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CARBON EMISSION EQUIVALENT OF NET ENERGY USE TO PRODUCE WHITE CORN IN ZAMBOANGA CITY, PHILIPPINES

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ABSTRACT

White corn is source of caloric energy, but to produce such energy also requires enormous energy in the form of direct energy input (DEI), indirect energy input (IEI) and embedded energy input (EEI) or call this the total energy input (TEI) calculated from the major farm activities such as pre-land operation (PLO), crop establishment (CE), crop care and maintenance (CCM), harvest and postharvest (HPH). The energy coefficients, calculations and its carbon emission equivalent were based from various literatures. All Mcal energy units were converted to liter diesel oil equivalent or LDOE, where 14.414 Mcal = 1.0 LDOE = 3.36 kg CO_{2e} emission equivalent. A total of 20 white corn growers were interviewed using a structured questionnaire. The relationships of predictors such as the DEI, IEI and EEI ha^{-1} were tabulated and analyzed using a descriptive statistic. Means, percentages and sums were compared. The TEI to produce white corn grown in the upland-rainfed conditions of Barangay Vitali, Zamboanga City, Philippines was calculated at 2,398.6 Mcal ha^{-1} or this is equal to 210.1 LDOE ha^{-1} or a total of 0.83 tCO_{2e} ha^{-1} emission equivalent, of this amount, the DEI, IEI and EEI contributed 8.4, 90.4 and 1.2% or this is 0.07, 0.75 and 0.01 tCO_{2e} ha^{-1} emission equivalent, respectively. The high IEI was attributed largely to high inorganic fertilizer usage (32.2%), chemical pesticides (18.5%), animal and man labor (44.3%) or call these the 'energy hotspots'. Despite the application of high dosage of inorganic fertilizers, yields are low (1.82 t ha^{-1}).

Keywords: Total energy input, direct energy, indirect energy, liter diesel oil equivalent, carbon emission equivalent

1.0 INTRODUCTION

Agriculture demands energy as an essential input in crop production and makes use of direct energy as fuel or electricity to run machinery and equipment for land preparations, crop establishment, crop care and maintenance, harvest and postharvest activities, and indirectly in the form of inorganic fertilizers, agrochemicals and labor [1,2] However, with the improvement of agricultural production and movement towards mechanization, there has been an increased requirement for energy resources in order to increase food supply to meet food demand.

The utilization of energy in food production has become more intensive due to the use of fossil fuel-based inorganic fertilizers, agrochemicals, and use of fuel to run machineries, and electricity to obtain substantial increase in food produce unit^{-1} area [3]. Due to the impact of rapid mechanization and looming population, food production has become increasingly dependent on energy derived from fossil fuels [4-8] such as the direct use of diesel or gasoline to run farm machineries, irrigation, transportation, cultivation and harvesting. Postharvest energy usage includes energy for food processing, storage, packaging and transport to markets [8-10]. Huge quantities of synthetic fertilizers require high energy inputs to produce and depend largely on machinery which implicated our food production system to be highly processed and heavily packaged, which further increased its energy footprint [1,2,8,10-13]. This is the reason why agricultural crop production is a major consumer of energy and producer of greenhouse gases (GHGs) derived from direct and indirect usage of fossil fuel-based inputs which resulted in the emission of GHGs such as carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). This explains why the agriculture sector is one of the major contributors to the increasing GHG emissions with a 10% contribution to the total global emissions [14].

The total energy input (TEI) is the sum total of direct energy input (DEI), indirect energy input (IEI) and embedded energy input (EEI) or call this the *'energy footprint'* [1,2]. Defined in various literatures, the energy footprint (EF) refers to the various energy inputs such as in the production of various agricultural crops, inorganic fertilizers and agrochemicals (particularly N fertilizer and herbicide), diesel and/or gasoline fuel used to run the farm machineries, human and animal labor, processing and transportation which has high carbon emission potential expressed in tCO_{2e} ha^{-1} [1,2,15]. The carbon emission equivalent described in this study is the amount of CO_2 emitted derived from the TEI or the energy footprint (EF) in the form of liter diesel oil equivalent (LDOE) either directly or indirectly utilized [1,2,9,16] during farm operations such as crop establishment, crop care and maintenance, harvest and postharvest of white corn production. In this case, the TEI ha^{-1}used to produce white corn was considered as potential source of carbon footprint (CF) expressed in LDOE ha^{-1}, where 1.0 LDOE is equal to 3.96 kg CO_{2e} emission equivalent [9], hence, the total CF derived from TEI is considered as the net CO_{2e} emission. This quantitative accounting procedures have been used in various studies [1,2,16].

