



Energy bill and CO₂ emissions of white corn (*Zea mays*) production systems of Calbayog, Samar, Philippines

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KEYWORDS

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ABSTRACT

Low production in white corn is usually encountered by many farmers due to the reduction of production areas, incidence of pest and diseases, soil degradation in terms of fertility and acidity and climate change. As the world population continues to expand, there is greater pressure on resources essential for food production, including fossil energy. Hence, quest for additional calorie food sources that will require less energy and less water are needed. Data in this study were gathered using formal survey questionnaire to account the energy bill, CO₂ emissions, and identify the high consuming practices in all production stages of corn. Under the farming conditions of Calbayog, Samar, at the energy audit analyses showed that white corn had 2,822.43 Mcal or 247.28 Liter Diesel Oil Equivalent (LDOE) which emits 978.12 kg of CO₂ per hectare.

Introduction

Philippine agriculture is an energy user that uses diesel for its production process such as tillage, farm input applications, irrigations and post-production (Alam et al., 2005). The world supply of oil is projected to last approximately 50 years at current production rates (BP, 1994; Campbell, 1997; Duncan, 1997; Duncan and Youngquist, 1999). Identifying the amount of CO_{2e} in every production is important so that we could identify which production practices needs to be enhanced in the cultural management since we all know that this indirectly causes climate change in which very harmful to our environment. Despite that the usage of oil-based “technology” have positive impacts in production, they have also negative drawbacks to the environment especially for the future generations. The largest proportion of carbon emissions is produced by burning oil, coal and gas, if all the known and probable fossil reserves were be used to generate energy, global emissions would amount to around 15,000 gigatonnes of CO₂ (Baake, 2016).

Energy accounting in agriculture is the approach to identify the energy intensive processes or stage of production. Since rice production was already known, corn should also be accounted to compare if corn will be less energy efficient and to be promoted as additional source of calorie. It is also important to determine energy consumption of

different farm activities to improve fossil energy use.

Province of Samar, having 780,481 of population, is rice deficit area importing about 33,787.57 tons per year of milled rice from other regions and provinces such as Manila, Cebu, Bicol, Ilo-ilo and Mindanao (CAO, 2017). The province has a total land area of 559,100 hectares. Of this, 140,529 hectares or 25.13% is agricultural land. The potential irrigable land of the province of Samar is 15,782 hectares and the total irrigated area now is only 2,327 hectares, which is only about 15% of the total potential irrigable (CAO, 2017). If main answer to increase rice yield is through the use of high yielding varieties and fertilizers under irrigated condition, constructions of big irrigation facilities is very expensive.

With the data, it clearly shows that the area still has 124,747 ha. that are rainfed and cannot be converted into rice field, therefore corn could be grown as additional to rice. Studies showed that corn can be mixed with our rice up to 30.0% (Pimentel, 2009).

In Calbayog, Samar, Philippines, the energy accounting of corn is yet to be done. Thus, specifically this study aimed to: 1) account the energy requirement of corn per ha and 2) identify high energy –consuming practices in all production and post production stages and compute the CO_{2e} of milled corn per ha.

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Research Methods

The study was conducted in Calbayog, Samar, Philippines from August 2017 to December 2018. Lists of white corn farmers as respondents were obtained from Municipal Agriculture Office and were surveyed using a structured questionnaire. The method to energy accounting of white corn production was identified through its various operations based on the data on cultural practices as provided by the Samar Local Government Unit (LGU), Calbayog City Agriculture Office (CCAO), and some relevant secondary data gathered from field informants.

The total energy bill was estimated in all major energy consuming farm operations from production to post-production. The total energy bill or the total energy input was outlined into direct (DE), indirect (IE) and embedded energy (EE). All energy units in Mcal were converted into Liter Diesel Oil Equivalent (LDOE), where 1.0 LDOE = 11.414 Mcal per unit (Ozkan et al., 2004).

Direct energy (DE) includes the direct usage of diesel and/or gasoline to run the machines for farm operations, hauling and transport of farm outputs.

