Environmental performance of farmer-level corn production systems in the Philippines

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Abstract: Four corn production systems at farmer-level of operation were evaluated. Environmental performance such as energy use, energy efficiency, greenhouse gas emission (GHG) and carbon efficiency were determined. Data were collected from 60 corn producing farmers using survey questionnaires and face to face interview. The input energy to produce an output energy of 69,714.06 and 73,029.60 MJ/ha for sun drying and mechanical drying, respectively, were 22,346.27, 31, 469.75, 22, 399.05 and 31,522.53 MJ/ha for systems 1 (manual harvesting and sun drying), 2 (manual harvesting and mechanical drying), 3 (mechanical harvesting and sun drying) and 4 (mechanical harvesting and mechanical drying), respectively. The highest energy input was observed for system 4 followed by system 2 because of the additional energy input of kerosene fuel during mechanical drying. Non-renewable and indirect forms of energy had contributed most to the total input energy in all corn production systems. In all systems evaluated, chemical fertilizer had the highest share in energy input followed by diesel fuel. Lower GHG emissions were measured for system 1 and 3 at 1276.5 and 1309.60 kg CO2eq per ha, respectively than system 2 and 4 at 2101.9 and 2135.0 kg CO2eq per ha due to additional non-renewable energy input like kerosene during mechanical drying. A kilogram of dried corn grain emitted 0.27 to 28 kg CO2eq for system 1 and 3 and increased further to 0.42 to 0.43 kg CO2eq for systems 2 and 4. The net carbon sequestered for systems 1, 2, 3 and 4 was 1785.98, 1662.36, 1776.94 and 1653.33 kg C/ha, respectively. The highest carbon efficiency ratio was observed for system 1 at 6.13 followed by system 3 at 5.98 due to non-utilization of fossil fuel during drying. Generally, all corn production systems evaluated did not emit carbon beyond the carbon produced and sequestered in corn itself as indicated by their positive net carbon ratio.

Keywords: corn, carbon, energy, global warming potential, greenhouse gases

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1 Introduction

Corn (*Zea mays*) is one of the most vital cereal crops grown worldwide, used for human food, livestock feed, fuel and various industrial food applications (Ranum et al., 2014; Gwirtz and Garcia-Casal, 2014). It is the second most important agricultural crops in the Philippines next to rice. About 20% of the Filipinos regarded corn as staple food. It also played as important role in the livestock development and poultry industries with 60% of its total production yield used as feeds while the remaining 40% used as food and other products (Dela Cruz et al., 2008). However, the production of corn in the Philippines is not enough to fully support its local requirements. Thus, the government through the Department of Agriculture (DA) is striving to improve the agricultural production and handling system of corn in order to increase the yield per hectare of corn farms.

In line with the enhancement of agricultural production systems and the aggressive step towards mechanization, the heavy reliance of energy resource would be expected to increase. Energy use in agriculture has been amplified in response to growing populations, decreasing arable land area and aspiration for increasing standard of living. These factors have stimulated an increase in energy inputs to maximize yields and

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minimize labor intensive practices (Esengun et al., 2007). Consequently, the use of excessive energy leads to some human health risk and environmental problems such as greenhouse gas emission (GHG) that leads to global warming. Therefore, the reduction of fossil energy inputs in agricultural system is necessary to reduce agricultural carbon dioxide emissions (Ghorbani et al., 2011).

Apparently, the input energy requirements in modern agriculture could be higher than traditional agriculture systems. In this case, the energy must be used efficiently since the increase of input energy in the production of crops may not always result in maximum profits due to the increase also in the production cost (Erdal et al., 2007). The effective use of energy in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings by decreasing the production costs, fossil resources preservation and air pollution reduction (Uhlin, 1998).

As well as the energy, the issues of global warming caused by GHGs emission are also critical in the agricultural production systems (Khoshnevisan et al., 2013). Gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are usually emitted and enhanced the natural greenhouse effect as a result of agricultural activities. Agriculture contributes significantly to atmospheric GHG emissions, with 14% of the global net CO_2 emissions (IPCC, 2007).