White corn is a source of caloric energy but to produce such energy also requires enormous energy in the form of machines, implements, equipment, farm tools, various farm inputs like white corn seeds, fertilizers and chemical pesticides, minitruck used for hauling and logistics, transport and transloading, animal and man labor - making the entire corn production system a highly fossil-fuel intensive. Increase in energy usage to produce white corn ha^{-1} can implicate to high carbon emission equivalent. The objective of this paper is to account the energy requirement to produce white corn in one of the corn cluster areas in the uplands of barangay Vitali, Zamboanga City, Philippines. Specifically, this study was undertaken to benchmark energy coefficients of various farm inputs, calculate the energy input and its carbon emission equivalent expressed in tCO_{2e} ha^{-1}.

2.0 MATERIALS AND METHODS

2.1 Site location

The study was conducted in one of the major corn growing areas in Barangay Vitali, Zamboanga City, Philippines. Barangay Vitali is 73.0 kmfrom the city proper. Its terrain is 30% or an area of 1,622.7 hectares is hilly/mountainous, 20% or about 1,081.8 hectares are coastal and 50% plain or 2,704.5 hectares.

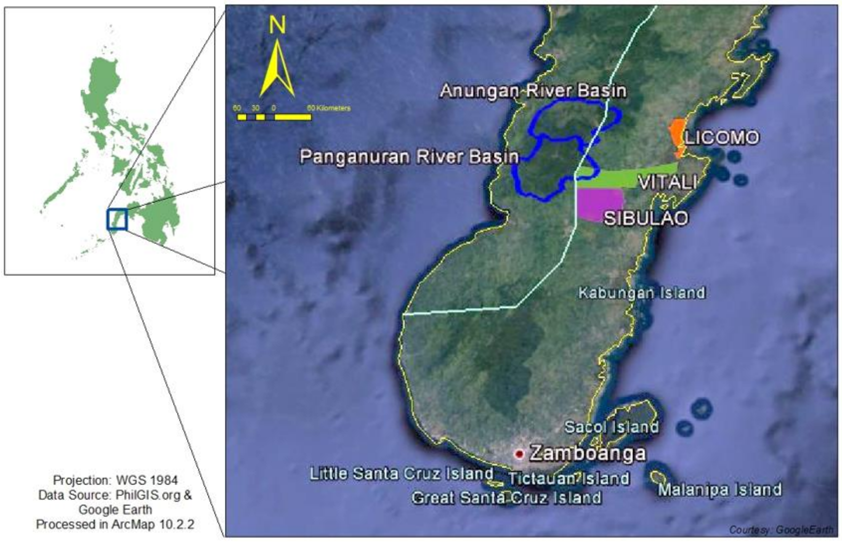

Figure 1: Location of the study area, Barangay Vitali, Zamboanga City, Philippines

2.2 Calculating the total energy input

The approach to energy accounting to produce white corn ha^{-1} was derived through its various operations based on the cultural practices. The total energy input (TEI) was calculated in all major energy consuming operations beginning at pre-planting operation (PPO) to crop establishment (CE), crop care and maintenance (CCM), harvest and postharvest (HPH) activities. The TEI was calculated from the three major components such as the direct energy input (DEI), indirect energy input (IEI) and embedded energy input (EEI), respectively [1,2,16]. The DEI includes the direct usage of diesel/gasoline to run the machines for farm operations and transport of farm products [9]. While, the IEI are farm inputs such as the corn seeds, NPK fertilizers, agrochemicals and labor derived from PPO, CE, CCM and HPH, respectively. Lastly, the EEI was accounted from the utilization of machines, farm equipment and implements, motorized vehicles and draft animal [1,2].

