# Energy Use and Greenhouse Gas Emissions of Farmer-level Sweet Potato Production Systems in the Philippines

Edgar D. Flores[1*], Renita SM. Dela Cruz[2] and Ma. Cecilia R. Antolin[3]

[1]Philippine Center for Postharvest Development and Mechanization (PhilMech),
Department of Agriculture, CLSU Compound, Science City of Munoz, Nueva Ecija, Philippines

[2] Philippine Center for Postharvest Development and Mechanization (PhilMech),
Department of Agriculture, CLSU Compound, Science City of Munoz, Nueva Ecija, Philippines

[3] Philippine Center for Postharvest Development and Mechanization (PhilMech),
Department of Agriculture, CLSU Compound, Science City of Munoz, Nueva Ecija, Philippines

[*] *Corresponding Author's email: egaydulayfloresr [AT] yahoo.com*

---

**ABSTRACT**—*Sweet potato (Ipomoea batatas L.) is one of the most important cash crops in the Philippines.Assessmentof energyuse and emission of greenhouse gases (GHGs)in sweet potato production can provide useful information to help implement environmentally-sound crop managementstrategiesfor improving energy efficiency and reduction of GHGs emission. In this study, the energy use and greenhouse gas (GHG) emissionsin kilogram carbon dioxide equivalent (kg $CO_{2eq}$) of three sweet potato production systems at farmer-level of operation were evaluated. Data were collected from 350 sweet potato farmers randomly selected from the sweet potato producing provinces of Albay, Bataan and Tarlac, Philippines. The energy input to produce output energy of 12068.40, 29619.20 and 53435.50 MJ ha$^{-1}$ were 4059.14, 16131.76 and 29326.78 MJ ha$^{-1}$ for systems 1, 2 and 3, respectively. System 3 had the highest input energy followed by system 2 because of the additional energy input of diesel fuel during land preparation and chemical fertilizer during crop management. The energy ratio of all the systems evaluated range from 1.82 to 2.97, among which system 3 was the lowest because of using more energy inputs of chemical fertilizers, diesel fuel and machinery. The amount of GHG emissions in the production systems of sweet potato, range from 77.97 to 1438.18 kg $CO_{2eq}$ ha$^{-1}$ (0.023 to 0.095 kg $CO_{2eq}$ kg$^{-1}$). Highest GHG emission value corresponds to system 3 which uses more energy inputs such as chemical fertilizer and diesel fuel. It is apparent that improving the production system by increasing energy inputs to increase the yield in sweet potato production would increase GHGs emission. Hence, energy management should be considered as an important strategy for resource conservation and climate protection. It is crucial to check the use of chemical inputs and non-renewable energy resources to maintain and enhance the sustainability of sweet potato production. The use of green manure instead of chemical fertilizer should be considered to control the high rate of non-renewable energy utilization, reduce the amount of GHGs emission and promote sustainable agriculture.*

**Keywords**— *Sweet potato, Energy ratio, Global warming potential, Greenhouse gases*

---

## 1. INTRODUCTION

Sweet potato (*Ipomoea batatas L.*) is one of the main crops grown in sub-tropical and tropical countries. It is the seventh most important food crop in the world. The demand for sweet potato worldwide in the fresh and process market is continuously increasing due to its nutritional value and substantial source for starch, sugar, alcohol, flour and other industrial products [1, 2]. Currently, sweet potato is considered as one of the energy crops like corn, cassava, sugarcane and sweet sorghum because of its potential source as feedstock for bioethanol production [3]. In the Philippines, sweet potato is considered one of the most important cash crops after maize and rice due to its low input requirements. The average annual production of sweet potato in the country is 532,443 MT [4]. The yield in sweet potato production can be increased through varietal improvement, improved crop management practices as well as reduced postharvest losses. Increasing the yield of sweet potato production using high-yielding clean planting materials, chemical fertilizers and pesticides has been done in some areas in the Philippines. These schemes however have increased the energy input per unit area. Increasing sweet potato production yield is related with higher input energy requirement both in the production and postproduction operations.

Energy is one of the major elements in modern agriculture as it depends heavily on fossil and other energy resources. The increase in input energy to obtain maximum yields may not usually obtain high profits due to the increase also in the cost of production [5]. Effective use of energy in agriculture is one of the conditions for sustainable agricultural production since it helps to save financial resources, conserve fossil fuels, and reduce air pollution. Therefore, there is a need that energy must be used efficiently to achieve increased production and productivity and ensures competitiveness and sustainability of agriculture [6, 7]. In this case, an assessment of the existing energy utilization must first be done to establish concrete data and information as basis for introducing potential technology intervention to further enhance energy efficiency of sweet potato production.