In this study, the input-output energy of corn production per hectare following different systems was evaluated. The GHG emissions of corn production systems at farmer-level of operations were estimated. The net carbon and carbon efficiency ratio of different corn production systems were also determined. The study was undertaken to identify operations where energy savings can be realized by altering existing practices in order to increase the energy ratio and reduce energy consumption. Furthermore, the information that would be generated could be used to promote an environmentally-sound crop management pattern leading to more efficient energy usage, increase yield and income of the corn farmers and reduction of the GHGs in the corn production.

2 Materials and methods

Data and information from the previous studies of Dela Cruz et al. (2014; 2008; 2006) were reviewed to identify the required and useful information for the study. Previous data obtained by these studies from the major corn producing areas in the Philippines were utilized. These data were updated and validated through face-to-face interview using structured questionnaires and actual field observation in the year 2015. The sample size was determined using Equation 1 (Kizilaslan, 2009; Mobtaker et al., 2010).

$$n = \frac{N(st)^2}{(N-1)d^2 + (st)^2} \quad (1)$$

Where; *n* is the required sample size; s, the standard deviation; *t*, the *t* value at 95% confidence limit (1.96); N, the number of holdings in target population and *d*, the acceptable error (permissible error 5%).

The computed sample size was 60, thus data and information on corn production were collected from the 60 corn farmers randomly selected from the study area. The collected information included the typical corn production systems at farmer-level of operation starting from land preparation, crop management, harvesting, hauling, shelling and drying. The input requirements for the corn production included fertilizers, planting seed, herbicides, insecticides, human, animal, machinery, on-farm diesel and kerosene used in the required operations to produce dried shelled corn while yield in dried corn grains was specified as output.

2.1 Systems boundary

In this study, four corn production systems at farmer-level of operation were evaluated (Figure 1).The most common postproduction systems adopted by 90% of the corn farmers in the Philippines were considered (Dela Cruz et al., 2008). The postproduction operations included are harvesting, piling, shelling, in-field hauling and drying (Dela Cruz et al., 2014). The assessment started from production-to-farm gate boundary, which provided flexibility for assessing corn with several end uses like food, feed, forage, and biofuel. Other on-farm processing beyond grain drying operation was not included because it is assumed that the crop is sold as dried corn grains.