2.3 Energy accounting procedures and energy coefficients

Energy accounting procedures were based from various literatures [5-9,17-21] and from the recent calculations [1,2,16,22]. The various energy coefficients of various farm inputs are shown in Table 1. All energy units calculated in Mcal ha^{-1} were converted into Liter Diesel Oil Equivalent or LDOE, where 1.0 LDOE = 11.414 Mcal [9] and the LDOE ha^{-1}become the basis for the computation of carbon emission equivalent. The energy input for the manpower that includes food, clothing and miscellaneous living costs of the farming household were not accounted. The working hour in a day was set at 8.0 hours.

Table 1: Energy coefficients of various farm inputs

PARTICULARS	UNIT	ENERGY EQUIVALENT UNIT^{-1}		REFERENCES
		MJ	Mcal	
A) INPUTS				
1. SEEDS				
(b) Corn	Kg	14.69	3.51	[17]
2. AGROCHEMICALS				
(a) Herbicide (glyphosate)	Lit	553.07	**132.19**[1]	[9, 23,24]
(b) Herbicide (Gen.), ave.	Lit	274.00	65.50	[25, 26]
(c) Insecticide (solid)	Kg	315.00	75.29	[24,25]
(d) Insecticide (liquid), ave.	Lit	281.32	67.24	[9,26]
(e) Fungicide (solid)	Kg	210.00	50.20	[24,25]
(f)Fungicide (liquid), ave.	Lit	104.10	24.88	[9,26]
3. FERTILIZERS				
(a) Nitrogen	Kg	102.23	**24.43**[2]	[4,27]
(b) Phosphate (P2O5), ave.	Kg	20.60	4.92	[28-30]

(c) Potassium (K2O), ave.	Kg	16.38	3.91	[4,9,27-29,31]
4. FUEL				
(a) Gasoline	Lit	42.32	10.11	[31]
(b) Diesel fuel	Lit	56.31	**13.46**[3]	[17,32-34]
5. Electricity	Kwh	3.60	0.86	[26]
6. Irrigation	cu m	1.02	0.24	[26]

Source: [1,2]

[1] The energy for production of Glyphosate is 440 MJ kg^{-1}, the formulation and packaging, and transportation is 113.03 MJ kg^{-1}[22].

[2] Estimates includes the drilling, processing, storage and transport to site of utilization [9,27].

[3] Estimates includes the processing, storage and transport to site of utilization [4].

The following equations were used to compute for the DEI, IEI and EEI following the work of [1,2]:

2.4 Direct Energy Input (DEI)

a) Direct energy (diesel or gasoline) used ha^{-1} for field operation (DFF_{Ope}): $DFF_{Ope} = (A_{fu} \times EF_{coef})$ (1), where: DFF_{Ope} = direct fuel usedfield^{-1} operation, Mcal ha^{-1}; A_{fu} = average fuel used working^{-1} hour (Lit hr^{-1}); and EF_{coef} = energy coefficient of fuel, Mcal Lit^{-1}.

b) Direct energy (diesel or gasoline) used ha^{-1} for hauling and transport (DFF_{trans}): $DFU_{trans} = (AF_{trans} \times EF_{coef})$ (2), where: DFU_{trans} = direct fuel used for hauling and transport, Mcal ha^{-1};AF_{trans} = average fuel used working^{-1} hour (Lit hr^{-1}); and EF_{coef} = energy coefficient of fuel, Mcal Lit^{-1}.

2.5 Indirect Energy Input (IEI)

a) NPK fertilizers applied (NPK_{fert}): $IEI_{NPKfert} = (A_{NPKfert} \times E_{coefNPK})$ (3), where: $IEI_{NPKfert}$ = indirect energy used on fertilizer (NPK), Mcal ha^{-1};$A_{NPKfert}$= amount of fertilizer (NPK) applied, kg ha^{-1}; and $E_{coefNPK}$ = energy coefficient of NPK fertilizer, Mcal kg^{-1}.

b) Human labor (HL): $IEI_{HL} = (N_{lab} \times N_{hrs} \times E_{coefHL})$ (4), where: IEI_{HL} = indirect energy used on human labor, Mcal ha^{-1};N_{lab}= number of laborers involved farm^{-1} operation ha^{-1};N_{hrs} = number of hoursfield^{-1} operation ha^{-1}; and E_{coefHL} = energy coefficient of human labor, Mcal hr^{-1}.

