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Energy Inputs of Selected Agroforestry Systems in Zamboanga City, Philippines

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Abstract: A study aimed to estimate the energy inputs of selected agroforestry systems (AFSs) within the Community-Based Forest Management (CBFM) in Zamboanga City, Philippines was conducted. All Mcal units were converted into Liter Diesel Oil Equivalent (LDOE), where 1.0 LDOE = 11.414 Mcal. Purposive sampling was used in determining the fitted characteristics and the number of respondents required across the 16 CBFM sites, where nine (9) dominant AFSs were identified. A total of 100 respondents were interviewed using a structured questionnaire. The relationships of predictors such as the direct, indirect and embedded energy inputs per AFS were analyzed using descriptive statistics. Means, percentages and sums were compared. The rubber+1based AFS obtained the lowest total energy inputs (TEI) at 5,790.5 Mcal ha^{-1} or equal to 507.3 LDOE ha^{-1}, while the rubber+3based AFS obtained the highest TEI at 11,801.3 Mcal ha^{-1} (1,034.0 LDOE ha^{-1}) compared to other AFSs such as the coconut+1based, mango-based, marang-based, lanzones-based, coconut+3based, rubber+2based and coconut+2based with individual TEI that ranged from 6,267.16-11,250.2 Mcal ha^{-1} (549.1-985.6 LDOE ha^{-1}). Of the total TEI across the nine (9) AFSs, the direct energy input (DEI) contributed 1.6-5.4%, indirect energy input (IEI) 94.1-98.0% and embedded energy input (EEI) 0.3-0.5%, respectively. The TEI is the sum total of DEI, IEI and EEI where each was accounted from pre-land preparation (PLP), crop establishment (CE), crop care and maintenance (CCM), harvest and postharvest (HPH) activities. The high imputed cost on IEI was attributed to high usage of agrochemicals and labor which are identified as the 'energy hotspots' or the energy-intensive inputs. The high plant density and number of trees present within the system contributed significantly in the overall TEI. Understanding the significant contributions of various energy-intensive systems will guide policy makers and local planners to initiate an integrated farming approach with reduced energy inputs that is climate smart with higher economic potential for the upland environment in the City of Zamboanga.

Keywords: Agroforestry Systems (AFSs), Total Energy Inputs (TEI), Indirect Energy Input (IEI), Liter Diesel Oil Equivalent (LDOE), Energy Hotspots

1. Introduction

Energy has always been essential for the production of food. Prior to the industrial revolution, solar power was the primary energy input for agriculture [1]. However, owing to the impact of rapid mechanization, food production has become increasingly dependent on energy derived from fossil fuels [2-4] making the system to require large amount of energy inputs such as the direct use of energy to run farm machineries, water management, irrigation, cultivation and harvesting, food processing, storage and transportation [5, 6]. Huge quantities of synthetic fertilizers require high energy inputs to produce and depend largely on machinery that runs on gasoline and diesel fuel. Food that are produced today is highly processed which further increased its energy footprint and are often transported long distances, which require additional energy inputs [7-10]. Enormous poultry and industrial livestock operations that raise thousands of animals in confined conditions require large quantities of feed produced by industrial crop farms using the energy-intensive processes [6]. Moreover, there were many indirect energy inputs (IEI) used in agriculture in the form of mineral fertilizers and chemical pesticides [10, 11] and farm equipment [5, 10]. The science of energy accounting in food agriculture has been used as early as 1973 [5] and it has continue to evolved [7, 12-17]. In recent years, energy accounting has been used for sugarcane production [2, 4, 18], rice and cotton [2], wheat [3] and lowland rice [19]. Food sources derived from agroforestry systems (AFSs) such as fruits and annuals as intercrops are sources of caloric energy but to produce such energy also requires enormous energy in the form of machineries, farm implements, equipment, farm tools, various inputs like seeds, fertilizers and chemical pesticides, trucks and other form of logistics used for hauling and transport including labor that are derived from human and draft animal. The entire production process is fossil fuel-based intensive, hence before reaching our plates, our food is produced, stored, processed, packaged, transported, prepared, and served. At every stage, there is potential energy footprint (energy inputs) equivalents. In this study we tried to account the energy requirement of the different dominant AFSs across the 16 CBFM sites in Zamboanga City, Western Mindanao, Philippines. Specifically, this study was conducted to establish energy usage, account the energy inputs, and determine the energy hotspots of the selected AFSs.

