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Calculating the energy input and carbon emission of chili production in Zamboanga City, Philippines

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Abstract

One of the major concerns of today's agricultural sectors is sustainability, which aims to address issues with crop processing as well as environmental repercussions. As the population's need for resources grows, so does the demand for energy to provide these resources, which is now at an all-time high. This is where the accounting of energy and carbon emissions is needed to limit energy inputs as much as possible, thus increasing the output of such goods. However, the focus of the study was on calculating the energy input and carbon emission of Chili Production in Zamboanga City, Philippines. The study revealed that out of all the farm operations involve in the said production the crop establishment is considered as the energy hotspot with 3,092.93 Mcal ha^{-1} or 56.10% (270.98 LDOE) and with 1,073.08 CO_2e. Thus, indirect energy input was also recorded with high energy inputs and considered as the energy hotspot with 5,399.37 Mcal ha^{-1} or 97.93% (473.05 LDOE) and with 1,873.28 CO_2e. Thus, the lowest energy inputs revealed in the study is embedded energy inputs with 46.33 Mcal ha^{-1} or 0.84% (4.06 LDOE) as well carbon emission with 16.078 CO_2e.The farm operation with lowest energy inputs and carbon emission is said to be the crop management with 118.19 Mcal ha^{-1} or 2.14% (10.36 LDOE) and 41.03 CO_2e. Concerned agencies should seek out alternative methods of carrying out farm operations involving agents or conditions that influence crop output. This is done to boost production yields while lowering energy consumption.

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Introduction

One of the most critical problems of our time is forecasting the future under the effects of climate change. Natural environments that provide protection for oxygen, clean water, and other resources, and the prospects for future opportunities, such as new stocks for agriculture, need to be preserved not just because they are part of good stewardship, but also because they will help us survive. Learning the first stage of modelling the impact on potential temperatures of greenhouse gas sources and sinks is as important as the same conditions that affect the increases in temperature, such as ocean circulation and reactions to terrestrial environments, will themselves be altered as climate changes. With too many different climate-sensitive factors to be taken into consideration, scientists or researchers need strategies to narrow down the number of possible environmental effects such that they know what particular concerns to fix (McNutt, 2013).

According to Tabal *et al.* (2021), everywhere, the ramifications of global warming are felt and have very real repercussions for agriculture, oceans, humans and other resources. Evidences is convincing that the high increase in global CO_2 emissions from coal, oil and natural gas burning is causing the acceleration that was already stated by Butler *et al.*(2021), which is why the United Nations Framework Convention on Climate Change (UNFCCC) envisaged a realistic policy framework through the Paris Agreement in 2015 that lays out precisely what needs to be done to stop climate disruption and reverse its impact but the agreement itself is meaningless without concrete action (Bodansky and Diringer, 2010; Friman and Hjerpe, 2014; Asadnabizadeh, 2019).

Energy, on the other hand, is important for the processing of crops and other agricultural resources, so it also has much to do with the current crisis we are currently facing, as well as the consequences of climate change. Much of the study results have shown that agriculture offers significant sources of greenhouse gas emissions and large energy needs (Beddington *et al.*, 2012; Kastner *et al.*, 2012).

In agriculture, one of the most common issues is the use of resources to grow crops and other agricultural commodities. This is also one of the challenges of the aforementioned industry in terms of achieving the so-called sustainability with respect to the facets of its output by also reducing its detrimental effects on the environment. A variety of recent research reports have proposed applicable agricultural methods that could help mitigate the environmental effects of such operations. The techniques are said to be organic farming and tillage conservation (Hoffman *et al.*, 2018). However, the above activities did not identify potential energy sources in terms of farm operations and other elements in terms of output per acre. In the same way, farmers, scholars, educators and policy makers need resources to solve the great challenges of agriculture and to increase productivity without losing the integrity of the environment and to help them to resolve the challenges of agriculture (Tabal *et al.*, 2021).

On the other hand, Zamboangeño is enjoyable in consuming chili spices that mix with their rice, according to DOLE Region 9, so in Zamboanga City, more people are fond of hot and spicy food, restaurants in the city need chili suppliers that could satisfy their demand. Beneficiaries of DOLE's Project HOPE (Helping Others Prosper Eco) take advantage of this market in the Zamboanga Peninsula. However, an increase in energy inputs is an increase also in carbon foot print (Tabal *et al.*, 2021). Hence, the current study will calculate the energy inputs and carbon emission to produce chili in Zamboanga City, Philippines.