c) Animal labor (AL): $IEU_{AL} = (N_{ani} \times N_{hrs} \times E_{coefAL})$ (5), where: IEU_{AL} = indirect energy used on animal labor, Mcal ha^{-1}; N_{ani} = number of animals used farm^{-1} operation ha^{-1};N_{hrs} = number of hours field^{-1} operation ha^{-1}; and E_{coefAL} = energy coefficient of animal labor, Mcal hr^{-1}.

d) Organic fertilizer (animal manure, AM): IEU_{AM} = (A_{AM} x E_{coefAM}) (6), where: IEU_{AM} = indirect energy used on animal manure, Mcal ha^{-1}; A_{AM} = amount of animal manure applied, kg ha^{-1}; and E_{coefAM} = energy coefficient of animal manure, Mcal kg^{-1}.

e) Corn seeds used, CS: IEU_{CS} = (A_{CS} x E_{coefCS}) (7), where: IEU_{CS} = indirect energy used on corn seed, Mcal ha^{-1}; A_{CS} = amount of corn seed used, kg ha^{-1}; and E_{coefCS}= energy coefficient of corn seed, Mcal ha^{-1}.

f) Pesticides (insecticide, fungicide, herbicide – IFH) applied: IEU_{IFH} = (A_{IFH} x $E_{coefIFH}$) (8), where: IEU_{IFH} = indirect energy used on pesticides, Mcal ha^{-1}; A_{IFH} = amount of pesticides applied, Lit ha^{-1}; and $E_{coefIFH}$ = energy coefficient of specific pesticide, Mcal Lit^{-1}.

2.6 Embedded Energy Input (EEI)

a) Embedded energy input in farm machineries (EEI_{FM}): EEI_{FM} = (W_M x E_{coefM}) / (LS_M x Hr) (9), where: EEI_{FM} = specific embedded energy input for machinery used $field^{-1}$ operation in Mcal ha^{-1}; W_M = weight of the machine, kg $unit^{-1}$; E_{coefM} = energy coefficient of a specific machinery in Mcal kg^{-1}; LS_M = life span of the machine in years $unit^{-1}$; and Hr = the no. of hours the machine was used in hours ha^{-1}.

b) Embedded energy input in farm equipment and tools (EE_{FET}): EE_{FET} = (W_{FET} x $E_{coefFET}$)/(LS_{FET} x Hr) (10), where: EE_{FET} = specific embedded energy for farm equipment and tools used $field^{-1}$ operation in Mcal ha^{-1}; W_{FET} = weight of the farm equipment and tools in kg $unit^{-1}$; $E_{coefFET}$ = energy coefficient of a specific farm equipment and tools in Mcal kg^{-1}; LS_{FET} = life span of the farm equipment and tools in years $unit^{-1}$; and Hr = no. of hours the equipment and tools were used in hours ha^{-1}.

2.7 Total Energy Input

The total energy input (TEI) is the sum total of DEI + IEI + EEI in Mcal (11).

2.8 Calculating the CO_2 emission equivalent

The CO_2 emission equivalent expressed in tCO_{2e} $ha^{-1}$was derived from the Total Energy Inputs (TEI) in Mcal ha^{-1}, where Mcal units were converted into liter diesel oil equivalent ha^{-1} (LDOE ha^{-1}), where 11.414 Mcal = 1.0 LDOE = 3.96 kg CO_2 emission equivalent (Pimentel, 1980).

2.9 Sampling and Statistics

Purposive sampling was used in selecting the fitted characteristics of corn area planted to white corn within the corn cluster area in barangay Vitali, Zamboanga City, Philippines. The estimated land area devoted to corn production was 350-400 hectares with 233-266 corn growers as reported by the Office of the City Agriculturist of the City of Zamboanga, Philippines, of this total, white corn farmers was about 60 individuals, where only 20 of the identified white corn growers were randomly interviewed as respondents using a structured questionnaire. The relationships of predictors such as the direct energy inputs (DEI), indirect energy inputs (IEI) and embedded energy inputs (EEI) ha^{-1} were tabulated and analyzed using a descriptive statistic. Means, percentages and sums were compared.