2. Materials and Methods

2.1. Site Selection

Zamboanga City is located at a latitude of 6°55'17.19"N and a longitude of 122°4'44.5"E, respectively with a total land area of 148,388.49 hectares (1,483.88 km^2). Record evaluation was done first at the regional office of the Community Environment and Natural Resources, Department of Environment and Natural Resources (CENRO-DENR) for the general overview of the community based forest management (CBFM) sites and subsequently conducted field assessment and validation to determine the different dominant crops (forest and fruit trees), systems and practices, approximate geographic, environmental and climatic information.

2.2. The CBFM Sites

There were sixteen (16) identified CBFM sites with a total land area of 12,406.6 hectares located mostly in the hilly and mountainous portion of Zamboanga City, Western Mindanao, Philippines and within these sites are the nine (9) identified dominant agroforestry systems (AFSs) with their individual tree and crop components (Table 1).

Table 1. *List of Dominant Agroforestry Systems (AFSs) and their Tree and Crop Components across the 16 CBFM Sites in Zamboanga City, Philippines.*

Types of AFSs	Tree and Crop Components
Coconut+1based	Coconut+banana
Coconut+2based	Coconut+rubber+banana
Coconut+3based	Coconut+rubber+banana+mahogany
Rubber+1based	Rubber+uplandrice
Rubber+2based	Rubber+coconut+banana
Rubber+3based	Rubber+coconut+banana+marang
Lanzones-based	Lanzones+coconut+banana+spanishcedar
Mango-based	Mango+coconut+banana+mahogany
Marang-based	Marang+coconut+banana

Coconut (Cocos nucifera), Rubber (Hevea brasiliensis), lanzones (Lanzium domesticum), mango (Mangifera indica), and marang (Artocarpus odoratissimus).

These major AFSs were subjected for comparisons in terms of energy usage. All field information were derived from formal survey interviews. Data generated were all based on the personal understanding, records, awareness and available information provided by the respondents.

2.3. Energy Use Determination

The 'energy inputs' derived from the questionnaire were analyzed and processed using the MS Excel Software package. Quantitative output from this operation was converted into average ha^{-1}. The total energy inputs (TEI) is the sum total of direct energy input (DEI), indirect energy input (IEI) and embedded energy input (EEI) where its individual calculations were calculated from the four (4) major energy consuming activities such as the pre-planting preparation (PLP), crop establishment (CE), crop care and maintenance (CCM), harvest and postharvest (HPH).

The DEI includes the direct usage of diesel and/or gasoline to run the machines for farm operations and transport of farm products. While, the IEI are various inputs such as seeds, fertilizers (NPK) used, agrochemicals applied and labor. Lastly, the EEI was accounted from the energy costs on the use of machines, farm equipment and implements, motorized vehicles including draft animal utilized during farm activities and were distributed to its entire lifespan [5].

2.4. Energy Use Calculations

Energy accounting procedures and various energy coefficients were based from the earlier work of Pimentel [5], Mohammadshirazi *et al.* [19], Goe and MacDowell [20], Ozkan *et al.* [16], Shresta [21], Esengan *et al.* [22], Yaldiz *et al.* [12], Singh *et al.* [14], Yilmaz *et al.* [23], Thu and Mendoza [2], Egle and Mendoza [4], Mendoza [10], Taghavi and Mendoza [3], Mendoza and Samson [15], Karimi *et al.* [24], Gliessman [25], Savuth [26], and from other relevant information as cited by Wells [27] and Bockhari-Gevao *et al.* [28]. All energy units in Mcal were converted into Liter Diesel Oil Equivalent (LDOE), where 1.0 LDOE = 11.414

Mcal [5]. The energy input for the manpower that includes food, clothing and miscellaneous living costs of the farming household were not accounted.

