertilization usage in the production was 150 kg/ha. Nitrogen has the highest share of 20.02% needed when planting coffee seedlings. Phosphate and potassium have a 3.77% and 3.37% share of energy, respectively. Minimal use of calcium dolomite with 0.28% and chemical with 2.06% energy share.

As seen in Table 4, they use less energy in machinery, 15.50%, as they do not use farm machinery. They only used vehicles for transportation and several pieces of equipment in the processing. This is connected with fuels, which account for 3.08% of diesel and 2.46% of gasoline energy share, respectively. The electricity also shows 0.69% of energy share as they used this at the end of their operation.

This indicates that the other operation was maintained at a low level compared to labor, water used, and fertilization application during the production of coffee beans.

The energy input and output, yield, energy use efficiency, specific energy, energy productivity, and net energy of coffee production are shown in Table 5. Energy use efficiency or ratio of output to input energy is calculated as 1.02. In this study, the energy productivity of the area was 0.456 for coffee cherries and 0.114 for processed coffee. This is the product output obtained per unit of energy.

The specific energy for coffee cherries and coffee, both bean or ground, are 2.19 MJ/kg and 8.78 MJ/kg, respectively. Processed coffee has the most significant specific energy, which will undergo drying and roasting. The net energy of coffee production is 219.03 MJ/ha, and it is reported to have good energy utilization.

Table 5. Energy input-output ratio in Coffee production.

Particulars	Unit	Production
Energy Input	MJ/ha	9911.47
Energy Output*	MJ/ha	10130.50
Coffee cherries yield	kg/ha	4517.50
Coffee (bean/ground) yield	kg/ha	1129.38
Energy use efficiency		1.02
Specific Energy		
Coffee cherries	MJ/kg	2.19
Coffee (bean/ground)	MJ/kg	8.78
Energy Productivity		
Coffee cherries	kg/MJ	0.456
Coffee (bean/ground)	kg/MJ	0.114
Net Energy	MJ/ha	219.03

*Note: *Fresh coffee cherries and processed coffee.*

3.2 Energy analysis of producing coffee

The total mean energy input as direct and indirect, renewable and nonrenewable energy forms are illustrated in Table 6. As can be seen, the maximum input is nonrenewable energy with 32.44% of the share. This is followed by indirect, direct, and renewable energy, with a share of 31.89%, 18.34%, and 17.32%, respectively. Direct inputs are mainly labor, oil-based fuels for field operation, and electricity in the processing of coffee beans. Indicated inputs are dominated by fertilizer use. Fertilizer management, particularly in using nitrogen and compost mix, labor, and machinery operation, are significant areas for improving efficiency.

The results indicate that the current energy use pattern is based on nonrenewable energy in coffee production. The proportion of renewable energy use in the area could be much higher. This means that production depends mainly on fossil fuels for transportation and processing, chemicals, and fertilizers. This implies that production is dependent on nonrenewable energy.

Table 6. Total energy input in the form of direct, indirect, renewable and nonrenewable for Coffee production

Form of Energy (MJ)	Unit	Coffee	%a
Direct Energy *b*	MJ	2678.80	18.34%
Indirect Energy c	MJ	4657.36	31.89%
Renewable Energy *d*	MJ	2530.04	17.32%
Nonrenewable Energy *e*	MJ	4737.88	32.44%
Total Energy Input	MJ	14604.08	100%

a-indicates percentage of total energy input.
b-includes human labor, diesel, and electricity.
c-includes fertilizers, manure, chemicals, and machinery.
d-includes human labor and manure.
e-includes diesel, chemical, fertilizers, machinery.

3.3 Economic analysis of producing coffee

The cost and return of the coffee cherries and coffee end products are given in Table 7. The total expenditure for the production is PhP 89,142.54 per hectare, while the total gross production value is PhP 116,393.66 per hectare. The coffee production's benefit-to-cost ratio (B-C) was calculated by dividing the gross value of the product by the total cost to determine economic efficiency. The B-C ratio revealed that the coffee production in the area is 1.31. This indicates that their operation has a good return from the inputs. Also, the net return from coffee production was PhP 27,251.12 per hectare.

Table 7. Economic Analysis of Coffee Production.

Cost and Return Components	Unit	Value
Production Yield (fresh coffee beans)	kg/ha	4517.50
End product yield (processed coffee bean/ground)	kg/ha	1129.38
Sale price of Major product	PhP/ha	54,210.00
Sale price of End product	PhP/ha	62,183.66
Total gross value of production	PhP/ha	116,393.66
Variable cost of production	PhP/ha	60,617.02
Fized cost of production	PhP/ha	28,525.52
Total cost of production	PhP/ha	89,142.54
Gross Return	PhP/ha	55,776.65
Net Return	PhP/ha	27,251.12
Benefit to Cost Ratio		1.31

4. CONCLUSION

This research examines the energy requirements of inputs and outputs for coffee production in Brgy. Dagohoy, Talaingod, Davao del Norte. Data for the production were collected from the identified area using the blended modality of the face-to-face questionnaire, followed by the responses through phone calls. The research revealed that coffee production depended on nonrenewable energy and utilized more labor and water inputs for production and processing. The labor inputs show 23.26% of the energy share, followed by water with 23.25%. Also, the energy input of chemical fertilizer with 27.44% energy share, mainly nitrogen, shows remarkable inputs, followed by machinery with 15.50% energy share used. The results indicate that labor and water are the most significant determinants of the total energy inputs in coffee production. However, combining the fertilizer inputs indicates the most important share in the operation, mainly nitrogen, which takes part in the total inputs. The machinery inputs give another part of the share as their operation focuses on transportation and several operations in processing. The energy ratio for coffee production is 1.02. This shows slight management of energy inputs in the cultivation and processing. The benefit-cost ratio is 1.31, a minor notable feature of their operation.

On average, the nonrenewable form of energy inputs is 32.44% of the total energy used in coffee production compared to only 17.32% for the renewable forms. The use of renewable energy in the area is shallow. Furthermore, this implies that coffee production is susceptible to price changes and supply availability.

Energy management is essential for efficient, sustainable, and economical energy use. Energy use in coffee production has allocated much input to labor, water, fertilizer, fuel, and machinery. Utilizing these inputs properly would provide more efficient practices operation. All these measurements would be useful in reducing adverse effects on the environment and human health, maintaining sustainability, decreasing production costs, and providing higher energy use efficiency.

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