Aside from energy, the issues of GHG emission and global warming potential (GWP) are also critical due to a more intensive use of energy in the production system [8]. As a result of agricultural activities, greenhouse gases such as carbon dioxide ($CO_2$), methane (CH4) and nitrous oxide ($N_2O$) are produced and enhanced the natural greenhouse effect in the environment. It is reported that the agricultural sector contributes significantly to the atmospheric GHG emissions with 14 percent of the global emissions [9]. Currently, there have been several studies on estimating GHG emissions in the production system of some agricultural crops but so far no studies have been conducted to analyze energy use and GHG emissions of sweet potato production in the Philippines.

In this study, the input-output energy and GHGs emissions following different sweet potato production systems were evaluated. The study was undertaken to establish baseline data on energy and GHG emission in sweet potato production as basis to identify opportunities for improving the environmental aspects at various points in the entire production system. Moreover, the information that would be generated could serve as basis in the decision making process of the Philippine-government for the application of agricultural policy that promotes an environmentally-sound crop management pattern leading to more efficient energy usage, increased yield and income of the sweet potato farmers and reduction of the global warming potential of sweet potato production in the Philippines.

## 2.   MATERIALS AND METHODS

### *2.1 Sweet potato production system boundary*

In this study, three typical sweet potato production systems at farmer-level of operation in in the provinces of Albay, Bataan and Tarlac, Philippines were considered and evaluated (Figure 1).These three provinces were purposively selected, representing the three cultural sweet potato production practices in the Philippines.

Albayisthe third sweet potato producing province in the country where majority of the sweet potato farmers dependsolely on working animals for land preparation and manual labor for harvesting ofsweet potato roots (Albay-System 1).

Bataanis one of theprovinces that supplies sweet potato rootsto the famous fruits and vegetables marketplacein the country called "Divisoria market"and served as the major source of sweet potato planting materials of Tarlac Province. Sweet potato farmers rely on both working animals and machinery for land cultivation while manual labor and working animal for harvesting of sweet potato roots (Bataan-System 2)

Tarlac ranked sixthamong the sweet potato producing provinces in the country and the main supplier of sweet potato roots to Divisoria market. Most of the farmers use machinery for land cultivation while manual labor and machinery for harvesting of sweet potato roots (Tarlac-System 3).

For the assessment of energy use and GHG emissions, the pre-harvest operations included are the crop cultivation and management while the postharvest operations considered are harvesting (vine removal and uprooting of tubers), field gathering, sorting and bagging and in-field hauling [10]. The assessment started from production-to-farm-gate boundary, which offered flexibility for analyzing different crops with various end uses (e.g., food, feed, biofuel, etc.) was considered. Other on-farm processing beyond in-field hauling operation was not included because it is assumed that the sweet potato is sold as fresh roots/tubers in the market.
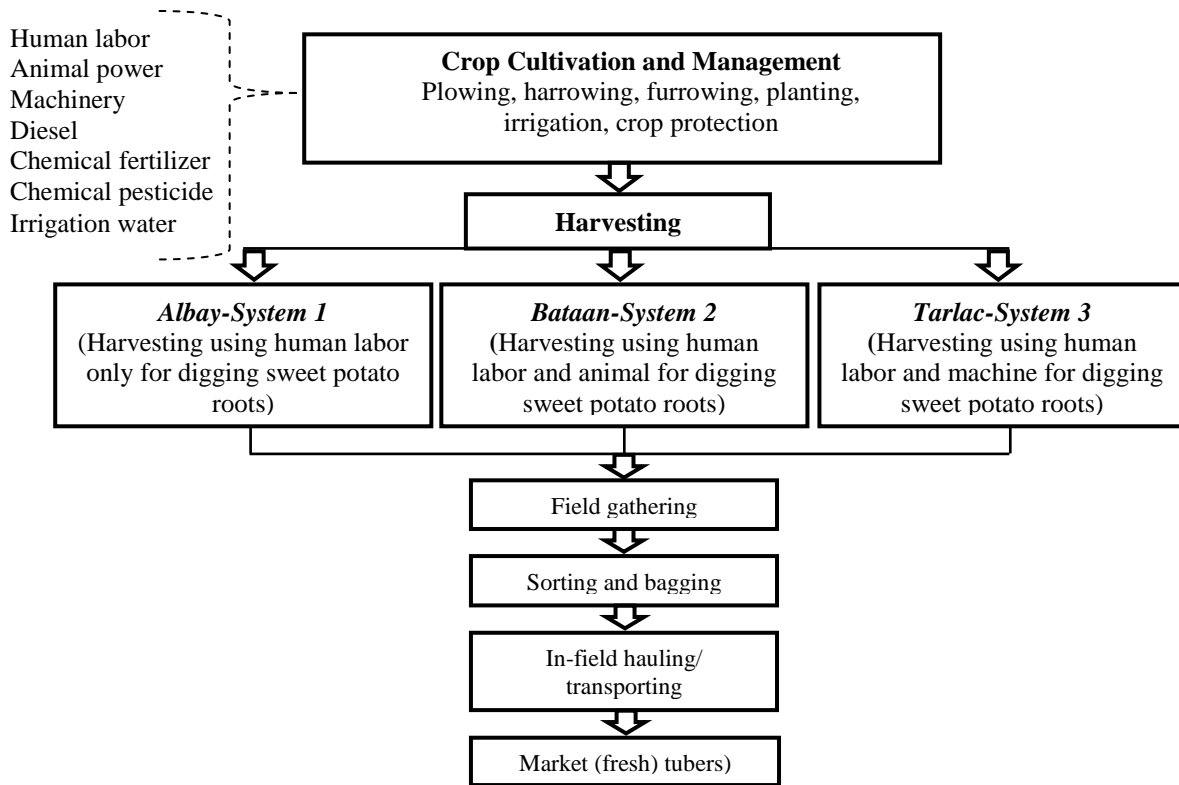
**Figure1:** Systems boundary used in the assessment of energy use and greenhouse gas emissions