2.5. Sampling and Statistics

Purposive sampling was used in selecting the fitted characteristics and identifying the actual respondents across the 16 CBFM sites. Subsequently, the identified 100 CBFM beneficiaries were interviewed as respondents using a structured questionnaire. Only the dominant identified AFSs were subjected for data collections. The major AFSs were determined and ranked based on the total land area cropped with more or less the same characteristics and crop/species involved within a system. The relationships of predictors such as the direct energy inputs (DEI), indirect energy inputs (IEI) and embedded energy inputs (EEI) per AFS were tabulated and analyzed using descriptive statistics. Means, percentages and sums were compared.

3. Results and Discussions

3.1. Total Energy Inputs

The rubber+1based AFS obtained the lowest total energy inputs (TEI) amounting to 5,790.85 Mcal ha^{-1} (507.35 LDOE ha^{-1}), while the rubber+3based AFS had the highest at 11,801.34 Mcal ha^{-1} (1,033.93 LDOE ha^{-1}) compared to coconut+1based, mango-based, marang-based, lanzones-based, coconut+3based, rubber+2based and coconut+2based AFSs, respectively. Across the nine (9) major AFSs, the individual share of direct energy input (DEI), indirect energy input (IEI) and embedded energy input (EEI) ranged from 1.6-5.4%, 94.1-98.0% and 0.30-0.50%, respectively (Table 2).

The low TEI of rubber+1based AFS was attributed to fewer components involved within the system and the short gestation period of upland rice crop that required no further inputs during crop care and maintenance (CCM). This means that the higher the plant density and the number of tree species present within a system, the higher the TEI required. This is due to the accrued energy inputs of each individual tree crops spent in various levels of energy-intensive activities. The energy cost per farm activity includes farm inputs and labor utilized from various farm operations including the pre-harvest energy inputs (PHEI) – the case of fruit tree components which require 5-6 years gestation period, and energy required on transportation which largely dependent on the volume of produce to be transported and proximity to the designated assembler or consolidator (traders).

Comparable to rubber+1based AFS was the coconut+1based AFS (Table 2), this was attributed to low farm input requirements of coconut and banana. It was not a practice by the farming households to fertilize their banana.

Generally, the high TEI of multi-tree crop AFSs were mainly attributed to high energy usage on farm inputs, labor and transportation. Energy costs on transportation includes the transport of farm produce such as rubber latex, copra and banana fruits on a weekly or monthly basis, and other seasonal fruits such as marang and lanzones. Increasing the costs of external inputs particularly on agrochemicals, labor and transportation will further implicate the increase dependence to fossil fuel.

On the other hand, to reach the local markets, agricultural produce have to be transported. Energy inputs on logistics would also increase the price of food delivered in the local markets of Zamboanga City, more so if they are transported far [26]. In the Philippines, the sugar production is an intensive energy-requiring process [29], including inorganic rice production [2, 18, 26], wheat production [3] and high valued crops [5]. These observations are also true with the nine (9) identified dominant AFSs in the uplands of Zamboanga City, where major agricultural crops such as coconut, rubber, banana, upland rice, lanzones and marang (seasonal crops) grown in combination and/or as an inter-crop were becoming energy intensive systems. In addition to energy costs on agrochemicals, energy on labor was also high, making the upland agriculture a highly labor intensive.

3.2. Direct Energy Inputs

The total contribution of direct energy inputs (DEI) was small which ranged from 1.6-5.4% or this is equivalent to 146.87-435.0 Mcal ha^{-1} (12.86-38.11 LDOE ha^{-1}) across the nine (9) AFSs (Table 2). The direct use of gasoline (or diesel oil) was necessary to run farm machineries and 'habal-habal' (motorized bike). Of these nine (9) AFSs, the rubber+1based AFS obtained the lowest DEI amounting only to 115.36 Mcal ha^{-1} (10.11 LDOE ha^{-1}), this was mainly attributed to zero latex collection of rubber since rubber trees were still in juvenile stage at the time the study was made. This means that no collection of raw latex, no additional energy cost on transportation needed. In a rubber+1based AFS, only the upland rice crop obtained an energy cost on diesel fuel that was used to run the rice thresher and milling machines, while, the *'habal-habal'* was used to facilitate the transport of fresh palay (unhusk rice) to the nearest dryer, to rice mill facility then to retail outlets. On the other hand, the highest DEI was significantly attributed to lanzones-based AFS amounted to 443.74 Mcal ha^{-1} (38.88 LDOE ha^{-1}) as compared to other types of AFSs (Table 2).