On the other hand, the indirect energy (IE) includes the various inputs such as the planting materials, fertilizers (NPK) used, agrochemicals (pesticides) applied, organic manures, farm machineries and labor and animal used.

Embedded Energy (EE) covers the utilization of machines, equipment, farm implements and tools; motorized vehicles and draft animal were estimated for the period of one cropping (Ozkan et al., 2004; Doering, 1980; Mendoza, 2005; Pfeiffer, 2004; Nabavi-Pelesaraei, 2013; Salazar, 2013; Hatirli et al., 2005; Kazemi et al., 2015; Gliesman, 2015; Mendoza, 2016).

The energy footprint or carbon emissions will be computed from the energy used (Mcal/ha), and then will be converted to liter diesel oil equivalent (1LDOE=11.414) and then multiplied by the CO_{2e} per LDOE. The carbon emission of 1 LDOE is equivalent to 3.96 kg CO_{2e} (Mendoza, 2016).

The total energy input and CO_{2e} of milled corn per hectare results was done by adding the total energy inputs and CO_{2e} consumed in the production (from land preparation, crop fertilizers and management until harvesting) and the total energy inputs and CO_{2e} consumed in the post-production (hauling, sun drying, milling).

Energy Coefficients and Formulas

Energy accounting procedures and various energy coefficients were based from the work of (Ozkan et al., 2004; Doering, 1980; Mendoza, 2005; Pfeiffer, 2004; Nabavi-Pelesaraei, 2013; Salazar, 2013; Hatirli et al., 2005; Kazemi et al., 2015; Gliesman, 2015; Mendoza, 2016) and from other relevant literatures.

The following equations were used to calculate the DE, IE and EE of corn in Samar:

- 1. Direct Energy (fuel) Used (DE):
 - a) *Direct energy (diesel or gasoline) used ha⁻¹ for field operation (FOpe)*

$$DE_{FOpe} = (A_{fu} \times E_{Fcoef}) / LDOE \dots\dots\dots (1)$$

Where :
 DE_{FOpe} : direct fuel used for a field operation (Mcal/ha)
 A_{fu} : average fuel used per working hour (L/hr)
 E_{Fcoef} : energy coefficient of fuel (Mcal/L)

- b) *Direct energy (diesel or gasoline) used per ha for hauling and transport (Ftrans)*

$$DE_{Ftrans} = (A_{Ftrans} \times E_{Fcoef}) / LDOE \dots\dots\dots (2)$$

Where :
 DE_{Ftrans} : direct fuel used for a hauling and transport (Mcal/ha)
 A_{Ftrans} : average fuel used per working hour (L/hr)
 E_{Fcoef} : energy coefficient of fuel (Mcal/L)

- 2. Indirect Energy Used (IEU):
 - a) *NPK fertilizers applied (NPKfert)*

$$IE_{NPKfert} = (A_{NPKfert} \times E_{NPKcoef}) / LDOE \dots\dots\dots (3)$$

Where :
 IE_{NPKfert} : indirect energy used on fertilizer (NPK) (Mcal/ha)
 A_{NPKfert} : amount of fertilizer (NPK) applied (kg/ha)
 E_{NPKcoef} : energy coefficient of NPK fertilizer (Mcal/kg)

- b) *Human labor (HL)*

$$IE_{HL} = (N_{lab} \times N_{hrs} \times E_{HLcoef}) / LDOE \dots\dots\dots (4)$$

Where :
 IE_{HL} : indirect energy used on human labor (Mcal/ha)
 N_{lab} : number of laborers involved in farm operation per ha
 N_{hrs} : number of hours per field operation per ha
 E_{HLcoef} : energy coefficient of human labor (Mcal/hr)

c) *Animal labor (AL)*

$$IE_{AL} = (N_{ani} \times N_{hrs} \times E_{ALcoef}) / LDOE \dots\dots\dots(5)$$

Where :

- IE_{AL} : indirect energy used on animal labor (Mcal/ha)
- N_{ani} : number of animals used in farm operation
- E_{ALcoef} : energy coefficient of animal labor (Mcal/hr)

