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Carbon Efficiency Ratio of Eggplant Production in Zamboanga City, Philippines

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Abstract— *The research study entitled Carbon Efficiency Ratio of Eggplant Production was conducted in Zamboanga City, Philippines, and aims to estimate the input-output carbon of eggplant production and to determine its carbon efficiency ratio. The eggplant production obtained the input carbon of 3,698.91CO2e kg^{-1} derived from the total energy inputs (TEI), the total energy inputs are the sum of 'direct energy input (DEI), indirect energy input (IEI)' and embedded energy input (EEI) was converted into Liter Diesel Oil Equivalent (LDOE), 1.0 LDOE were equal to 11.414 Mcal unit^{-1} and multiplied by 3.96 kg CO2e emission to obtain the carbon dioxide emission. The crop establishment activity obtained the highest input carbon of 58.35% potential share of carbon emission, followed by pre-land preparation of 38.46% potential share, while harvest and pre-harvest obtain 2.13%, among the entire activities, the crop management activity obtained the lowest input carbon of 1.06% potential share. The eggplant production has a carbon output of 4,081.99 CO2e kg^{-1}. The entire eggplant production system obtained a net carbon of 463.81 CO2e kg-1 mainly derived from output carbon less input carbon, obtaining the carbon efficiency (ratio) was derived from output carbon divided by input carbon that gives the result of 1.13. The carbon efficiency ratio was related to the average yield of eggplant. This shows that the existing cultural practices of eggplant production in the city are carbon neutral whereas it does not emit carbon to the atmosphere beyond the output carbon produced from the production of eggplant. It implies that the amount of carbon emitted is the amount of carbon sequestered*.

Keywords— *Total Energy Inputs, Input Carbon, Output Carbon, Carbon efficiency ratio*.

I. INTRODUCTION

Climate change is one of the most prominent global issues that have attracted the attention of global academic researchers, policymakers, and other related professionals. Climate change has caused several issues, such as global warming, ecological imbalance, technological issues, economic issues, and societal issues.

Increasing concentration of greenhouse gas emissions is considered a prime cause for these issues [4][10]. Amongst the greenhouse gases, carbon dioxide has been considered the most prominent contributor to global climate change [19][18]. Human interventions are now increasing the number of greenhouse gases in the atmosphere, leading to climate change. These changes are affecting many human activities, including agriculture [17].

If this phenomenon is not properly addressed, humans will suffer from heat-related illnesses, disasters, and even death attributed to these hazards globally. Due to these issues, governments and policymakers around the world are implementing solutions to neutralize carbon emissions like enhancing the carbon sink. Enhancing carbon sink is a good strategy to neutralize carbon emissions and as well as the finding of Flores [2] that some agricultural crops are carbon neutral.

One way to test whether the crops are carbon neutral is by using the carbon efficiency ratio done by Flores [2]. Hence, this study aims to estimate the input-to-output carbon of eggplant production and to determine its carbon efficiency ratio of the work of Taib [15].

II. MATERIALS AND METHODS

Site selection and time of study

The study used the purposive sampling technique in selecting the sampling unit due to difficulty in finding the location of the farmers that engaged in eggplant production. The study was conducted in Zamboanga city, Philippines.

Fig. 1. Study site map adapted from Taib [15].

Collection of data

The Data were collected from the published paper entitled Net Energy Use and Carbon Emission Equivalent of Tomato and Eggplant Production in Zamboanga City, Philippines of Taib [15]. The carbon input is derived from the energy inputs of various activities applied to eggplant production such as pre-land preparation, crop establishment, crop management, harvest, and pre-harvest.