The main driver on increased amount of fuel usage was the bulk of farm produce being processed and transported to long distances crossing bad terrains and muddy conditions especially during the wet months. This explain the high DEI of multi-tree based systems due to the volume of copra, rubber latex (cup lumps) and banana products being transported in a regular basis including the bulk of farm produce that comes from marang and lanzones fruits in a seasonal basis. As practiced by upland farmers, rubber latex were collected weekly and transported twice a month. Coconuts were harvested four times a year processed into copra and transported to the buying stations, while the banana fruits were transported and sold weekly to local traders. The lanzones and marang fruits (seasonal commodities) were also transported to local markets, to various fruit stalls and traders normally from September to October annually. The DEI in the form of gasoline fuel needed to transport these goods increased the energy input requirement further more. This was contrary to mahogany and Spanish cedar forest trees since there was a moratorium that banned the cutting of any forest tree species across the 16 CBFM sites, thus no wood products that were transported and traded, while the lower DEI of mango-based AFS was mainly attributed to zero harvest of mango fruits for the past three years (2016-2018) due to unfavorable climatic conditions, high cost on agrochemicals and labor.

3.3. Indirect Energy Inputs

About 94.1-98.0% of the TEI were largely contributed by indirect energy inputs (IEI) with an energy usage equivalent of 5,648.0-11,356.24 Mcal ha^{-1} (494.84-994.94 LDOE ha^{-1}) across the nine (9) AFSs (Table 2).

Table 2. *Energy inputs of the different agroforestry systems (AFSs) across the 16 CBFM sites in Zamboanga City, Philippines.*

Types of AFS	DEI Mcal Ha^{-1}	%	IEI Mcal Ha^{-1}	%	EEI Mcal Ha^{-1}	%	TEI Mcal Ha^{-1}	TEI LDOE Ha^{-1}
Rubber+1based	115.36	2.0	5,648.00	97.5	27.49	0.5	5,790.85	507.3
Rubber+2based	248.59	2.0	10,954.65	97.6	38.87	0.3	11,242.11	985.0
Rubber+3based	391.98	3.2	11,356.24	96.3	53.12	0.5	11,801.34	1,033.9
Coconut+1based	219.77	3.2	6,018.22	96.3	29.17	0.5	6,267.16	549.1
Coconut+2based	246.16	2.0	10,963.03	97.6	41.15	0.4	11,250.34	985.7
Coconut+3based	231.85	2.0	10,899.10	97.7	41.15	0.3	11,172.10	978.8
Lanzones-based	443.74	4.2	9,637.70	95.3	41.15	0.4	10,122.59	886.9
Marang-based	435.00	5.4	7,262.59	94.1	41.15	0.5	7,738.74	678.0
Mango-based	146.87	1.6	7,383.73	98.0	29.17	0.4	7,559.77	662.3

AFS (agroforestry systems), DEI (direct energy input), IEI (indirect energy input), EEI (embedded energy input), TEI (total energy input) and (LDOE) liter diesel oil equivalent, respectively.