3.0 RESULTS AND DISCUSSIONS

3.1 Total energy inputs and carbon emission equivalent

The average total energy input (TEI) to produce white corn ha^{-1}in barangay Vitali, Zamboanga City, Philippines was calculated at 2,398.6 Mcal ha^{-1}or this is equal to 210.1 LDOE ha^{-1}ora total of 0.83 tCO$_{2e}$ ha^{-1} emission equivalent, of this amount, the DEI, IEI and EEI contributed 8.4, 90.4 and 1.2% or this is equivalent to 0.07, 0.75 and 0.01 tCO$_{2e}$ ha^{-1} emission equivalent, respectively (Table 2).

Table 2: Energy input and carbon emission equivalent to produce white corn ha^{-1}

Energy Input	Total			CO$_2$ Emission Equivalent	
	Mcal ha^{-1}	LDOE ha^{-1}	%	kg CO$_{2e}$ ha^{-1}	tCO$_{2e}$ ha^{-1}
DEI	213.6	18.7	8.4	74.1	0.07
IEI	2,148.6	188.2	90.4	745.4	0.75
EEI	36.4	3.2	1.2	12.6	0.01
TEI	**2,398.6**	**210.1**		**832.2**	**0.83**

DEI=direct energy input
IEI=indirect energy input
EEI=embedded energy input
TEI=total energy input
LDOE=liter diesel oil equivalent

The 8.4% (Table 2) contribution of direct energy input (DEI) to the total energy input (TEI) consisted only of direct fuel usage (gasoline) by an ‘habal-habal’ (motorized bike) utilized for the hauling and transport of farm inputs from site of purchase to site of production. On the other hand, the transport of corn grains in bags with the use of a minitruck run by diesel fuel also contributed high to DEI. Corn growers usually used animal driven cart from site of production to site where this corn produce was hauled if road is passable by a 4-wheeled vehicle, while the direct fuel usage during the shelling and milling on-site operations also contributed to high DEI. The use of machines and the mode of logistic was based on the actual practice of the majority of corn growers in barangay Vitali, Zamboanga City. Transport of corn produce (and other agricultural crops) from the uplands of Barangay Vitali at some distance can be energy intensive especially during the rainy months (June-November), where habal-habal is being utilized as this is the only type of transport vehicle can cross muddy terrains at long distance. This is the reason why the current upland agriculture especially in corn producing area is becoming energy intensive than some 5-10 years ago, where the current system had contributed 8.4% of the TEI and this translated to 0.07 tCO_{2e} ha^{-1} emission equivalent. This maybe small but there are hundreds of hectares devoted to corn production every year in barangay Vitali alone. And every year, corn farmers in this area increase their investment on direct energy since prices of gasoline and diesel fuel also increases every year. The effect of increase in fuel prices can implicate more usage of direct energy to run machines and engines, hence increase in direct energy and carbon emission equivalent.

The IEI or the indirect energy input (188.2 LDOE, Table 2) was derived from the energy cost on various farm inputs including the utilization of animal and human labor. The farm inputs include the white corn seeds and NPK fertilizers, agrochemicals such as insecticide and herbicide used, and labor requirement, where each contributed 32.2, 18.5 and 44.3%, respectively. The total labor requirement was computed from various farm operations in hour day^{-1} such as in pre-planting operation (32 hrs), crop establishment (744 hrs), crop care and maintenance (32 hrs), harvest and postharvest (176 hrs) operations. The high indirect energy usage on NPK fertilizers were mainly attributed from the 60-30-30 ha^{-1} recommended rate (RR) prescribed by the Department of Agriculture - Bureau of Soils and Water Management (DA-BSWM), Zamboanaga City station. Based on the RR, bulked of the amount was attributed to N fertilizer. This was also the findings of earlier studies [9,35]. High indirect energy usage for hauling and transport of input materials and corn produce also contributed to the IEI and has further increase fossil fuel usage [8,9,27].