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

$$IE_{am} = (A_{am} \times E_{amcoef}) / LDOE \dots\dots\dots(6)$$

Where :

- IE_{am} : indirect energy used on animal manure (Mcal/ha)
- A_{am} : amount of animal manure applied (kg/ha)
- E_{amcoef} : energy coefficient of animal manure (Mca/kg)

e) *Seeds used*

$$IE_S = (A_S \times E_{Scoef}) / LDOE \dots\dots\dots(7)$$

Where :

- IE_S : indirect energy used on seed (Mcal/ha)
- A_S : amount of seeds used (kg/ha)
- E_{Scoef} : energy coefficient of seed (Mcal/ha)

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

$$IE_{IFH} = (A_{IFH} \times E_{IFHcoef}) / DLOE \dots\dots\dots(8)$$

Where :

- IE_{IFH} : indirect energy used on pesticides (insecticide, fungicide, herbicide) (Mcal/ha)
- A_{IFH} : amount of pesticides (insecticide, fungicide, herbicide) applied (L/ha)
- E_{IFHcoef} : energy coefficient of specific insecticide, fungicide, herbicide (Mcal/L)

3. *Embedded Energy (EE)*

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

$$EE_{FM} = (W_M \times E_{Mcoef}) / (LS_M \times Hr) / LDOE \dots\dots(9)$$

Where :

- EE_{FM} : specific embedded energy for machinery used for a field operation (Mcal/ha)
- W_M : weight of the machine (kg/unit)

- E_{Mcoef} : energy coefficient of a specific machinery (Mcal/kg)
- LS_M : life span of the machine (years/unit)
- Hr : the number of hours the machine was used (hours/ha)

b) *Embedded Energy used in farm equipment and tools (EE_{FET})*

$$EE_{FET} = (W_{ET} \times E_{Mcoef}) / (LS_{ET} \times Hr) / LDOE \dots(10)$$

Where :

- EE_{FET} : specific embedded energy for farm equipment and tools used for a field operation (Mcal/ha)
- W_{ET} : weight of the farm equipment and tools (kg/unit)
- E_{ETcoef} : energy coefficient of a specific farm equipment and tools (Mcal/kg)
- LS_{FET} : life span of the farm equipment and tools (years/unit)
- Hr : the number of hours the equipment and tools was used (hours/ha)

Total Energy Input (TEI)

$$TEI = \sum(DE + EI + EE) \dots\dots\dots(11)$$

Where :

- TEI : total energy input (Mcal/ha)
- DE : direct energy used
- IE : indirect energy used
- EE : embedded energy used

Energy Use Indicators

a) *Total Energy Output (TEO)*

$$TEO = (Y \times E_{coef}) / LDOE \dots\dots\dots(12)$$

Where :

- TEO : total energy output (Mcal/ha)
- Y : yield (kg/ha)
- E_{coef} : energy coefficient of specific farm commodity (Mcal/kg)

In computing the carbon emission per hectare per cropping season, LDOE will be multiplied to the carbon emission per liter diesel oil equivalent (3.96 kg).

$$CO_{2e} = LDOE \times CO_{2e}/LDO \dots\dots\dots(13)$$

Where :

- CO_{2e} : carbon emission
- LDOE : Liter Diesel Oil Equivalent

Results and Discussions

The total energy inputs of white corn (production and post-production) per cropping season yielding 1.25 t/ha was 2,822.43 Mcal or 247.28 LDOE. In

Indonesia, a corn yield of 1.72 t/ha consumed 5,082 Mcal or 445.24 LDOE while in the US system, the yield is 9.4 t/ha per cropping but the total fossil fuel input is higher which is estimated to be 8,200 Mcal or 718 LDOE (Ozkan et al., 2004).