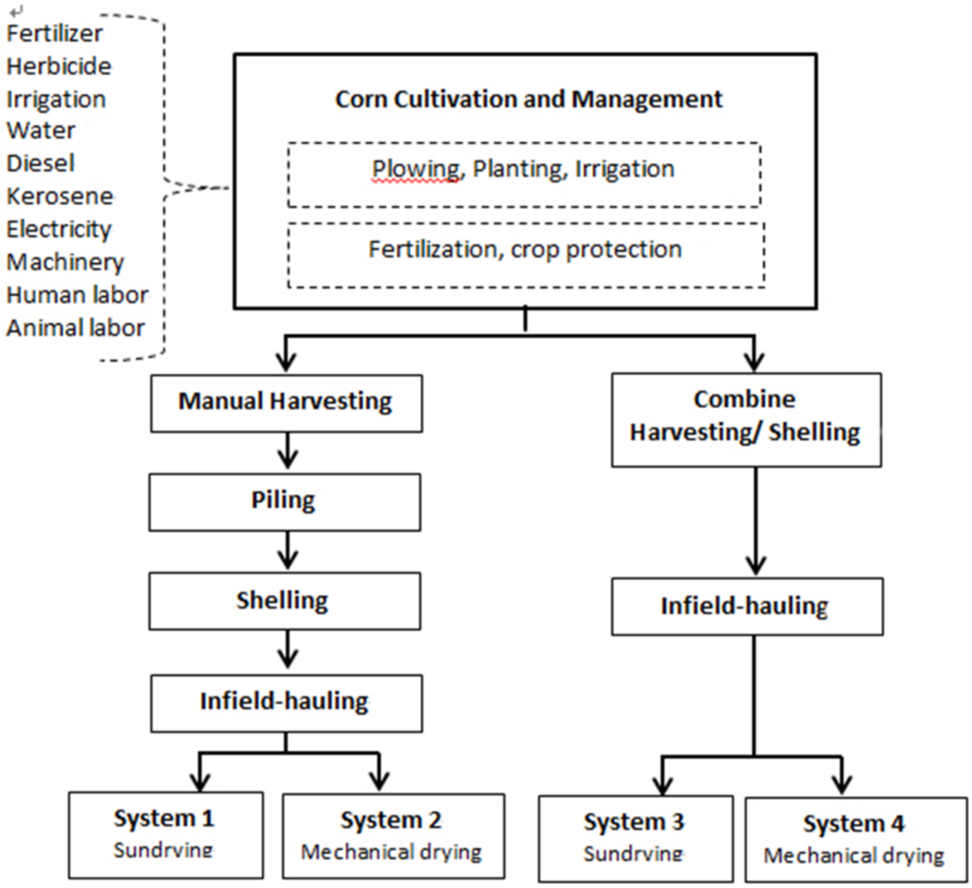

Figure 1 Systems boundary used in the assessment of energy and greenhouse gases

2.2 Assessment of energy input-output of corn production systems

The machinery, human labor, diesel fuel, chemical fertilizer for irrigation and seeds were specified as inputs to estimate the amount of energy usage while the corn grains in dried form as output. The amount of each input was multiplied with the energy coefficient equivalent as listed in Table 1to calculate the energy use per hectare. The energy input of each system was examined as direct and indirect, renewable and non-renewable forms of energy. Energy indicators such as energy ratio (*ER*), energy productivity (*EP*), specific energy (*SE*) and net energy (*NE*) were determined using Equations 2 to 5, respectively (Yousefi and Mohammadi, 2011).

$$ER = \frac{Energy\ output\ (MJ/\ ha)}{Energy\ input\ (MJ/ha)} \quad (2)$$

$$EP = \frac{Corn\ grain\ output\ (kg/\ ha)}{Energy\ input\ (MJ/ha)} \quad (3)$$

$$SE = \frac{Energy\ input\ (MJ/\ ha)}{Corn\ grain\ output\ (kg/ha)} \quad (4)$$

$$NE = Energy\ output\ \left(\frac{MJ}{ha}\right) - Energy\ input\ \left(\frac{MJ}{ha}\right) \quad (5)$$

Table 1 Energy equivalent of inputs utilized and output generated in corn production systems

Input/output	Unit	Energy, MJ/unit	Reference
Inputs			
Human labor	h	1.96	Mohammadi et al., 2010
Machinery	h	62.70	Ghorbani et al., 2011
Diesel fuel	L	51.33	Erdal et al., 2007
Kerosene fuel	L	46.20	Annamalai et al., 2006
Rice husk	kg	12.5	Martinez et al., 2009
Chemical Fertilizers			
Nitrogen (N)	kg	66.14	Esengun et al., 2007
Phosphorous (P_2O_5)	kg	12.44	Esengun et al., 2007
Potassium (K_2O)	kg	11.15	Esengun et al., 2007
Chemical Pesticides			
Insecticides	kg	101.20	Ozkan et al., 2007
Herbicides	kg	238.00	Ozkan et al., 2007
Fungicides	kg	216.00	Ozkan et al., 2007
Water for irrigation	m3	0.63	Hatirli et al., 2005
Planting seeds	kg	14.7	Ozkan et al., 2004
Electricity	kW ћ	3.6	Asgharipour et al., 2012
Output			
Corn grains	kg	14.7	Ozkan et al., 2004

2.3 Estimation of GHG emissions

The amount of GHG emissions from inputs in corn production per hectare were calculated by using CO_2, N_2O and CH_4 emissions coefficient of chemical inputs (diesel, fertilizer-nitrogen, etc.). GHG emission can be calculated and represented per unit of the land used in crop production, per unit weight of the produced yield and per unit of the energy input or output (Soltani et al., 2013).

The amount of CO_2 produced was calculated by multiplying the input application rate per hectare (e.g. diesel fuel, chemical fertilizer, biocide/pesticide and water irrigation) by its corresponding coefficient enumerated in Table 2. For irrigation water, the energy consumption was converted to the diesel fuel amount and also the total CO_2 emission in water irrigation was calculated by multiplying the diesel fuel consumption by GHG coefficient.