The study is focuses on the calculation of energy inputs of Chili Production in Zamboanga City. The specific goals are as follows:

1. Provide quantitative procedures in determining the energy inputs.
2. Determine the energy coefficient of input and output.
3. Calculate the Carbon Footprint.

Materials and methods

The study was conducted at Ecozone, San Ramon, Talisayan, Zamboanga City Philippines. Approximately about 23 kilometers away from city proper. The researchers utilized a descriptive design using adapted questionnaire with modified contents to fit in the needed information for the study. An actual face to face or individual interview was performed with the consent and proper approval from the respondents. The researcher informed the rights of the respondents as to the information to be collected and as to the withdrawal rights. The inclusion, exclusion and withdrawal criteria were also observed in the study wherein it was focused and included only the calculation of energy inputs and output and determining the energy carbon emission on Chili Production in Zamboanga City.

The respondents who wish not to participate was properly observed and was considered. Documentations during the ocular visit and gathering data were done in the field. The respondents were the farmers who engaged on the production of the said crop or commodity and were chosen using purposive sampling method from the list of farmers from the Ayala district office of the City Agriculturist. The data collected was done by tabulating and was analyzed using appropriate tool which is the energy consumption determination which geared towards determining the energy inputs as well the carbon emission based on the activity made in the production aspect of a specific crop. The energy consumption computation particularly the different equations was adapted from the study of Tabal *et al.* (2021). The researcher also used percentage and mean to elaborate and to make comparison on the given data, to wit:

1. Direct Energy Used (DEU):

a) Direct energy (diesel or gasoline) used ha^{-1} for field operations (*FFOpe*)

$DEUF_{FOpe} = (A_{fu} \times E_{fcoet})$ Eq. 1

Where:

DEU_{FFOpe} = direct fuel used per field operation, Mcal ha^{-1}

A_{fu} = average fuel used per working hour (Lit hr^{-1})

Efcoef = energy coefficient of fuel, Mcal Lit^{-1}

b) Direct energy (diesel or gasoline) used ha^{-1} for hauling and transport (*Ftrans*)

$DEU_{Ftrans} = (A_{Ftrans} \times E_{Fcoef})$ Eq. 2

Where:

DEU_{Ftrans} = direct fuel used for a hauling and transport, Mcal ha^{-1}

A_{Ftrans} = average fuel used per working hour (Lit hr^{-1})

E_{Fcoef} = energy coefficient of fuel, Mcal Lit^{-1}

c) Direct energy (diesel or gasoline) used liters for purchasing inputs (*Gtrans*)

$DEU_{Gtrans} = (A_{Gtrans} \times E_{Fcoef})$ Eq. 3

Where:

DEU_{Gtrans} = direct fuel used for purchasing inputs, Mcal ha^{-1}

A_{Gtrans} = average fuel used per working hour (Lit hr^{-1})

E_{Fcoef} = energy coefficient of fuel, Mcal Lit^{-1}

2. Indirect Energy Used (IEu):

a) NPKfertilizers applied (*NPKfert*)

$IEU_{NPKfert}(A_{NPKfert} \times E_{NPKcoef})$ Eq. 4

Where:

IEU = indirect energy used on fertilizer (NPK), Mcal ha^{-1}

$A_{NPKfert}$ = amount of fertilizer (NPK) applied, kg ha^{-1}

$E_{NPKcoef}$ = energy coefficient of NPK fertilizer, Mcal kg^{-1}

b) Human labor (HL)

$IEU_{HL} = N_{lab} \times N_{hrs} \times E_{HLcoef})$ Eq. 5

Where:

IEU_{HL} = indirect energy used on human labor, Mcal ha^{-1}

N_{lab} = number of laborers involved in farm operation ha^{-1}

N_{hrs} = number of hours per field operation ha^{-1}

E_{HLcoef} = energy coefficient of human labor, Mcal hr^{-1}

c) Animal labor (AL)

$TEUAL = (N_{ani} \times N_{hrs} \times E_{ALcoef})$ Eq.6

Where:

IEU_{AL}= indirect energy used on animal labor, Mcal ha^{-1}

N_{ani} = number of animals used in farm operation ha^{-1}

N_{hrs} = number of hours per field operation ha^{-1}

E_{ALcoef} = energy coefficient of animal labor, Mcal hr^{-1}

d) Organic fertilizer (*animal manure*) (*AM*)

$IEU_{AM} = (A_{AM} \times E_{AMcoef})$ Eq. 7

Where:

IEU_{AM} = indirect energy used on animal manure, Mcal ha^{-1}

A_{AM} = amount of animal manure applied, kg ha^{-1}

E_{AMcoef} = energy coefficient of animal manure, Mcal kg^{-1}

e) Seeds used (*Chili*)

$IEU_s = (A_s \times E_{scoef})$ Eq. 8

Where:

IEU_s = indirect energy used on seed (chili), Mcal ha^{-1}

A_s = amount of seed (chili) used, kg ha^{-1}

E_{Scoef} = energy coetficient of seed (chili), Mcal ha^{-1}

f) Pesticides (*insecticide, fungicide, herbicide*) used (*IFH*)

$IEU_{IFH} = (A_{IFH} \times E_{IFHcoef})$ Eq. 9

Where:

IEU_{IFH} = indirect energy used on pesticides, Mcal ha^{-1}

A_{IFH} = amount of pesticides applied, Lit ha^{-1}

$E_{IFHcoef}$ = energy coefficient of specific pesticide, Mcal Lit^{-1}

g) PHEI on PLP, CE and CCM

$PHEl_{PLP} = (PLP_{SA} \times E_{LABORCOEF}) / Y_{SPC}$ Eq. 10

Where:

$PHEl_{PLP}$ = pre-harvest energy input on pre-land preparation, Mcal

PLP_{SA} = Specific activity on pre-land preparation, Mcal

$E_{LABORCOEF}$= energy coefficient of labor, Mcal

$PHEI_{CE} = (CE_{SA} \times E_{LABORCOEF}) / Y_{sc}$ Eq. 11

Where:

$PHEl_{CE}$ = pre-harvest energy input on crop establishment, Mcal

CE_{SA} = specific activity on crop establishment, Mcal

$E_{LABORCOEF}$ = energy coefficient of labor, Mcal

Y_{sc} = number of unproductive years of eggplant

$PHEl_{CCM} = (CCM_{SA} \times E_{LABORCOEF}) Y_{SC}$ Eq. 12

Where:

$PHEl_{CCM}$ = pre-harvest energy input on crop care and management, Mcal

CCM_{SA} = specific activity on crop care and management, Mcal

$E_{LABORCOEF}$ = energy coefficient of labor, Mcal

Y_{sc} = number of unproductive years of eggplant

3. Embedded Energy Used (*EEu*)

a) Embedded Energy used in farm machineries (*EFM*)

$EFM = (W_M \times E_{Mcoef}) / (LS_M \times Hr)$ Eq. 13

Where:

EFM specific embedded energy for machinery used for a field operation Mcal ha^{-1}

W_M = weight of the machine, kg $unit^{-1}$

E_{Mcoef} = energy coefficient of a specific machinery, Mcal kg^{-1}

LS_M= life span of the machine, years $unit^{-1}$

Hr = the no. of hours the machine was used, hours ha^{-1}

b) Embedded Energy used in farm equipment and tools (*EET*)

$EET = (W_{ET} \times E_{Mcoef}) / (LS_{ET} \times Hr)$ Eq. 14

Where:

EET= specific embedded energy for farm equipment and tools used for a field operation, Mcal ha^{-1}

W_{ET}-Weight of the farm equipment and tools, kg $unit^{-1}$

E_{ETcoef} = energy coefficient of a specific farm equipment and tools, Mcal kg^{-1}

LS_{ET} = life span of the farm equipment and tools, years $unit^{-1}$

Hr = the no. of hours the equipment and tools was used, hours ha^{-1}

Total Energy Input (TE):

$TEI = DE + IE + EE$ Eq. 15

Where:

TEl = total energy input, LDOE ha^{-1}

DEU= direct energy

IEU=indirect energy

EEU= embedded energy

Energy Use Indicators

a) Total Energy Output (*TEO*)

$TEO = (Y \times E_{coef})$ Eq. 16

Where:

TEO = total energy output, Mcal ha^{-1}

Y= yield, kg ha^{-1}

E_{coef} = energy coefficient of specific farm commodity, Mcal kg^{-1}

b) Energy Return on Energy Input (*EnROEI*)