The large aggregate of energy expended was on labor, this was attributed to high manual labor requirements in plowing, harrowing, furrowing, planting, fertilizer application, re-planting, weeding, hilling-up, field monitoring, spraying, harvesting, corn picking, de-husking, corn-ear drying, shelling, grain drying, sacking, hauling (use of animal driven cart), storage (seed and grits), and milling. This is the reason why the high energy inputs consumption derived from fertilizers usage, application of agrochemicals and utilization of manual labor were also identified as the ‘energy hotspots’ [1,2]. In the calculations made in earlier study [35], the energy bill ha^{-1} (or the energy input) corn production in Mexico using manpower amounted to 1,114 hours ha^{-1} and consumed high N fertilizer and pesticides application. The energy accounting procedures [35] affirmed the production condition in barangay Vitali, Zamboanga City, where man and animal labor combined expended 984 hoursha^{-1}.Bulk of IEI utilized derived from agricultural inputs particularly inorganic fertilizers and pesticides, transportation and labor which made the current production system a highly fossil fuel-based intensive [1,2,4,9,12,16,27,35], which the IEI in the current study contributed 90.4% of the TEI or this is equal to 0.75 tCO_{2e} ha^{-1} emission equivalent share. Hence, increase usage of fossil fuel-based inputs also increase emissions of greenhouse gases (GHGs) aggravating climate change [4,27,36]. But petroleum-based agriculture also increased crop yield by 250%[12] and this increase was made possible through the use of agrochemicals and oil-powered machineries, engines and motors to pump water for irrigation [8,11]. This is the reason why corn growers in the area cannot just move out from fuel-based to produce corn.

An estimated energy input of 36.4 Mcalha^{-1} (3.2 LDOE ha^{-1}) form the embedded energy input (EEI) or this is 1.2% share to the TEI which is attributed largely from the labor expended by draft animal and human, habal-habal used for hauling and transport of inorganic inputs, mini truck used for hauling and transport of corn produce, and machines, equipment, farm implements and tools utilized during the entire production activities. The contribution of EEI was small and negligible because its energy usage was spread out in the entire lifespan of the draft animal, machines, tools and equipment used. For instance, an average corn farmer will have to invest on labor for the care, feeding, management, maintenance and training of the draft animal. This incurred labor can be derived from conception to calving (214 days) until the calf is fully weaned from the parent (6 months) and until the time the animal is able to begin farm work (at least 3 years). In totality, the farmer will have to wait a little over of four years before he could fully utilize the animal for draft labor. It was assumed that the animal has to render farm labor for a period of 15 years (life span) and an estimated of 600.0 hectares is served for the entire period. The labor incurred from the care, feeding, management, maintenance and training of the draft animal was very small, estimated at 0.017 LDOE because it was spread out to the entire lifespan of the animal (15 years). The same procedure will follow for the calculations on machines, equipment and tools. However, the energy input incurred on labor on the care, management and maintenance of the animal by the farmer could also increase depending on the season, the nature of work and the number of times that the animal is utilized for work [37].

Clearly, to reduce the energy input to produce white corn is through the reduction of indirect used of energy in man-animal labor and inorganic inputs usage particularly N fertilizer. For the man-animal labor, machines can replace efficiently the labor requirement since it only consumed lesser direct energy input in the form of diesel oil. The adaption of organic approach can help address the increased application of inorganic inputs but this should be realized in a long-term perspective through continued application of organic composts and by not burning the corn trashes after harvest instead returning these in the field, in time, when these decomposes it helps improve several soil properties, increase in organic nutrients in the soil by 25% N and P, 50% of sulfur and 75% of K every cropping season [38].