## 2.2 Data collection and analysis

Data and information were collected from a total of 350 sweet potato farmers using structured survey questionnaires. The sample size of each sweet potato production system was determined using Equation 1 [11].

$$n = \frac{N}{1 + Ne^2} \qquad (1)$$

Where n is the required sample size; N, the number of sweet potato farmers/producers in the study area and e, the acceptable error (permissible error was chosen as 5%). Farms were randomly selected from the sweet potato producing provinces of Albay, Bataan and Tarlac, Philippines.Using equation 1, the sample size for *Albay-System 1* was 110, 60 for *Bataan-System 2* and 180 for *Tarlac-System 3*.

The collected information included the sweet potato production systems starting from land preparation, crop management, harvesting and in-filed hauling of fresh sweet potato roots. The input requirements for the sweet potato production included human labor, animal power, machinery, diesel fuel (used in obtaining vines as planting materials, land preparation, irrigation, harvesting and in-field hauling), fertilizers and pesticides for crop management while yield in fresh sweet potato roots/tubers was specified as output.

## 2.3 Assessment of energy input-output of sweet potato production systems

The machinery, diesel fuel, chemical fertilizers, chemical pesticides, human labor, animal power and irrigation water were specified as inputs to estimate the amount of energy usage while the sweet potato roots in fresh form as output. The amount of each input was multiplied with the energy coefficient equivalent as listed in Table 1 to 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 [12].

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

$$EP = \frac{Sweet\ potato\ roots\ output\ (kg/\ ha)}{Energy\ input\ (MJ/ha)} \qquad (3)$$

$$SE = \frac{Energy\ input\ (MJ/\ ha)}{Sweet\ potato\ roots\ output\ (kg/ha)} \qquad (4)$$

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

**Table 1:** Energy equivalent of inputs and output in sweet potato production system

| Input/output | Unit | Energy (MJ unit$^{-1}$) | Reference |
|---|---|---|---|
| **A. Inputs** | | | |
| 1. Human labor | h | 1.96 | [13] |
| 2. Animal power | h | 3.49 | [14] |
| 3. Machinery | h | 108.90 | [15] |
| 4. Diesel fuel | L | 47.8 | [15, 16, 17] |
| 5. Chemical Fertilizers | | | |
|    a. Nitrogen (N) | kg | 78.1 | [16] |
|    b. Phosphorous (P2O5) | kg | 17.4 | [16] |
|    c. Potassium (K2O) | kg | 13.7 | [16] |
| 6. Chemical Pesticides | | | |
|    a. Insecticides | kg | 101.20 | [7] |
|    b. Herbicides | kg | 238.00 | [7] |
|    c. Fungicides | kg | 216.00 | [7] |
| 7. Water for irrigation | m3 | 0.63 | [18] |
| 8. Electricity | kWh | 3.6 | [19] |
| **A. Output** | | | |
| 1. Sweet potato roots | kg | 3.59 | [20] |

## 2.4 Estimation of GHG emission and GWPs

The amounts of GHG emissions from inputs in sweet potato 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 computed 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 [21]. The amount of $CO_2$ produced was calculated by multiplying the input application rate per hectare (e.g. diesel fuels, chemical fertilizers, herbicides and pesticides) by its corresponding coefficient enumerated in Table 2.

Following the energy methodology, mean emissions from farm inputs (diesel, nitrogen, phosphate, potash) were converted to kg $CO_2$eq. Greenhouse gases (GHGs) such as $CH_4$ and $N_2O$ were converted to kg $CO_2$eq on the basis of their 100-year global warming potentials (GWPs), which are 1 for $CO_2$, 25 for $CH_4$ and 298 for $N_2O$ [22]. The total emissions of greenhouse gases are determined using equation 6 [23].

$$GHG\ emission = \sum GWPi \times Mi \qquad (6)$$

*Where Mi* is the mass (in kg) of the emission gas. The score is expressed in terms of kilogram carbon dioxide equivalent [$kgCO_{2eq}$].