Calculating input carbon

The total energy inputs are the sum of 'direct energy input (DEI)' including the use of diesel/gasoline to run the machines for farm operations and transport of farm products, while the 'indirect energy input (IEI)' were seeds used, NPK fertilizers,

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agrochemicals and labor inputs. Lastly, the 'embedded energy input (EEI)' was accounted for from the utilization of machines, farm equipment, implements, motorized vehicles, and draft animal indicated in Mcal [8] [5] [12] [13] [14] [15]. Then, were converted into Liter Diesel Oil Equivalent (LDOE), according to Pimentel and Table [9] [12] 1.0 LDOE was 11.414 Mcal unit^{-1}. After getting the LDOE, it will then multiply by 3.96 kg CO2e emission to obtain the carbon dioxide emission according to Pimentel; Tabal and Mendoza; Taghavi and Mendoza; Thu and Mendoza; and Savuth [8] [12] [11] [16] [17]. The sum of carbon emissions of DEI, IEI, and EEI is the input carbon.

Calculating output carbon

The inputs-output carbon was adopted from the work of Flores [2] but was modified specifically for the computation of inputs carbon. To obtain the amount of output carbon, the fresh output yield was converted to carbon (C) content equivalent. The carbon content is usually 45% of the total yield [1] [2]. The fresh output yield of eggplant was multiplied by 0.45 to obtain the output carbon. Net carbon was computed from output carbon less input carbon.

Calculating carbon efficiency ratio

To determine whether the production of eggplant is carbon neutral, carbon sequestration, or more on carbon emission by calculating the carbon efficiency ratio. The carbon efficiency ratio was calculated from output carbon divided by input carbon [2].

Statistical Analysis

All data were tabulated on Microsoft excel and analyzed using simple descriptive and inferential statistics, in comparing the carbon emission the researcher used the mean, percentage, the sum per activity in eggplant production.

III. RESULTS

Table 1 shows the input carbon derived from the total energy inputs of the entire activities of eggplant production acquired from the work of Taib [15]. The overall energy inputs applied to eggplant production was 10,670.44 Mcal ha^{-1} (934.86 LDOE ha^{-1}). Crop Management obtained the lowest energy inputs at 112.69 Mcal ha-1 (9.87 LDOE ha^{-1}), while Crop establishment obtained the highest total energy inputs at 6,220.54 Mcal ha^{-1} (544.99 LDOE ha^{-1}) compared to other activities such as Pre-Land Preparation at 4,100.75 Mcal ha^{-1} (3.59.27 LDOE ha^{-1}) and Harvest and Pre-Harvest activity obtained 227.46 Mcal ha^{-1} (19.93 LDOE ha^{-1}).

The crop establishment activity obtained the highest input carbon of 2,155.31 CO_2e kg^{-1}at 58.35% potential share of carbon emission, followed by pre-land preparation of 1,422.71 CO_2e kg^{-1} at 38.46% potential share of carbon emission, then the harvest and pre-harvest obtain 78.92 CO_2e kg^{-1}at 2.13%, among the entire activities, the Crop Management activity obtained the lowest carbon input of 39.10 CO_2e kg^{-1} at 1.06% potential share of carbon emission.

Table 2 below shows the input-output carbon and carbon efficiency ratio of eggplant production. The fresh output yield has a carbon content of usually 45% of the total yield [3] [1] [2] [7] [6] [13] [14]. The fresh output yield of eggplant was accounted for in the input-output carbon analysis. The average production yield of eggplant was 9,071.11kg/ha to give a total carbon output of 4,081.99CO2e kg^{-1}. The entire eggplant production system obtained a net carbon of 463.81 CO2e kg-1 mainly derived from output carbon less input carbon, to obtain the carbon efficiency (ratio) was derived from output carbon divided by input carbon that gives the result of 1.13.

TABLE 1. Input carbon derived from total energy inputs (TEI) of eggplant production.

Type of Labor	TEI	LDOE	CO_2e	%
	Mcal ha^{-1}	ha^{-1}	kg	
I. Pre-Land Preparation	4,100.75	359.27	1,422.72	38.46
II. Crop Establishment	6,220.54	544.99	2,158.17	58.35
III. Crop Management	112.69	9.87	39.10	1.06
IV. Harvest and Pre-Harvest	227.46	19.93	78.92	2.13
TEI	**10,670.44**			
Inputs carbon			**3,698.91**	

TABLE 2. Input-output carbon and carbon efficiency ratio (sustainability index) of eggplant production