The rubber+1based AFS obtained an IEI of 5,648.0 Mcal ha^{-1} (494.83 LDOE ha^{-1}) but this was significantly lower compared to: coconut+1based, mango-based, marang-based, lanzones-based, coconut+3based, rubber+2based, coconut+2based, and rubber+3based AFSs, respectively (Table 2). This would only mean that the tree-based AFSs were energy-intensive systems due to high usage of agrochemicals and high labor requirements that were accounted from the four (4) major farm operations such as the pre-land preparation (PLP), crop establishment (CE), crop care and maintenance (CCM), harvest and postharvest (HPH). The PLP includes the purchasing and hauling of farm inputs and the collection of soil samples that were required for analysis. The CE includes plowing, harrowing, furrowing, digging/holing, planting and replanting, watering, hilling-up, field visit and monitoring. The CCE includes weeding and application of fertilizers and pesticides. The HPH for permanent perennials includes harvesting (cutting) and picking, tapping (rubber), sorting, packing, hauling, loading and transport, while the HPH for cash crops (upland rice) includes cutting, field drying, hauling, stocking/piling, threshing, cleaning, bagging, grain drying, sacking, storage and milling, loading and transport. Accounting all the activities, this answers why over 94.0% of the TEI across the nine (9) AFSs were attributed to *IEI* (Table 2).

In fact, of the total IEI, 16.4-50.0% was contributed by fertilizers, 15.5-23.5% by pesticides and 24.4-66.0% by labor, respectively. This means that the tree-based systems were energy-intensive systems due to high usage of NPK fertilizers, pesticides and labor utilized from crop establishments to harvest and postharvest operations. According to Egle and Mendoza [4] the main driver of high energy input in cane production up to harvesting and hauling to the mill was the fertilizer used especially the N fertilizer input. While, Savuth [26], concluded that the main contributors of high energy costs on rice production in Cambodia was due to high indirect energy costs on N fertilizer, insecticide and Glyphosate herbicide applications. In this study, input like the insecticide was used primarily to control 'cocolisap' infestation (coconut scale insect), while the herbicide was applied to avoid high cost on labor particularly on ground brushing and weeding. This is the reason why, of the total IEI that ranged from 5,648.0-11,356.24 Mcal ha^{-1} (Table 2), the energy used on fertilizers, pesticides, and labor contributed 16.4-50.0%, 15.5-23.5%, and 24.4-66.0%, respectively.

In Zamboanga City, the upland rice farming has become a fossil fuel intensive system for the past five (5) years. The reason for this was a constant increase in fertilizer usage. Increase application on inorganic NPK fertilizers was necessary in order to achieve the required yield. Although, the similarity and/or variability of fertilizers usage was also influenced by other external factors such as capital on inputs and prevailing practices on fertilizer application and management. The results significantly revealed that the intensive energy requirements per AFS were due to fertilizer, pesticides and labor usage.

Also, the IEI costs on labor comprised of four major farm operations (PLP, CE, CCM and HPH). These explain the high energy usage on labor. Across the nine (9) AFSs, the PLP, CE, CCM and HPH obtained an average contribution that ranged from 0.43-1.55%, 5.66-24.95%, 30.76-63.75% and 9.74-60.86%, respectively. Of the four (4) major farm operations, the CCM and HPH were identified to be the most labor-intensive. Increase requirements in labor also increase significantly the TEI levels of each AFSs.

3.4. Embedded Energy Inputs

The embedded energy inputs (EEI) across the nine (9) AFSs were small and insignificant compared to DEI and IEI, where its total share accounted only from 0.3-0.5% (Table 2).

The EEI was small because its expended energy usage was distributed in the entire lifespan of the machines used such as the 'habal-habal', rice thresher, rice mill and power sprayer that were utilized during farm operations including draft animal used for labor and transport. While, the farm equipment used such as the knapsack sprayer and moldboard plow their lifespan were shorter than the machines. Clearly, the EEI cost was largely attributed to 'habal-habal' that was used for transporting of farm produce from the highlands over long distances and bad terrains in bulk volumes.

The embedded energy use on machines was calculated using the number of hours that the machine/s was used in farm activities and was spread over a 10-15 year (estimated life span of machines) period. The case of 'habal-habal', its contribution to the EEI was due to its constant use as it was the only practical way to transport farm produce crossing rough terrains bringing marang and lanzones fruits, copra, rubber latex and banana fruits. Pimentel [1, 5], Mendoza [10], and Savuth [26] attributed the high EEI usage to processing and transport of produce in long distances.