Table 2 Gaseous emissions (g) per unit of chemical sources and their global warming potential (GWP) in corn production systems

Inputs, unit	CO_2	N_2O	CH_4	Reference
Diesel, L	3560	0.70	5.20	Kramer et al.,1999
Kerosene, L	2682	0.02	0.11	IPCC, 2007
Rice husk, kg	1750	3.86	291.0	IPCC, 2007
Nitrogen fertilizer, kg	3100	0.03	3.70	Snyder et al., 2009
Phosphate (P_2O_5), kg	1000	0.02	1.80	Snyder et al., 2009
Potash (K_2O), kg	700	0.01	1.00	Snyder et al., 2009
Electricity, kWh	61.20	8.82	0.02	Tzilivakis et al., 2005
GWP CO_2 equivalent factor	1	298	25	IPCC, 2007; Eggleston et al., 2006

Following the energy methodology, mean emissions from selected farm inputs (nitrogen [N], phosphate, potash, herbicide, insecticide, seed, crop drying) production, input transportation and on-farm fuel consumption emissions were converted to kg CO_2eq. GHGs, such as methane (CH_4) and nitrous oxide (N_2O) were converted to kg CO_2eq on the basis of their 100-year global warming potentials (GWPs), which are1 for CO_2, 25 for $CH_4$and 298 for N_2O (Eggleston et al., 2006). After GWP conversion, GHGs were integrated, because they have the same units of kg CO_2eq.

The total emissions of greenhouse gases are determined using Equation 6 (Kramer et al, 1999).

$$GHG\ Effect = \sum GWPi\ x\ Mi \quad (6)$$

Mi is the mass (in kg) of the emission gas. The score is expressed in terms of kilogram CO_2 equivalent [kg CO_{2eq}].

In order to determine whether the production of dried shelled corn is a carbon neutral, carbon sequestration or more on carbon emission, the carbon efficiency ratio was calculated using Equation 7.

$$Carbon\ efficiency\ ratio = \frac{Output\ yield\ \ (kg\ C/\ ha)}{GWP\ (kg\ C/ha)} \quad (7)$$

Where, the output yield must be converted to carbon (C) content equivalent. Usually the carbon content is 45% of the total yield (Bolinder et al, 2007). GWP is based on carbon dioxide equivalent, thus, to determine the carbon C content, this amount should be multiplied by the ratio of carbon to carbon dioxide that is 12/44 (0.2727).

3 Results and discussion

3.1 Input-output energy use in corn production system

The average dried corn yield in the study area was 4742 kg/ha using sun drying while 4968 kg/ha using mechanical drying method with an equivalent energy output of 69714.06 and 73029.60 MJ/ha, respectively. The dried corn yield in sun drying method was lower because of the 4.54% drying loss from over drying, spillage and grains consumed by stray animals (Salvador et al., 2012). The output and input rates in corn production systems with their energy equivalents are summarized in Table 3. The total energy inputs in corn production systems 1, 2, 3 and 4 were 22346.27, 31469.75, 22399.05 and 31522.53 MJ/ha, respectively. The majority of the total inputs were contributed by chemical fertilizer and diesel fuel for corn production systems 1 and 3 while chemical fertilizer, diesel and kerosene for corn production systems 1 and 4 (Figures 2a-d).

Similar results have been observed in the production of sugar beet (Asgharipour et al., 2012), potato (Pishgar-Komleh et al., 2012), wheat (Singh et al., 2007) and corn (Yousefi et al., 2014) in Kermanshah Province, Turkey where chemical fertilizer, specifically nitrogen had the highest share in the total input of the crop production.

Table 3 Energy equivalents of inputs and output utilized in corn production systems (MJ/ha)

Equipment/	Manual harvesting		Combine harvesting	
Inputs	S_1-Sundrying[a]	S_2-Recirculating[b]	S_3-Sundrying[c]	S_4-Recirculating[d]
1. Human labor	820.64	785.36	564.39	529.11
2. Animal labor	85.76	85.76	85.76	85.76
3. Machinery	773.84	2404.04	646.56	2276.76
4. Diesel	8472.53	8472.53	8908.83	8908.83
5. Chemical fertilizer	11423.50	11423.50	11423.50	11423.50
6. Chemical Herbicide	476.00	476.00	476.00	476.00
7. Kerosene	0.00	6966.96	0.00	6966.96
8. Ricehusk	0.00	0.00	0.00	0.00
9. Electricity	0.00	561.60	0.00	561.60
10. Planting seed	294.00	294.00	294.00	294.00
Total Input, MJ/ha	22346.27	31469.75	22399.05	31522.53
Total Output, MJ/ha	69714.06	73029.60	69714.06	73029.60