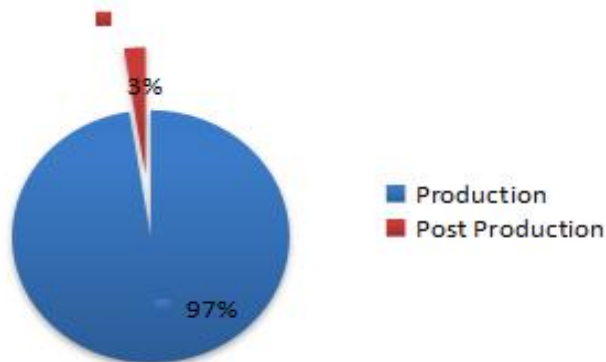


Figure 1. Comparative energy used of production and post-harvest per hectare of white corn

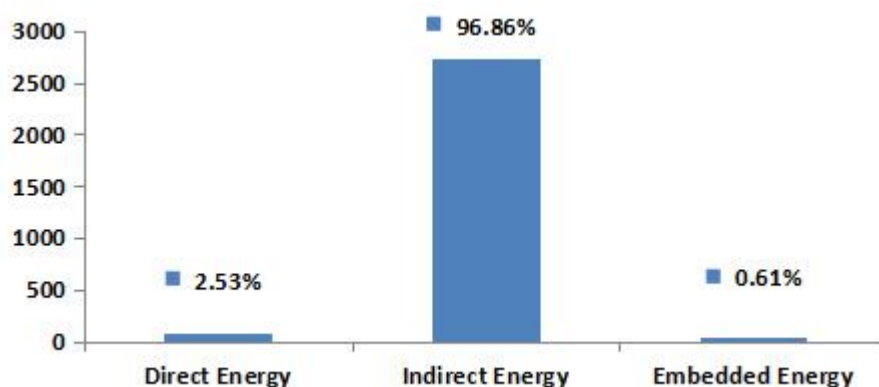


Figure 2. White corn comparative energy consumption types per hectare

The production expended 2,752.63 Mcal or 241.16 LDOE in which it was 97% of the total energy inputs consumed from land preparation, planting, fertilizer applications, pesticide management, until harvesting. The post-production expended energy consumed for hauling, sun-drying, until milling was only 69.80 Mcal or 6.12 LDOE which was 3% of the total energy inputs. Under production activities, indirect energy per ha expended 2,727.90 Mcal or 239.00 LDOE in which it was 96.66 % of the total energy bill. Of that 96.66%, 88.07% in which 2,485.38 Mcal or 217.75 LDOE was expended for farm inputs such as seeds which expended 70.20 Mcal or 6.15 LDOE, chemical pesticides which expended 228.38 Mcal or 20.02 LDOE while chemical fertilizer expended the highest indirect energy inputs at 2,186.70 Mcal ha⁻¹ or 191.58 LDOE (77.49%). This was composed

of Potassium 198.60 Mcal ha⁻¹ or 17.40 LDOE, Phosphorous 248.70 Mcal ha⁻¹ or 21.79 LDOE and most specially the nitrogen 1,739.40 Mcal/ha or 152.39 LDOE.

On the other hand, 8.59% (242.52 Mcal or 21.25 LDOE) of 96.66% was expended for labour (58 md.) Among these labours, crop establishments such as ploughing, harrowing, furrowing, planting or seeding, fertilizer application, hilling up, etc. which expended 103.40 Mcal or 9.06 LDOE. This was followed by post-harvest handling (75.20 Mcal or 6.60 LDOE), harvesting expended (37.60 Mcal or 3.29 LDOE), pre-planting (11.28 Mcal or 0.99 LDOE), crop management 15.05 or 1.32 LDOE.

The direct energy consumed the least which was 18.83 Mcal or 1.65 LDOE. This was utilized in the diesel fuel used by a tricycle for hauling of inputs (4.57 Mcal or 0.40 LDOE), fuel used by a

sheller during shelling (13.70 Mcal or 1.20 LDOE) and fuel used by a truck for hauling of produce from farm area to storage area (0.57 Mcal or 0.05 LDOE). Energy cost for shelling depends on the amount of corn harvested. Embedded energy was the least consuming (5.90 Mcal or 0.52 LDOE).