**Table 2:** Gaseous emissions (g) per unit of chemical sources and their global warming potential (GWP) in sweet potato production system

| Inputs (unit) | $CO_2$ | $N_2O$ | $CH_4$ | References |
|---|---|---|---|---|
| 1.  Diesel (L) | 3560. | 0.70 | 5.20 | [23] |
| 2.  Nitrogen fertilizer (kg) | 3100 | 0.03 | 3.70 | [24] |
| 3.  Phosphate ($P_2O_5$) (kg) | 1000 | 0.02 | 1.80 | [24] |
| 4.  Potash ($K_2O$) (kg) | 700 | 0.01 | 1.00 | [24] |
| GWP $CO_2$ equivalent factor | 1 | 298 | 25 | [22] |

Other farm inputs such as machinery and chemical pesticides (insecticide, herbicides and fungicides) were directly multiplied with their GHG emission coefficients presented in Table 3. The total GWPs (in kg $CO_{2eq}$) were integrated and determined the GWPs per hectare of sweet potato production.

**Table 3:** GHG emission coefficients of agricultural inputs

| Inputs (unit) | GHG Coefficient (kg $CO_{2eq}$ unit$^{-1}$) | References |
|---|---|---|
| 1.  Machinery (MJ) | 0.071 | [25] |
| 2.  Chemical pesticides | | |
| Insecticides (kg) | 5.1 | [26] |
| Herbicides (kg) | 6.3 | [26] |
| Fungicides (kg) | 3.9 | [26] |

## 3.  RESULTS AND DISCUSSION

### 3.1 Energy input-output in sweet potato production system

The output and input rates of different sweet potato production systems with their energy equivalents are summarized in Table 4. The mean sweet potato yield in Albay was 3320 kg ha$^{-1}$, 8320 kg ha$^{-1}$ in Bataan and 15010 kg ha$^{-1}$ in Tarlac. Highest mean yield of sweet potato was observed in Tarlac province because of the suitable type of soil (sandy loam) for planting sweet potato as well as the good cultural and management practices compared to Bataan and Albay provinces[10].The total energy inputs in sweet potato production systems 1, 2 and 3 were 4059.14, 16131.76 and 29326.78 MJ ha$^{-1}$, respectively. These resulted to a net energy of 8009.26, 13387.44 and 24108.82 MJ ha$^{-1}$ for system 1, 2, and 3, respectively. In the case of system 1, which did not utilize fertilizer during crop production, the total input energy was contributed most by human labor and diesel fuel (Figure 2).

**Table 4:** Energy inputs and outputs in sweet potato production systems (MJ ha$^{-1}$)

| Items | Albay- System 1[a] | Bataan-System 2[b] | Tarlac-System 3[c] |
|---|---|---|---|
| **A.   Inputs** | | | |
| 1. Machinery | 0.00 | 276.79 | 477.80 |
| 2. Diesel | 1026.60 | 2566.00 | 10060.68 |
| 3. Human labor | 1905.12 | 1568.00 | 1422.96 |
| 4. Animal power | 448.60 | 265.24 | 111.68 |
| 5.  Chemical fertilizers | 0.00 | 10349.45 | 15134.80 |
| 6.  Chemical pesticides | 0.00 | 339.20 | 202.40 |
| 7.  Irrigation water | 638.82 | 766.58 | 1916.46 |
| **Total Input** | 4059.14 | 16131.76 | 29326.78 |
| **B.   Output** | | | |
| Sweet potato roots | 12068.40 | 29619.20 | 53435.50 |
| **C.   Net Energy** | 8009.26 | 13487.44 | 24108.82 |

[a]*System 1- Planting area is prepared by human labor and animal power; harvesting of roots is done by human labor only*
[b]*System 2- Planting area is prepared by human labor, animal power & machinery; harvesting of roots is done by human labor and animal power*
[c]*System 3- Planting area is prepared by human & machinery; harvesting of roots is done by human labor and machinery*

On the other hand, chemical fertilizer and diesel fuel were the major contributors of input energy for systems 2 and 3 (Figures 3-4). Both systems 2 and 3 were utilized chemical fertilizers during the production stage with the aimed to enhance sweet potato production yield.