[a]system 1- manual harvesting plus sun drying
[b]system 2- manual harvesting plus mechanical drying using recirculating dryer
[c] system 3- mechanical harvesting plus sun drying
[d] system 4- mechanical harvesting plus mechanical drying using recirculating dyer

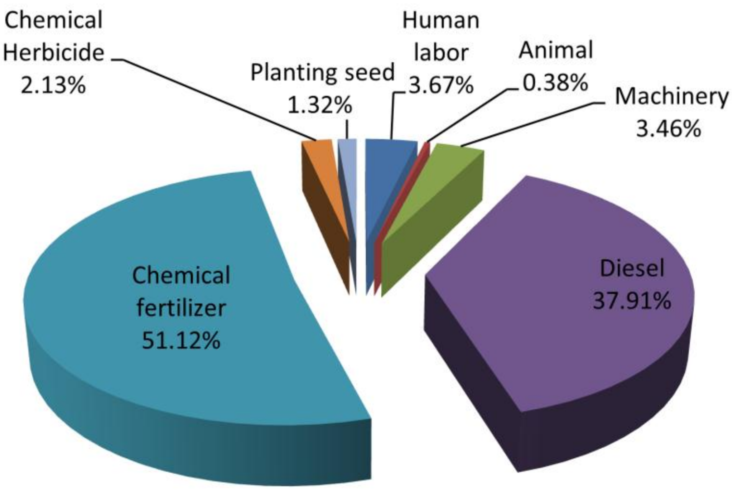

Figure 2a System 1 manual harvesting plus sun drying

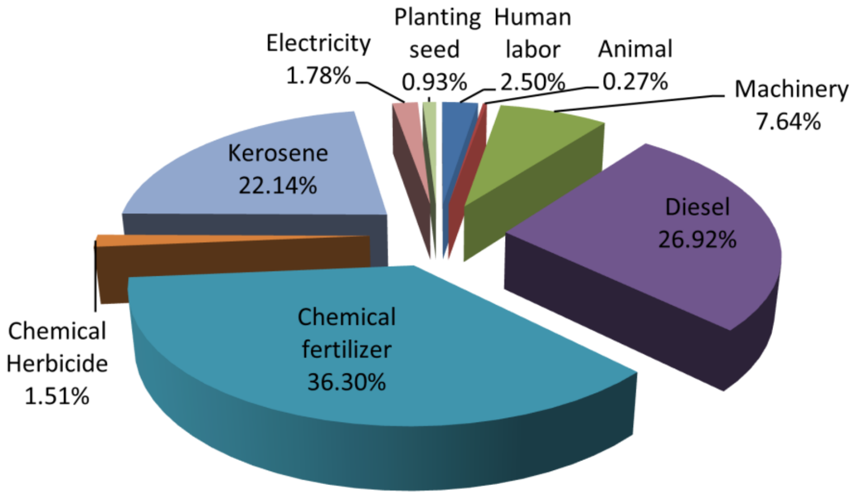

Figure 2b System 2 manual harvesting plus mechanical drying

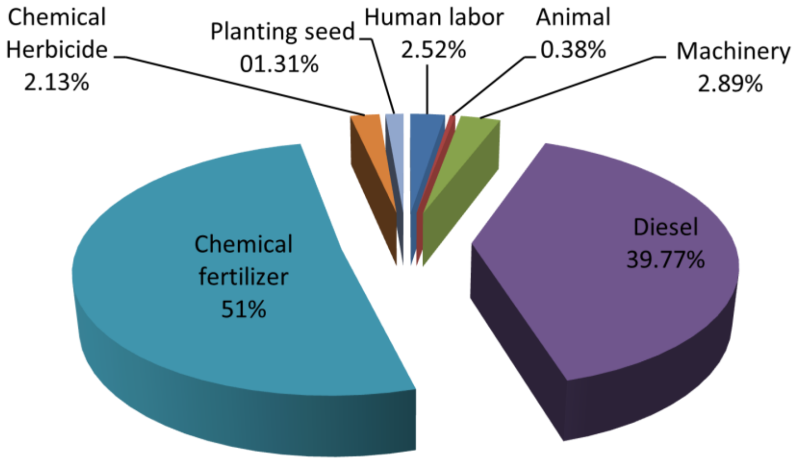

Figure 2c System 3 combine harvesting plus sun drying

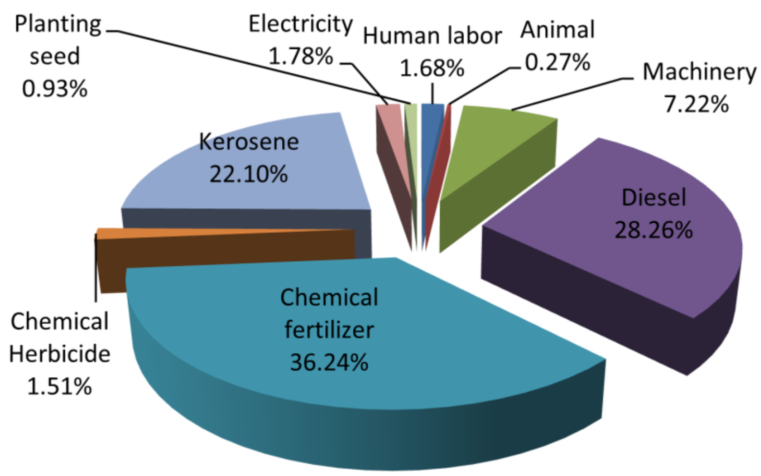

Figure 2d System 4 combine harvesting plus mechanical drying

3.2 Analysis of energy indicators in corn production systems

The energy use efficiency, energy productivity, specific energy and net energy of the four corn production systems are enumerated in Table 4. The energy ratio is usually used as an index to assess energy efficiency in crop production systems. The efficient use of energy resources is vital in terms of increasing production, productivity, competitiveness in agriculture as well as sustainability (Hatirli et al., 2005) of rural production systems.

Table 4 Indicators of energy use in corn production systems

Indicators, Unit	Manual harvesting		Combine harvesting	
	S_1-Sundrying[a]	S_2-Mechanical drying[b]	S_3-Sundrying[c]	S_4-Mechanical drying[d]
Total Input, MJ/ha	22346.27	31469.75	22399.05	31522.53
Total output, MJ/ha	69714.06	73029.60	69714.06	73029.60
Net energy, MJ/ha	50683.33	41559.85	50630.55	41507.07
Energy use efficiency	3.12	2.32	3.11	2.32
Energy prod., kg/MJ	0.21	0.16	0.21	0.16
Specific energy, MJ/kg	4.71	6.33	4.72	6.35

[a]system 1- manual harvesting plus sun drying

[b]system 2- manual harvesting plus mechanical drying using recirculating dryer

[c] system 3- mechanical harvesting plus sun drying