Energy bill under post-production, direct energy was the highest energy expenditures. This energy was expended for hauling of unmilled rice from storage area to milling station up to public market at 11.40 Mcal or 1.00 LDOE. Milling expended 41.09 Mcal or 3.60 LDOE. Indirect energy inputs expended 60.16 Mcal or 5.28 LDOE. This was the labour expended for loading and unloading of milled rice from milling station to public market. Embedded energy was the least energy bill which consumed 11.14 Mcal or 0.98 LDOE.

Energy Return on Energy Input (EnROI) was 1.87. These gave potential ratio of 1.87 to 1.0. The ratio of energy output to energy input of plain corn grain yield to a value of 2.14 to 1.0 for a modern tractor system (energy intensive system) in Colorado, USA. This means that the production system of corn in Calbayog is lower than the modern production system of 2.14 to 1.0. However, high usage of agrochemical and oil-powered machineries is detrimental to the environment. The energy used per kilogram or milled corn was 1.88 Mcal/ha or 0.16 LDOE. It means that about 0.16 LDOE or 1.88 Mcal was needed to produce one kg of milled white corn. This means that 160 LDOE is needed to produce a ton of milled corn.

As mention above, for all the production operations, indirect energy had the highest and this was from the usage of inorganic fertilizer. The adoption of organic fertilizer can help reduce the huge application of inorganic inputs. This will be realized in a long-term effect through continued application of composts and by not burning stalks of corn after harvesting, instead, return this in the field. The application of fertilizer N combined with cattle manure and incorporated corn stover contributed to the increased soil available N and plant N uptake (Ozkan et al., 2004). Incorporations of corn stover compost and N fertilizer enhanced plant growth and development (Mendoza, 2016). Incorporating 5 t straws adds about 30 kg N, 5kg P, and S, 100 kg K and 250 kg Si to the soil which can reduce 30% or more energy input of fertilizer. Recycling of the residues of rice will have a larger effect in the Philippines because 50% of all fertilizers are used in rice production (Hatirli et al., 2005)

Pest and diseases have developed resistance to the use of pesticides, and pesticides have contaminated farm environments and natural ecosystems, causing health problems for farmers and farm workers and destroying pollutions of beneficial insects and microorganisms and reducing agricultural biodiversity.

Under Calbayog, Samar condition, the total energy bill in various field productions per ha of milled rice was 4,533.60 Mcal or 397.20 LDOE which will emit 1,572.90 kg of CO₂. This still means that corn had the lowest energy bill compared with rice. It also signifies that to produce a hectare of corn, 978.12 kg of CO₂ will be emitted while rice will emit 1,572.90 kg of CO₂. This means that corn has a potential as additional calorie source since it has lower energy requirements and CO₂ emission.

In other study, Zamboanga, Philippines, consumes 1,939.32 Mcal or 169.90 LDOE per ha of white corn. This also supports that among the total energy bill, indirect energy comes 1,868.36 Mcal ha⁻¹ or a total of 163.69 LDOE. Of this, 58.11% (95.12 LDOE) was expended on the manufacture of NPK fertilizer materials, 25.85% (42.32 LDOE) energy derived from labour, 12.28% (20.10 LDOE) on the manufacture of insecticide and fungicide, and 3.76 (6.15 LDOE) energy derived for the seeds used. However, Colorado, USA, consumes 518.4 LDOE of corn production (use of hybrid seeds) employing man labour and machines (Tabal, 2017). In comparison with the present places who conducted the energy bill of a hectare of white corn, Calbayog had a lower energy bill and CO₂ emission compared to Zamboanga City Philippines, Indonesia and Colorado, USA.

Conclusion

To suffice the food insufficiency, about 33,787.57 tons per year of milled rice should be produced. Hence in a year 5,594,752.70 LDOE and 22,155,220.70 kg of CO₂ will be emitted per year while if we will use corn as additional crop, only 5,565,150.83 LDOE will be expended in corn per year and will only emit 22,037,997.30 CO_{2e}. In the reduction of corn energy bill, this can be made through the reduction of high indirect used of energy by decreasing usage of inorganic input application.

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Conflict of interest

The author declares that there is no conflict of interest in this publication.

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