The flow of energy intensive input throughout the production system or call this the ‘energy hotpots’ have been identified and delineated from pre-planting operation to postharvest activities with an estimated number of days needed using man-animal labor which ranged from 110-120 days. The given period however, also depends on the nature of weather and climate in a given time, and the amount of manual labor deployed which determine the speed of pre-production to post-production activities. Bulked of the estimated energy input used was on inorganic inputs and labor. This contributed a staggering amount of fossil fuel and carbon emission equivalents to produce white corn ha^{-1}. The energy equivalent on the use of inorganic fertilizers was high following the 60-30-30 recommended rate (RR) for growing an open pollinated variety (OPV) white corn. Ideally, application of organic composts (e. g., cow or chicken dung) was preferred in the upland areas of barangay Vitali, Zamboanga City, where soil organic matter (OM) continuously to decline due to soil erosion. Such application can help soil to rejuvenate by returning considerable amount of OM [38]. But the high provisions of chicken manure or cow dung $unit^{-1}$ area have always been a challenge, for one, the source is far which consumed enormous direct energy input during hauling and transport; and second, it is scarce. In general, majority of corn growers who grow white corn in upland areas for food cannot provide the total amount of inputs needed, hence resulting to lower yields if pure organic system is employed. There have been various causes of lower crop yield but mostly complained on the lack of capital and low yielding traditional varieties. Moreover, the combined man-animal labor incurred the highest number of hours attributed mostly to crop establishment and postharvest operations owing to the increase deployment of man-animal labor as compared to machine-run operations which can replace manual labor efficiently as in the US corn production systems [9] but non-climate change compliant [4]. Although, this led to an increase in yield but the local government unit (LGU) of Zamboanga City should make giant steps in order to reduce GHGs emissions from modern agriculture and acclimatize our food-production system to cope with the pressure of changing climate and the effect of global warming to be able to meet the complexity of food production and delivery systems over time in order to meet the needed demands for food [39] of over a million people mostly (>80%) of the population leaves in highly urbanized zone where food scarcity is hardly felt.

4.0 CONCLUSION

The current production system of white corn ha^{-1}in barangay Vitali, Zamboanga City is less energy input consuming compared to the modern systems on corn production but lower yield level than the US modern system. White corn production ha^{-1} consumed a total energy input of 2,398.6 Mcal or this is equal to 210.1 LDOE, or a total of 0.83 tCO_{2e} ha^{-1} emission equivalent, of this amount, the DEI, IEI and EEI contributed 8.4, 90.4 and 1.2% or this is equivalent to 0.07, 0.75 and 0.01 tCO_{2e} ha^{-1} emission equivalent, respectively. However, despite the high energy inputs requirement, yield level of white corn was recorded at an average of 1.87 mt ha^{-1} only.

White corn production in the uplands of barangay Vitali requires more energy input to be able to increase yield potential but this could also lead to a more energy-intensive and non-climate change compliant production system.

Inorganic inputs particularly N application consumed the highest indirect energy input amounting to 95.12 LDOE ha^{-1}. Energy input on labor was also high amounted to 42.32 LDOE ha^{-1} than the modern production system with the use of machines. But machines can complete with high energy efficiency the bulk of farm operations that requires intensive labor than the use of man-animal labor. Machines can shell and mill faster and efficiently than manual labor. Motorized vehicles can efficiently transport several tons of inputs and corn produce than when using draft animal which technically would require more energy inputs on traction and labor. In this case, the LGU of Zamboanga City and the national government should invest to manufacture their own machineries, custom-fit to our local conditions and not become sales agents for the already rich manufacturing foreign companies, if our country leaders are serious in their quest to mechanize food production systems across the country.

Due to climate change brought about by the intensive used of petrochemical products in modern agriculture, both the local and the national government should evaluate the current mechanization programs in line with the Department of Agriculture’s thrusts on food sufficiency and mechanization programs since all inorganic fertilizers, petrochemical products including the manufacture of machines, equipment, farm implements and tools are all fossil fuel dependent, however, it is also true that the increase in energy inputs could increase yield substantially.

Acclimatization of our food-production system can help cope with the pressure of changing climate to still meet the complexity of food production and delivery systems to match the increasing food demands. Moreover, substantial reduction of energy input can be made through the reduction of high indirect usage of energy by decreasing usage of man-animal labor and inorganic inputs application. Mechanized system can replace with high energy efficiency the labor requirement since it only consumed less direct energy input in the form of diesel oil. The adaption of organic approach can help address the increased application of inorganic inputs but this should be realized in long term perspective through continued application of organic composts and through “non-burning approach” of corn trashes after harvest, in return, this can help increase organic nutrients in the soil substantially (nutrients build-up), but the high provisions of organic composts is a big challenge, for one, the source is far which can command increase in direct energy usage for hauling and transport, and second, it is scarce, hence other sources of organic inputs should be optimized to address such limitations.

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