[d] system 4- mechanical harvesting plus mechanical drying using recirculating dyer

The energy ratio calculated for corn production system 1 and 3 were 3.12 and 3.11, respectively while systems 2 and 4 had both 2.32. Lower energy ratio was observed for system 2 and 4 compared to system 1 and 3, mainly because of the additional energy input of kerosene fuel during grain drying. With this, higher specific energy values of 6.33 and 6.35 MJ/kg were calculated for system 2 and 4, respectively compared to 4.71 and 4.72 MJ/kg, respectively for system 1 and 3. Thus, the energy productivity values of system 2 and 4 were lower compared to systems 1 and 3. The results generated for systems 1 and 3 were close to the figures generated by Yousefi et al. (2014) and Yaldiz et al. (1993) on corn production systems with 2.67 and 3.66 energy ratio, respectively.

3.3 Energy forms in corn production systems

The forms of energy in the corn production systems were classified into direct and indirect or renewable and non-renewable energies which are presented in Table 5.The majority of the total energy of corn production systems in the area of the study was non-renewable energy ranging from 95%-97% while the remaining renewable energy input ranged from 3%-5%. The share of indirect energy form for systems 1 and 3 were higher than that of systems 2 and 4.The increase however in direct energy form for systems 2 and 4 was attributed to the additional use of kerosene fuel during drying.

Based on the results, the level of dependence to non-renewable energy form was generally high in the corn production systems evaluated. It is expected that in modern agriculture production systems, the use of non-renewable energy is greater than the renewable energy. The introduction of organic farming and the use of renewable input resources are encouraged as a way to conserve fossil resources and promote sustainable agriculture.