Currently, there have been no studies related to energy use of sweet potato production. However, the results of systems 2 and 3 have been observed in other agricultural crop production such as irish potato [27], sugar beet [19], wheat [28] and corn [29] where chemical fertilizer, specifically nitrogen played the highest contributor of energy in the total input energy of most crop production.
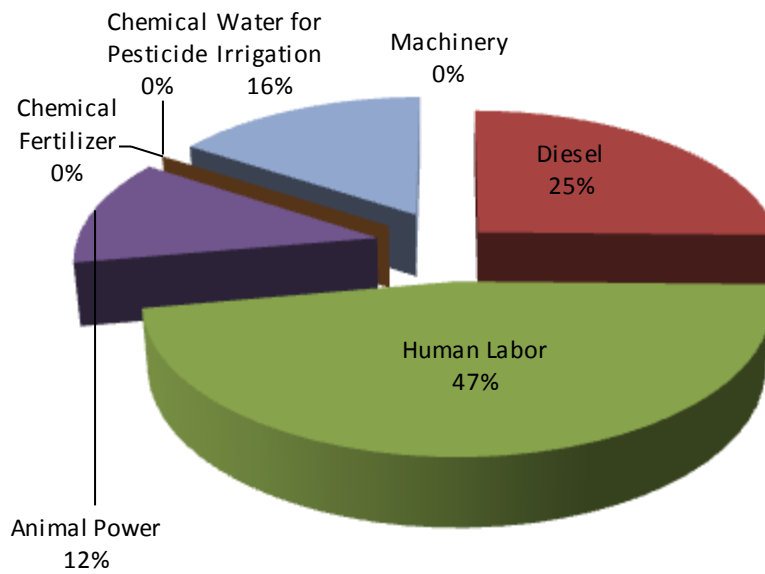


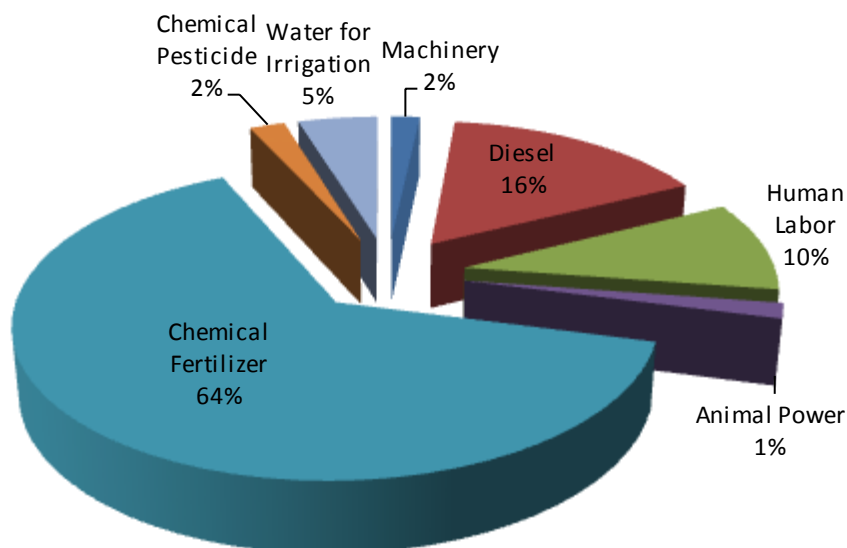**Figure 2:** Percentage share of input energy in Albay-System 1

**Figure 3:** Percentage share of input energy in Bataan-System 2
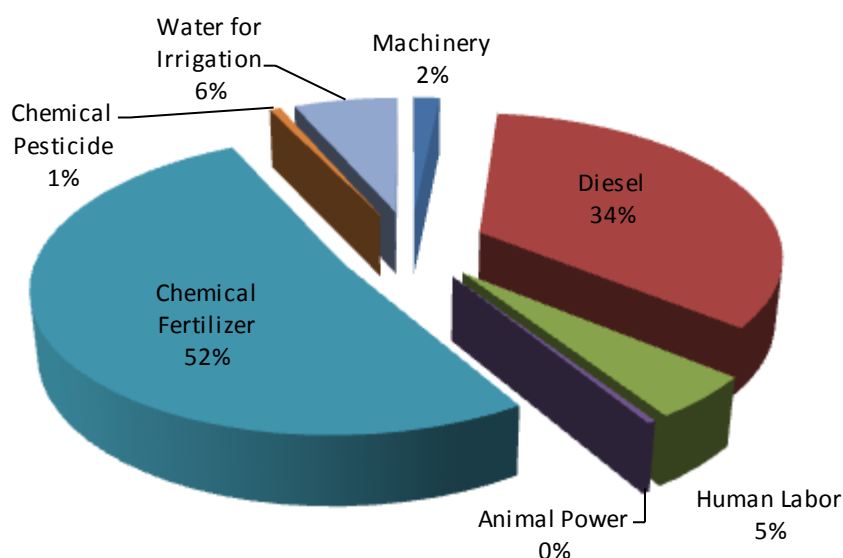


**Figure 4:** Percentage share of input energy in Tarlac-System 3

### 3.2 Energy indicators in sweet potato production systems

Energy indicators such as energy efficiency (ratio), energy productivity, specific energy and net energy of the sweet potato production systems are enumerated in Table 5. Energy ratio is generally used as an index to measure the efficiency of energy in crop production systems. Thus, the higher the energy ratio, the more efficient use of energy is attained in the crop production. The use of efficient energy resources is crucial in terms of increasing production, productivity, competitiveness and sustainability in agricultural of crop production systems [30].