EnROEI = TEY/ TEI Eq. 17

Where:

EnREOI = energy return on energy input, kg $Mcal^{-1}$

TEY = total economic yields, kg ha^{-1}

TEI= total energy input, Mcal ha^{-1}

c) Energy Productivity (*EP*)

EP = TEO/ TEI Eq. 18

Where:

EP = energy productivity, Mcal ha^{-1}

TEO = total energy output, Mcal ha^{-1}

TEI = total energy input, Mcal ha^{-1}

d) Net Energy (NE)

NEB = TEO – TEI Eq. 19

Where:

NE = net energy, Mcal ha^{-1}

TEO = total energy output, Mcal ha^{-1}

TEI = total energy input, Mcal ha^{-1}

Results and discussion

Energy coefficient of various farm inputs and outputs is shown in Table 1. The total energy inputs stated in Table 2 indicated the different farm operations and its equivalent energy inputs in Mcal ha^{-1}, including its percentage and LDOE. It was also appeared in the Table 2 the equivalent energy inputs of the Direct energy, Indirect energy and Embedded energy inputs and to include its percentage and LDOE. The computed carbon footprint was also indicated in the form of CO_2e.

Table 2 showed the total energy inputs and revealed that the highest carbon emission resulted from Indirect Energy Inputs (IEI) with 1,873.28 CO_2e (97.93%) or with 5,399.37 total mcal ha^{-1} (LDOE of 473.05) of the total energy inputs of 5,513.53 (LDOE of 483.05) 1,912.88 CO_2e or including Direct Energy Input, Indirect Energy Input, and Embedded Energy Input respectively. Hence, direct energy input has 67.83 mcal ha^{-1} or 1.23% (5.94 LDOE) with 23.52 CO_2e and embedded energy input has 46.33 mcal ha^{-1} or 0.84% and with 4.06 LDOE (16.08 CO_2e).

However, the result shows that out of the four (4) major farm operations given in the chili production, crop establishment has the highest carbon emission with 1,073.08 CO2e (56.10%) or with the total energy inputs of 3,092.93 mcal ha^{-1} and with 270.98 as the LDOE. It comprises of 3,074.54 mcal ha^{-1} energy inputs from indirect energy inputs with (269.46 LDOE) 1,067.06 CO_2e and about 18.39 mcal ha^{-1} as energy inputs from embedded energy inputs and with (1.61 LDOE) 6.38 CO_2e. Thus, harvest and post-harvest has an energy inputs of 1, 970.78 mcal ha^{-1} with LDOE of 172.66 (683.73 CO_2e) and is considered as the second with highest energy inputs and carbon emission, followed by pre-land preparation with 331.63 mcal ha^{-1} energy inputs and with 29.05 LDOE (115.04 CO_2e). The lowest energy inputs with 118.19 mcal ha^{-1} and 10.36 LDOE (41.03 CO_2e) is the crop management. From the given data, the energy hot spot was observed in the crop establishment in terms of the farm operations and was also observed in Indirect Energy Inputs that falls under the energy input category.

The computed data where direct, indirect and embedded energy inputs of the given farm operation activities applied in chili production, the energy hotspot revealed in Table 2 or the total energy inputs appeared to be indirect energy input with 5,399.37 Mcal ha^{-1} or 97.93% (473.05 LDOE) and with 1,873.28 CO_2e respectively, where crop establishment as part of one of the activities in farm operation is also considered as energy hotspot wherein it contributed the highest energy inputs with 3,092.93 Mcal ha^{-1} or 56.10% (270.98 LDOE) as well as carbon emission with 1,073.08 CO_2e. Thus, the lowest energy inputs revealed in the study is embedded energy inputs with 46.33 Mcal ha^{-1} or 0.84% (4.06 LDOE) as well carbon emission with 16.078 CO_2e.The farm operation with lowest energy inputs and carbon emission is said to be the crop management with 118.19 Mcal ha^{-1} or 2.14% (10.36 LDOE) and 41.03 CO_2e.