Table 5 Forms of energy input in corn production systems

Form of energy	Manual harvesting		Combine harvesting	
MJ/ha	S_1 Sundrying	S_2 Mechanical drying	S_3 Sundrying	S_4 Mechanical drying
Total Energy Input	22346.27	31469.75	22399.05	31522.53
Direct Energy [a]	9378.93	16872.21	9558.98	17052.26
Indirect Energy [b]	12967.34	14597.54	12840.06	14470.26
Renewable Energy [c]	1200.40	1165.12	944.15	908.87
Non-renewable Energy [d]	21145.87	30304.63	21454.90	30613.66

[a]Includes human labor, animal labor, diesel, kerosene, electricity
[b]Includes machinery, planting seeds, chemical fertilizer, chemical herbicide
[c]Includes human labor, animal labor, planting seeds
[d]Includes diesel, kerosene, chemical fertilizer, herbicide, electricity, machinery

3.4 GHG emissions in corn production systems

The amount of GHG emissions such as CO_2, N_2O and CH_4 emissions with the use of chemical inputs in corn production systems were calculated and tabulated in Tables 6 and 7. The calculated total GHG emissions of corn production for system 1 and 3 at 1276.5 and 1309.60 kg CO_2eq per ha, respectively were lower than that of system 2 and 4 at 2101.9 and 2135.0 kg CO_2eq per ha, respectively. Systems 2 and 4 have higher total GHG emissions because of using more non-renewable energy sources like kerosene during mechanical drying.

Table 6 GHG emissions of chemical inputs in corn production systems 1 and 2

Environmental	System 1[a]				System 2[b]			
Indicators	CO_2	N_2O	CH_4	CO_2eq	CO_2	N_2O	CH_4	CO_2eq
Diesel	587.61	0.12	0.86		587.61	0.12	0.86	
Chemical fertilizer								
Nitrogen -N	413.23	0.00	0.49		413.23	0.00	0.49	
Phosphorus-P_2O_5	150.00	0.003	0.270		150.000	0.003	0.270	
Potassium -K_2O	46.69	0.001	0.067		46.690	0.001	0.067	
Kerosene	0.00	0.00	0.00		404.45	0.003	0.017	
Electricity	0.00	0.00	0.00		9.55	1.376	0.003	
Total GHGs	1197.53	0.12	1.69		1611.53	1.50	1.71	
T otal GWP	1197.53	36.72	42.21		1611.53	447.64	42.70	
Total kg CO_2eq per ha				1276.46				2101.86
kg CO_2eq per kg corn				0.27				0.42
kg CO_2eq per MJ				0.06				0.07

[a]system 1- manual harvesting plus sun drying

[b]system 2- manual harvesting plus mechanical drying using recirculating dryer

Table 7 GHG emissions of chemical inputs in corn production systems 3 and 4

Environmental	System 3[c]				System 4[d]			
Indicators	CO_2	N_2O	CH_4	CO_2eq	CO_2	N_2O	CH_4	CO_2eq
Diesel	617.87	0.12	0.90		617.87	0.12	0.90	
Chemical fertilizer	0.0	0.0	0.0		0.0	0.0	0.0	
Nitrogen -N	413.23	0.004	0.49		413.23	0.004	0.49	
Phosphorus-P2O5	150.00	0.003	0.27		150.00	0.003	0.27	
Potassium -K_2O	46.69	0.0007	0.067		46.69	0.0007	0.067	
Kerosene	0.0	0.0	0.0		404.45	0.003	0.017	
Electricity	0.0	0.0	0.0		9.55	1.38	0.003	
Total GHGs	1227.79	0.13	1.73		1641.79	1.51	1.75	
T otal GWP	1227.79	38.49	43.31		1641.79	449.41	43.80	
Total kg CO_2eq per ha				1309.59				2135.00
kg CO_2eq per kg corn				0.28				0.43
kg CO_2eq per MJ				0.06				0.07

[c]system 3- mechanical harvesting plus sun drying

[d]system 4- mechanical harvesting plus mechanical drying using recirculating dyer

The results indicated that the production of a kilogram of dried corn grain would lead to the emission of 0.27 to 0.28 kg CO_2eq (0.06 kg CO_2eq per MJ) both for system 1 and 3 and further increased to 0.42 to 0.43 kg CO_2eq (0.07 kg CO_2eq per MJ) for system 2 and 4 because of the increased in energy input in the production system. These GHG emission values however are still lower than the GHG emission obtained in the production of corn in Turkey at 1.2 kg CO_2eq per kg of grain yield (Yousefi et al., 2014) which could be due to the different production practices, soil and climate conditions among others. More mechanized production system would possibly incur more energy inputs that lead to more emission of greenhouse gases. Thus, the improvement of energy use efficiency in the corn production systems is imperative for reducing the GHGs emission.