**Table 5:** Indicators of energy use in sweet potato production systems

| Indicators (Unit) | Albay- System 1[a] | Bataan-System 2[b] | Tarlac-System 3[c] |
|---|---|---|---|
| Inputs Energy (MJ ha$^{-1}$) | 4059.14 | 16131.76 | 29326.78 |
| Output Energy (MJ ha$^{-1}$) | 12068.40 | 29619.20 | 54435.60 |
| Net Energy (MJ ha$^{-1}$) | 8009.26 | 13487.44 | 24108.82 |
| Energy ratio | 2.97 | 1.84 | 1.82 |
| Energy Productivity (kg MJ$^{-1}$) | 0.84 | 0.52 | 0.51 |
| Specific Energy (MJ kg$^{-1}$) | 1.20 | 1.94 | 1.95 |

[a]*System 1- Planting area is prepared by human labor and animal power; harvesting of roots is done by human labor only*
[b]*System 2- Planting area is prepared by human labor, animal power & machinery; harvesting of roots is done by human labor and animal power*
[c]*System 3- Planting area is prepared by human & machinery; harvesting of roots is done by human labor and machinery*

The energy efficiency ratio calculated for sweet potato production systems 1, 2 and 3 were 2.92, 1.84 and 1.82, respectively. This implied that the energy consumed in each of the production system has been replenished 2.92, 1.84 and 1.82 times by the source of energy produced from harvested sweet potato roots in system 1, 2 and 3, respectively. Higher energy ratio was observed for system 1 compared to systems 2 and 3 because of the less energy input of machinery and chemical fertilizer. With this, lower specific energy value of 1.20 MJ kg$^{-1}$ was calculated for system 1 compared to 1.94 and 1.95 for system 2 and 3, respectively. In relation to this, the energy productivity value of system 1 was higher compared to systems 2 and 3.Currently, there is no or limited studies on energy generated for sweet potato production. However, in some related researches, the value of energy ratio for potato of 1.71 [27]; 1.14 and 0.95 [31]; and 1.25 [32]

were close to energy ratio generated by systems 2 (1.84) and 3 (1.82) in this study. Likewise, system 1 (2.92) was close to energy ratio figures generated for corn [29] and greenhouse vegetable [6] with 2.67 and 2.8 energy ratio, respectively.

### 3.3 Energy forms in sweet potato production systems

The forms of energy in the sweet potato production systems were classified into direct and indirect or renewable and non-renewable energies as presented in Table 6. The share of direct energy for system 1 was 100 percent. This was attributed to the non-utilization of inputs such as chemical fertilizers and machinery during the cultivation process. Also, majority of the total input energy share in system 1 was in the form of renewable energy. As revealed, the share of indirect and non-renewable forms of energy for systems 2 and 3 were higher than system 1 due to the use of machinery, chemical fertilizers and pesticides, as well as the more intense use of diesel fuel.

It is expected that the use of more modern crop production system to increase yield, the consumption of non-renewable energy is greater than 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 6:** Forms of energy input in sweet potato production systems (MJ ha$^{-1}$)

| Indicators | Albay- System 1 | Bataan-System 2 | Tarlac-System 3 |
|---|---|---|---|
| Direct Energy [a] | 4059.14 | 5166.21 | 13511.78 |
| Indirect Energy [b] | 0.00 | 10965.44 | 15815.00 |
| Renewable Energy [c] | 3032.54 | 2599.82 | 3451.10 |
| Non-renewable Energy [d] | 1026.60 | 13531.94 | 25875.68 |
| Total Energy Input | 4059.14 | 16131.76 | 29326.78 |

[a] *Includes human labor, animal labor, diesel, irrigation water*

[b] *Includes machinery, chemical fertilizers, chemical pesticides*

[c] *Includes human labor, animal labor, planting materials, irrigation water*

[d] *Includes diesel, chemical fertilizers, chemical pesticides, machinery*

### 3.4 GHGs emissions in sweet potato production systems

The amount of greenhouse gas emissions of different sweet potato production systems were calculated and summarized in Table 7. The GHGs emission of sweet potato production for system 1 at 77.97 kg $CO_{2eq}$ ha$^{-1}$ was the lowest among the systems evaluated. Highest GHG emission was observed for system 3 at 1432.18 kg $CO_{2eq}$ ha$^{-1}$ due to further increased in the use of input energy in the production system. The results indicated that the production of a kilogram of fresh sweet potato roots would lead to a GWP of 0.023, 0.078 and 0.095 kg $CO_{2eq}$ kg$^{-1}$ for system 1, 2 and 3, respectively. The disparities in emissions of the systems evaluated were due to the different in production practices, soil and climate conditions among others.