3.5. Energy Hotspots

The 'energy hotpots' refers to the high requiring energy activities or processes relative to the growth stages of a particular crop or tree species in a particular AFS accounted in IEI during the PLP, CE, CCM and HPH operations. Earlier discussed, there were two (2) major 'energy hotspots' that were identified: the agrochemical inputs and labor utilized.

The agrochemical inputs include fertilizers (NPK) and pesticides (insecticide and herbicide) used. Of the total 'energy hotspots' across the nine (9) AFSs, the energy input contributed by agrochemicals ranged from 34.1-75.0% or this is equal to 2,517.13-4,141.08 Mcal ha^{-1} (220.5-362.8 LDOE ha^{-1}) (Table 3), of this amount, the energy input on fertilizers contributed 44.72-67.97% (1,125.66-2,814.69 Mcal ha^{-1}), while energy input on pesticides contributed 32.03-55.28% (806.24-2,289.19 Mcal ha^{-1}), respectively. Of the total energy usage on fertilizers, fertilizer N shared 45.4-81.6%, fertilizer P (6.1-11.2%), and fertilizer K (7.2-48.5%), respectively. Fertilizer N had the highest energy use compared to fertilizers P and K.

On the other hand, of the total energy usage on pesticides, insecticide contributed 17.2-24.6% and herbicide 74.4-82.8%, respectively. Herbicide had the highest energy inputs compared to insecticide. This further showed that fertilizer N and herbicide contributed the highest energy inputs, making the major AFSs a fertilizer N and herbicide intensive systems.

In general, in terms of the energy input on fertilizers usage, the rubber+1based AFS obtained a total of 2,814.6 Mcal ha^{-1} (246.59 LDOE ha^{-1}). The amount is comparable to rubber+2based AFS, rubber+3based AFS, coconut+2based AFS, and coconut+3based AFS, but significantly higher compared to lanzones-based AFS, coconut+1based AFS, marang-based and mango-based AFSs, respectively (Table 3). The energy hotspots in rubber+1based AFS was directly attributed to high requirement of N fertilizer for upland rice production and rubber tree component. The case of rubber-based and coconut-based AFSs, fertilizer N was directly imputed from high application to rubber and coconut trees, hence increase in the overall energy input. While, the coconut+1based, marang and mango-based AFSs where each obtained a lower 'energy hotspot' was mainly attributed to zero N application on mango, marang, banana, and mahogany tree components. This is to explain the advantage of marang, banana and mahogany trees within an AFS where each can significantly impact in the reduction of the overall energy input requirements.

On the other hand, the lanzones-based AFS (1,582.2 Mcal ha^{-1}) obtained a relatively lower energy input on fertilizer mainly due to zero NPK fertilizers application on Spanish cedar tree and banana components. The presence of forest trees and banana have been considered advantageous compared to rubber, coconut and lanzones tree components because it can help reduce the energy usage significantly, hence reducing the overall 'energy hotspots'.

Table 3. *'Energy hotspots' (Mcal ha^{-1}) of the different agroforestry systems across the 16 CBFM sites in Zamboanga City, Philippines.*

TYPES OF AFSs	AGROCHEMICALS						TOTAL (F+P+L)
	F	P	TOTAL	%	L		
	Mcal Ha^{-1}	Mcal Ha^{-1}	(F+P)		Mcal Ha^{-1}	%	
Rubber+1based	2,814.60	1,326.48	4,141.08	75.0	1,378.92	25.0	5,520.0
Rubber+2based	2,777.17	1,755.25	4,532.42	41.4	6,422.23	58.6	10,954.65
Rubber+3based	2,990.94	1,755.25	4,746.19	41.8	6,610.05	58.2	11,356.24
Coconut+1based	1,290.64	1,226.49	2,517.13	41.8	3,501.09	58.2	6,018.22
Coconut+2based	2,785.75	1,755.25	4,541.00	41.4	6,422.03	58.6	10,963.03
Coconut+3based	2,539.21	1,755.25	4,294.46	39.4	6,604.64	60.6	10,899.10
Lanzones based	1,582.20	1,955.59	3,537.79	36.7	6,099.91	63.3	9,637.70
Marang based	1,290.64	1,226.49	2,517.13	34.7	4,745.46	65.3	7,262.59
Mango based	1,290.64	1,226.49	2,517.13	34.1	4,866.60	65.9	7,383.73

F=fertilizers, P=pesticides, L=labor.