3.5 Analysis of output-input carbon (kg C per ha) and sustainability index of corn production systems

Corn grains in dried form were the only yield considered in the analysis of input-output carbon since other parts of the plants were not recovered for other purposes such as forage for animal and fuel for biomass furnace (e.g. silage, corn cobs). In this case, the output yield (in dried corn grains) should be multiplied with 45% as the usual carbon content of the total yield based on carbohydrates (Bolinder et al., 2007). Thus the total carbon output for sun drying was 2134 kg C per ha (4742 kg/ha×0.45) while 2235.60 kg C per ha (4968 kg/ha×0.45) for mechanical drying (Table 8). On the other hand, the total input carbon related to applying chemical inputs was 348.12, 573.24, 577.16 and 582.27 kg C per ha for systems 1, 2, 3 and 4, respectively. Thus, the net carbon which can be considered as potential to carbon sequestration was 1887.5, 1662.36, 1878.44 and 1653.33 kg C per ha for systems 1, 2, 3 and 4, respectively. Accordingly, the carbon efficiency ratio (sustainability index) for systems 1, 2, 3 and 4 are 6.13, 3.90, 5.98 and 3.84, respectively. Higher carbon efficiency ratios were observed for systems 1 and 3 because of their lower energy inputs in the production of corn compared to systems 2 and 4. The consumption of chemical inputs including chemical fertilizer and fossil fuel are the major factors affecting carbon efficiency ratio in corn production systems. Thus, to sustain the sustainability of the corn production systems and reduce the environmental impact of GHG emissions and global warming, it is necessary to correct the pattern of use of chemical inputs and non-renewable energy resource.

Table 8 Output-input carbon and carbon efficiency (sustainability index) of corn production systems

Indicators (Unit)	Manual harvesting		Combine harvesting	
	S_1-Sundrying	S_2.Mechanical drying	S_3.Sundrying	S_4.Mechanical drying
Input Carbon, kg C per ha	348.12	573.24	357.16	582.27
Output Carbon, kg C per ha	2,134.00	2235.60	2134.00	2235.60
Net Carbon, kg C per ha	1785.98	1662.36	1776.94	1653.33
Carbon efficiency ratio	6.13	3.90	5.98	3.84

4 Conclusions and recommendation

The environmental performance such as energy use, energy efficiency, GHG emissions and carbon efficiency ratio of four corn production systems were evaluated in this study. Based on the results of investigation, the total energy inputs for systems 1, 2, 3 and 4 were 22346.27, 31469.75, 22399.05 and 31522.53 MJ/ha, respectively. Chemical fertilizer followed by diesel fuel provided the highest share of the total energy inputs in all corn production systems. Systems 2 and 4 have lower energy efficiencies than systems 1 and 3 because of using more energy inputs during mechanical drying. The shares of indirect and non-renewable forms of energy have dominated most of the total energy inputs in all corn production systems. The total GHG emissions for systems 2 and 4 at 2101.9 and 2135.0 kg CO_2eq/ha, respectively were higher than systems 1 and 3 at 1276.5 and 1309.60 kg CO_2eq/ha, respectively due to additional non-renewable energy inputs like kerosene fuel during mechanical drying. For all the four corn production systems evaluated, the carbon efficiency ratio range from 3.84 to 6.13, the lower range representing the system using more of renewable resources like sun drying for drying instead of mechanical dryers. All of the corn production systems did not emit carbon in the atmosphere beyond the carbon being produced and sequestered in corn. This confirmed that corn plants can be a good absorber of GHG such as carbon dioxide in the atmosphere.

To sustain the positive environmental performance of producing corn in the Philippines, energy management should be considered by all concerned stakeholders as an important strategy for resource conservation and climate protection.

The recent effort of the Philippine government to reduce environmental burdens by utilizing renewable energy inputs in mechanizing farm operations (e.g. use of biomass furnace instead of kerosene-fed furnace for mechanical dryers) should be evaluated to determine the environmental as well as the economic impacts of the "environmental burden reduction measure".

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