Table 1. Energy coefficient of various farm inputs and outputs

Particulars	Unit	Energy equivalent Per unit MJ	Mcal	References
A.) Inputs				
Seed				
Chili seed	kg	1.17	0.28	Singh *et al.* (2002)
Agrochemicals:				
a)Herbicide (gyphosate)	Lit	553.07	132.19	Pimentel (2019); Tabal (2022)
b) Herbicide (Gen.), ave.	Lit	274	65.5	Ledgard *et al.* (2007); Gundogmus (2013); Tabal (2022)
c) Insecticide (solid)	kg	315	75.29	Yilmaz *et al.* (2005); Ledgard *et al.* (2007); Tabal (2022)
d) Insecticide (liquid), ave.	Lit	281. .32	67.24	Pimentel (2019); Gundogmus (2013); Tabal (2022)
e) Fungicide (solid)	kg	210	50.2	Yilmaz *et al.* (2005); Ledgard *et al.* (2007); Tabal (2022)
f) Fungicide (liquid), ave.	Lit	104.1	24.88	Gundogmus (2013); Pimentel (2019); Tabal (2022)
Chemical fertilizers				
a) Nitrogen	kg	102.23	24.43**	Lockeretz (1981); Mendoza (2014); Tabal (2022)
b) Phosphate (P205), ave.	kg	20.6	4.92	Lockeretz (1981); Mendoza (2014); Tabal (2022)
c) Potassium (K20), ave.	kg	16.38	3.91	Lockeretz (1981); Pimentel (2019); Mendoza (2014); Tabal (2022)
Organic fertilizer	kg	1.26	0.30	Mendoza (2014); Tabal (2022)
Fuel				
a) Gasoline	Lit	42.32	10.11	Tabal (2022); Gundogmus (2013)
b) Diesel fuel	Lit	56.31	13.46**	Tabal (2022); Gundogmus (2013)
Labor				
a) Human labor	Hr	1.96	0.47	Yilmaz *et al.* (2005); Gundogmus (2013)
b) Draft animal	Hr	12.01	2.87	Pimentel (2019); Gliessman (2014)
Steel/Metal	Kg	75.31	18	Pimentel (2019)
B.)Output				
Chili	Kg	3.35	0.8	Singh *et al.* (2002)

Table 2. Summary of Total Energy Inputs (TEI)

Farm operation	DEI Total mcal ha^{-1}	DEI %	DEI LDOE	IEI Total Mcal ha^{-1}	IEI %	IEI LDOE	EEI Total mcal ha^{-1}	EEI %	EEI LDOE	TEI Total mcal ha^{-1}	TEI %	TEI LDOE
Pre-land preparation	32.55	47.99	2.85	286.04	5.30	25.06	13.04	28.15	1.14	331.63	6.02	29.05
Crop establishment	0	0	0	3,074.54	56.94	269.37	18.39	39.69	1.61	3,092.93	56.10	270.98
Crop management	0	0	0	114.59	2.12	10.04	3.6	7.77	0.32	118.19	2.14	10.36
Harvest and pre-harvest	35.28	52.01	3.09	1,924.2	35.64	168.58	11.30	24.39	0.99	1,960.89	35.74	172.66
Total energy inputs	67.83	1.23	5.94	5,399.37	97.93	473.05	46.33	0.84	4.06	5,513.53	100	483.05

Total Energy Inputs (TEI). Mcal ha^{-1} of different types of farm operations applied on Chili production.

Conclusion

From the given data in the study where direct, indirect and embedded energy inputs computed from the farm operation activities applied in chili production, the energy hotspot revealed or the total energy inputs appeared to be indirect energy input with 5,399.37 Mcal ha^{-1} or 97.93% (473.05 LDOE), where crop establishment as part of one of the activities in farm operation is also considered as energy hotspot wherein it contributed the highest energy inputs with 3,092.93 Mcal ha^{-1} or 56.10% (270.98 LDOE).

Hence, higher energy efficiency means lower dissipation in the production system. Thus, a reduction in farm operation or activities proportional to the energy shortfall is inevitable unless if energy efficiency is increased. Furthermore, it can be achieved either through higher conversion efficiency between final or primary energy inputs or finding alternative ways which is convenient and can sustained the whole production with energy efficient.

Recommendation(s)

Based on the calculation of energy inputs in the chili production, the farmers and other related field including academe, LGU and other stakeholders should come up with alternative ways in farm operation activities and practices that include agents or factors affecting the production of the said crop. This is to increase the yield of outputs at the same time to limit the contribution of the energy inputs in the mentioned production.

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