Aside of N fertilizer, the energy use on K fertilizer was significantly higher in AFSs with coconuts and lanzones trees. Of the total fertilizer usage across the nine (9) AFSs, fertilizer K shared a total of 203.3-724.1 Mcal ha^{-1} (17.8-63.4

LDOE ha^{-1}). Fertilizer K was believed by majority of farmers to influence flowering and fruit development of coconuts and lanzones. While the P fertilizer had the lowest energy input which contributed low in the overall 'energy hotspots' which is equal to 78.7-314.9 Mcal ha^{-1} (6.9-27.6 LDOE ha^{-1}) across all AFSs. Among the fertilizers, P contributed less energy intensive compared to N and K. According to Chamsing *et al.* [30], fertilizers consume the highest amount of energy usage. In Brazil, the energy use in fertilizer was about 66.96 MJ tc^{-1} (1.4 LDOE tc^{-1}) or 35.27% of the total energy input in agriculture industry [31]. Egle and Mendoza [4] and Savuth [26] they concluded that production systems on rice and cane sugar are high fertilizer intensive, particularly N, while Thu and Mendoza [2], the indirect fossil energy use on fertilizer inputs accounted for the highest energy input which accounted to about 86.22% in rice, 81.46% in cotton, and 68.23% in sugarcane production, respectively.

There were two types of pesticides identified across the nine (9) AFSs: the insecticide and herbicide. Herbicide especially the use of round-up played an important role in weed management in the upland environment of Zamboanga City. The popular use of 'round-up' product was attributed to its accessibility in major agricultural stores locally, easy to use and cheap. Farmers often resort at using round-up to avoid high cost on labor especially for ground brushing and weeding operations, hence, the energy input on herbicide was significantly high compared to insecticide. The tree-based AFSs were herbicide-intensive systems this was attributed to high usage of round-up applied to control weeds under coconut and rubber components. Among the AFSs with high energy input on herbicide were the rubber+2based, rubber+3based, coconut+2based, coconut+3based, and the lanzones-based where each had an average of 1,454.1 Mcal ha^{-1} (127.39 LDOE ha^{-1}), this was about 80-83% of its individual energy input on pesticides. While the coconut+1based, marang and mango-based AFSs had similar amount at 925.33 Mcal ha^{-1} (81.1 LDOE ha^{-1}), this was 75.4% from its individual energy input on pesticides, respectively.

The observed similarity of energy input on herbicide in various tree-based systems were attributed to the common preference and practice of farmers which influence their decision attributes on the use of chemicals and dosage of application, since their existing tree-based systems possessed similar major tree components. Also noted that herbicide was not used on forest tree components such as on Spanish cedar and mahogany trees. This suggests that the presence of forest trees can substantially reduce herbicide usage aside from zero NPK and insecticide application, hence reduce in the overall 'energy hotspots'.

Moreover, about 1,379.0-4,866.6 Mcal ha^{-1} (120.81 to 426.4 LDOE ha^{-1}) or this is 25.0-66.0% of the 'energy hotspots' were attributed to *labor*. This was significantly high compared to the energy imputed on fertilizer and pesticides across the different AFSs (Table 3). This means that significant contribution in the overall 'energy hotspots' also came from high labor requirements involving human and draft animal utilized during farm operations, where the individual contribution of PLP, CE, CCM and HPH was calculated at 0.43-1.55%, 5.66-25.94%, 30.76-63.75% and 9.74-60.86%, respectively. Both the CCM and HPH have high energy input on labor, hence considered 'energy hotspots'.