**Table 7**. GHGs emission of agricultural inputs in sweet potato production systems

| Environmental Indicators | Albay- System 1 [a] (kg $CO_{2eq}$ ha$^{-1}$) | Bataan-System 2 [b] (kg $CO_{2eq}$ ha$^{-1}$) | Tarlac-System 3 [c] (kg $CO_{2eq}$ ha$^{-1}$) |
|---|---|---|---|
| Machinery | 0.00 | 3.02 | 33.92 |
| Diesel fuel | 77.97 | 194.93 | 764.13 |
| Chemical Fertilizers | | | |
| (a) Nitrogen (N) | 0.00 | 408.18 | 611.48 |
| (b) Phosphorous (P2O5) | 0.00 | 17.87 | 7.36 |
| (c) Potassium (K2O) | 0.00 | 5.10 | 5.10 |
| Chemical Pesticides | | | |
| (a) Insecticides | 0.00 | 5.10 | 10.20 |
| (b) Herbicides | 0.00 | 0.00 | 0.00 |
| Total GHG emission | 77.97 | 650.83 | 1432.18 |
| kg $CO_{2eq}$ kg$^{-1}$ S. Potato | 0.023 | 0.078 | 0.095 |

[a] *System 1- Planting area is prepared by human labor and animal power; harvesting of roots is done by human labor only*

[b] *System 2- Planting area is prepared by human labor, animal power & machinery; harvesting of roots is done by human labor and animal power*

*[c]System 3- Planting area is prepared by human & machinery; harvesting of roots is done by human labor and machinery*

It is evident that diesel fuel and chemical fertilizer were the main contributors to the GHG emissions in sweet potato production for systems 2 and 3. And among the chemical fertilizers, nitrogen supplied the highest GHG emission. The results also indicated that more mechanized or improved agricultural production system would incur more energy inputs that would lead to more emission of greenhouse gases and higher global warming potential. While more improved production system would enhance yield in sweet potato production, the improvement however of energy use efficiency is vital for reducing GHGs emission and GWP rate.

## 4. CONCLUSION AND RECOMMENDATIONS

For all the three sweet potato production systems evaluated, the energy ratio range from 1.82 to 2.97, from which the highest energy ratio value represents the system with less usage of energy inputs such as diesel fuel and chemical fertilizer. The amount of greenhouse gas emission in the production of sweet potato using different cultural practices range from 77.97 to 1438.18 kg $CO_{2eq}$ ha$^{-1}$ (0.023 to 0.095 kg $CO_{2eq}$ kg$^{-1}$), among which the highest GHGs emission value corresponds to the sweet potato production system with more use of energy inputs such as chemical fertilizer and diesel fuel

It is evident that improving the production system by increasing more energy inputs would enhance yield in sweet potato production. However, energy management should be considered as an important strategy for resource conservation and climate protection.

In order to maintain and enhance the sustainability of sweet potato production, it is crucial to check the use of chemical inputs and non-renewable energy resources. The use of green manure or organic fertilizer instead of chemical fertilizer should be considered to control the high rate of non-renewable energy utilization and reduce the amount of GHGs emissions. 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.

## 5. ACKNOWLEDGEMENT

## 6. REFERENCES

[1] Lee, J.S., Kim, H.S., Chung, M.N., Ahn, Y.S., Jeong, B.C., and Bang, J.K. Various forms of utilization and breeding of sweet potato in Korea. AciaHort (ISHS), vol. 703, pp. 125-132, 2006.
[2] Adenuga, W. Nutritional and sensory profiles of sweet potato based infant weaning food fortified with cowpea and peanut. Journal of Food Technology, vol. 8, pp. 223-228, 2010.
[3] Qiu H.G., Huang J.K., Yang J. Bioethanol development in China and the potential impacts on the agricultural economy. Applied Energy, vol. 87, no. 1, pp. 76-83, 2010.
[4] BAS-Bureau of Agricultural Statistics. 2014. Production volume of sweet potato. Department of Agriculture, Philippines.
[5] Erdal G, Esengun K, Erdal H, Gunduz O. Energy use and economic analysis of sugar beet production in Tokat province of Turkey. Energy, vol. 32, pp. 35–41, 2007.
[6] Ozkan B, Akcaoz H, Fert C. Input energy–output analysis in Turkish agriculture. Renewable Energy, vol. 29, pp. 39–51, 2004.
[7] Ozkan B, Fert C, Karadeniz C.F. Energy and cost analysis for greenhouse and open- field grape production. Energy, vol. 32, pp. 1500-1504, 2007.
[8] Khoshnevisan B, Rafiee Sh, Omid M, Yousefi M, Movahedi M. Modeling of energy consumption and GHG (greenhouse gas) emissions in wheat production in Esfahan province of Iran using artificial neural networks. Energy, vol. 52, pp. 333–338, 2013.
[9] IPCC. Climate change 2007; impacts adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE, editors. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. Cambridge UK: Cambridge University Press,p. 976, 2007.