Indicator	Value	Unit
Input carbon	3,618.18	CO_2e kg^{-1}
Output carbon	4,081.99 kg	CO_2e kg^{-1}
Net carbon	463.81	CO_2e kg^{-1}
Carbon efficiency (ratio)	1.13	

IV. DISCUSSION

The amount of input carbon was attributed to total energy inputs obtained from direct energy inputs (DEI), indirect energy inputs (IEI), and embedded energy inputs (EEI), the results of these were accounted from the following activities; Pre-land preparation obtained from land clearing and purchasing inputs with the use of machinery and vehicle. In Crop, establishment activity was attributed to plowing, harrowing, fertilizer application, seedling, and weeding. For crop management was mainly with the use of an insecticide. Harvest and pre-harvest were obtained from harvesting, bundling, hauling, and transport. The input carbon in eggplant production per hectare was calculated and tabulated in Table 2. The input carbon of eggplant production was 3,618.18kg CO2eq/ha. This indicated that every 1-hectare production of eggplant would lead to carbon emission of 3,618.18 kg CO2eq. The highest share of carbon emission was observed for crop establishment at 58.35%, followed by pre-land preparation at 38.46% potential share of carbon emission, while harvest and pre-harvest obtain 2.13%, among the entire activities, the Crop Management activity obtained the lowest of 1.06% potential share of carbon emission. Generally, the results indicated that more usage of chemicals, diesel, and labor would incur more energy inputs that would lead to more potential carbon dioxide emissions.

Eggplant in fresh form was the output yield considered in the input-output carbon analysis according to Flores [2]. The average harvested yield of eggplant was 9,071.11kg/ha to give a total carbon output of 4,081.99CO_2e kg^{-1} as shown in table 2. The input carbon related to total energy inputs which were obtained from direct energy inputs (DEI), indirect energy inputs

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(IEI), and embedded energy inputs (EEI) was 3,618.18 CO_2e kg. As observed, the carbon ratio in the entire production system of eggplant was 1.13. This carbon efficiency ratio was related to the average yield of eggplant in the study areas. This shows that the existing cultural practices of eggplant production in Zamboanga City, Philippines, are carbon neutral whereas it does not emit carbon to the atmosphere beyond the output carbon produced from the production of eggplant. It implies that the amount of carbon emitted is the amount of carbon sequestered. The result of the study has the same findings as Flores [2] that eggplant production is carbon neutral.

Intensive agricultural production results in large energy consumption per unit area of production. However, when intensive production results in elevated yields, it can result in more efficient crop production. The impact of high yields is twofold, as higher yields also lead to efficient usage of energy per unit weight of fruit produced. Proper management, correct timing and amount of fertilizer application, proper application of pesticide, proper tillage, adequate irrigation, proper allocation of manpower per unit area, and proper allocation of activity per working hour will lead to efficient usage of energy. The imbalance of these activities can affect the yield of the production, energy loss, reduce profits, and also can lead to environmental problems and health problems the individuals such as pollution, erosion, and greenhouse gas emission.

The excess of energy inputs will tend to increase carbon emissions which it will lead to global warming. Thus, global warming will hamper agricultural production due to drought, and when the water will be limited the crops will not survive. To have eco-friendly farming there is a need to adopt the use of crop rotation with nitrogen-fixing plants such as leguminous plants, green manuring, composts or organic fertilizers can be used instead of synthetic fertilizers should be considered to reduce the high utilization of energy, environment-friendly biological control agent for pest and diseases, biodiesel, etc, utilization of new machinery for cultivation, more efficient pumps for extracting irrigation water, application of mulches to conserve soil moisture and prevent the growth of weeds thereby reducing irrigation frequency can lead to cultivation/production of eggplant with less carbon emission.

V. Conclusion and Recommendation

The entire production of eggplant using the present cultural practices is carbon neutral or its outputs can store or sequester more C than what was generated by the inputs used in production. With proper management, correct timing and amount of fertilizer application, proper application of pesticide, proper tillage, use of mulch, proper irrigation, proper allocation of manpower per unit area, and proper allocation of activity per working hour will lead to efficient usage of energy and adopting organic agriculture will lead to eco-farming system and less carbon emission.

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