Also, the rubber+3based and coconut+3based AFSs obtained the highest energy input utilization on labor amounting to 6,610.05 Mcal ha^{-1} (579.12 LDOE ha^{-1}) and 6,604.64 Mcal ha^{-1} (578.64 LDOE ha^{-1}), respectively, compared to marang-based, mango-based, coconut+1based, rubber+1based, lanzones-based, rubber+2based and coconut+3based AFSs (Table 3). The varying results of energy input on labor suggests that the different AFSs in the uplands of Zamboanga City are becoming more labor-intensive systems, hence increase in the overall 'energy hotspots'. The low energy input on labor of rubber+1based AFS (1,378.92 Mcal ha^{-1}) was attributed to short gestation period of the upland rice component compared with the multi-tree based systems. While the high energy input on labor of the tree-crop systems were directly attributed to the accrued manual and animal draft labor especially during harvest operations and transport of farm produce in a regular basis. During hauling of farm products only an animal drawn cart was possible, while during transport of farm produce only an 'habal-habal' (motorized bike) was practical and economical to use. The high energy hotpots are often link to high energy footprint and carbon emissions [17].

According to Mendoza [17], the increase usage of N fertilizer can lead to the increase in carbon footprint (CF). High N will likely lead to high carbon monoxide (CO), nitrous oxide (NO_2) emissions, which have powerful global warming potential (GWP) relative to CO_2 [29]. The 'energy hotpots' from the major sources which have high energy footprint is an important information to better address options at reducing energy inputs, thus reducing the energy hotspots, thereby reducing carbon footprint.

There are other implications when energy input of a particular production system is high. Its direct effect is on the increase of total production costs. Often, farmers experienced low incomes as a result of high costs of production, this has affected greatly the socio-economic welfare of the farming community. Low income directly affects food security, education of children, nutrition and health. Lower income opportunities in farming lead to lower on-farm wage. The dual effect of 'lower incomes and lower wages' have led farming in becoming unattractive to younger generations, this threatens farm labor and food security. The meager opportunity in farming will encourage more migration from 'on-farm to off-farm' activities and this will further threatens farm lands being abandoned, hence food prices will escalate in years to come.

Understanding the significant contributions of various energy-intensive systems delineated into direct, indirect and embedded energy inputs will help guide policy makers and local planners to initiate a 'green agriculture economy' – a food production system with reduced energy footprints and higher economic returns for all.

4. Conclusion

The total energy inputs (TEI) is the sum total of direct energy input (DEI), indirect energy input (IEI) and embedded energy input (EEI). Across the nine (9) agroforestry systems (AFSs) identified within the 16 community based forest management (CBFM) sites, the DEI contributed 1.6-5.4%, IEI 94.1-98.0% and EEI 0.30-0.50%, respectively. About 94.0-98.0% of the TEI across all AFSs were attributed to IEI that comes largely from the individual contributions of agrochemicals and labor. The agrochemicals constitute the NPK fertilizers and herbicides used, while labor were computed from pre-land preparation (PLP), crop establishment (CE), crop care and maintenance (CCM), harvest and postharvest (HPH) operations, respectively.

Of the total IEI (5,648.0-11,356.24 Mcal ha^{-1}), agrochemicals contributed 34.1-75.0% and labor 25.0-65.9%, respectively, hence named as the most energy-intensive inputs. The high energy input on agrochemicals and labor were identified as the 'energy hotspots'. Reducing these hotpots is the way to reduce energy footprint.

The high plant density and the number of tree species present in the system contributed significantly in the overall TEI. This is due to the accrued energy inputs that each individual tree crops contributed. Generally, the high TEI of multi-tree based systems is attributed to high energy usage on farm inputs, labor and transportation.

Understanding the significant contributions of various energy-intensive systems delineated into DEI, IEI and EEI will guide policy makers and local planners to initiate a food production system with reduced energy footprints and responsive to changing climate with higher economic potential for the upland growers in the City of Zamboanga and in the entire Zamboanga Peninsula.

5. Recommendation

Energy use analysis in selected agroforestry systems is a pioneering work that has been conducted in the City of Zamboanga, Philippines. However, recognizing the extent of energy utilization in various agricultural landscapes, the use of energy accounting procedures can also be done on agricultural crops grown in various locations to derive the estimates of energy inputs delineated as direct, indirect and embedded.

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