[10] Flores E.D., R.SM. Dela Cruz, M.C.R. Antolin, G.F. Aninipot. Benchmark studies on postharvest handling of sweet potato. Unpublished Terminal Report. Philippine Center for Postharvest Development and Mechanization, Munoz, Nueva Ecija, Philippines, 2015.

[11] Yamane, T. Statistics: An Introductory Analysis, 2nd Ed., New York: Harper and Row, 1967.

[12] Yousefi, M., M. Khoramivafa, and F. Mondani. 2014a. Integrated evaluation of energy use, greenhouse gas emissions and global warming potential for sugar beet (Beta vulgaris) agroecosystems in Iran. Atmospheric Environment, vol. 92, pp. 501-505, 2014a.

[13] Mohammadi A, Omid M. Economic analysis and relation between input energy and yield of greenhouse cucumber production in Iran. Applied Energy, vol. 87, pp. 191–196, 2010.

[14] Pimentel D. Energy in food production. Department of Entomology and Limnology. Cornell University, Ithaca, New York, USA. URL: http:// www.jtor.org/, 1979.

[15] Pimentel D. Energy inputs in production agriculture. In: Fluck RC, editor. Energy in World Agriculture. Amsterdam: Elsevier Science, pp. 13-29, 1992.

[16] Kitani O. CIGR handbook of agricultural engineering. Energy and biomass engineering, vol. 5. St Joseph, MI: ASAE Publication, 1999.

[17] Esengun K, Gunduz O, Erdal G. Input–output energy analysis in dry apricot production of Turkey. Energy Conversion Management, vol. 48, pp. 592–598, 2006.

[18] Hatirli SA, Ozkan B, Fert C. An econometric analysis of input energy/output in Turkish agriculture. Renewable and Sustainable Energy Review, vol. 9, pp. 608–623, 2005.

[19] Asgharipour MR, Mondani F, Riahinia S. Energy use efficiency and economic analysis of sugar beet production system in Iran: a case study in Khorasan Razavi province. Energy, vol. 44, pp. 1078–1084, 2012.

[20] Oke M.O., T.S. Workneh. 2013. A review on sweet potato postharvest processing and preservation technology. African Journal of Agricultural Research, vol. 8, no. 40, pp. 4990-5003, 2013.

[21] Soltani A, Rajabi MH, Zeinali E, Soltani E. Energy inputs and greenhouse gases emissions in wheat production in Gorgan Iran. Energy, vol. 50, pp. 54–61, 2013.

[22] Eggleston S., Buendia L., Miwa K., Ngara T., Tanabe K., eds. IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change, 2006.

[23] Kramer K.J., Moll H.C., Nonhebel S. Total greenhouse gas emissions related to the Dutch crop production system. Agriculture, Ecosystems & Environment, vol. 72, pp. 9–16, 1999.

[24] Snyder C.S., Bruulsema T.W., Jensen T.L., Fixen P.E. Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agriculture, Ecosystems & Environment, vol. 133, pp. 247–66, 2009.

[25] Dyer J.A., Desjardins R.L. Carbon dioxide emissions associated with the manufacturing of tractors and farm machinery in Canada. Biosystems Engineering, vol. 93, no. 1, pp. 107-118, 2006.

[26] Nabavi-Pelesaraei A., Abdi R., Rafiee S., Mobtaker H.G. Optimization of energy required and greenhouse gas emissions analysis for orange producers using data envelopment analysis approach. Journal of Cleaner Production, vol. 65, pp. 311-317, 2013.

[27] Pishgar-Komleh S.H., Ghahderijani M., Sefeedpari P. Energy consumption and CO2 emissions analysis of potato production based on different farm size levels in Iran. Journal of cleaner production, vol. 33, pp. 183-191, 2012.

[28] Singh H., Singh A.K., Kushwaha H.I., Singh A. Energy consumption pattern of wheat production in India. Energy, vol. 32, pp. 1838-1854, 2007.

[29] Yousefi M., Damghani A.M., Khoramivafa M.Energy consumption, greenhouse gas emissions and assessment of sustainability index in corn agroecosystems of Iran. Science of the Total Environment, vol. 493, pp. 330-335, 2014b.

[30] Hatirli S., Ozkan B., Fert C. Input energy crop yield relationship in greenhouse tomato production. Renewable Energy, vol. 31, pp. 427-438, 2006.

[31] Zangeneh M., M. Omid, A. Akram. A comparative study on energy use and cost analysis of potato production under different farming technologies in Hamadan province of Iran. Energy, vol. 35, pp. 2927-2933, 2010.

[32] Mohammadi A., A. Tabatabaeefar, S. Sashin, S. Rafiee, A. Keyhani. Energy use and economical analysis of potato production in Iran a case study: Ardabil province. Energy Conversion and Management, vol. 49, pp. 3566-3570, 2008.