The energy input-output analysis of maize production in Sundarharaincha Municipality, Morang district, Nepal

Sandesh Poudel¹, Saurabh Bhattarai¹, Tsering Sherpa¹, Anish Karki¹, Dae Hyun Kim², and Sagar Kafle¹,*

¹Department of Agricultural Engineering, Purwanchal Campus, Institute of Engineering, Tribhuvan University, Dharan-08, Sunsari, Nepal
²Department of Biosystems Engineering, College of Agriculture and Life Sciences, Kangwon National University, Hyoja 2 Dong, 192-1, Chuncheon 200-701, Republic of Korea
*email: sagarkafle@ioepc.edu.np, sagarkaflenp@gmail.com

Abstract. Maize is the second largest crop grown in Nepal and is grown in all three geographic zones. The objective of this study is to analyse the energy input-output of maize production systems. The study was conducted in Sundarharaincha municipality of Morang district, Nepal, using direct questionnaire methods for the collection of primary data of varying landholding sizes farmers. The study revealed that total energy input and output for maize production system found about 10,999.61 MJ/ha and 45,501.52 MJ/ha, respectively, with the highest share by farmyard manure (FYM) about 50%. The energy use efficiency was found 4.14. Total CO₂, N₂O and CH₄ emissions due to chemical inputs were found 163.24 kg/ha, 0.03 kg/ha and 0.33 kg/ha, respectively. The total Global warming potential was found 178.58 CO₂ eq. per ha. The average cost of production were calculated USD 301.35/ha and profit USD 272.26/ha.

1. Introduction
About two third of populations of Nepal depends on agriculture (agriculture, forest and fisheries), but it contributes only about 27.7% of gross domestic product (GDP) in 2017/18 [1]. Maize is one of the major crops grown in Nepal, in terms of area and production second to paddy. Maize is grown mostly in hilly and terai region of Nepal, in 2017/18 it is grown in 900,288 hectare (ha) land and produced about 2.3 million tons (Mt) with the average yield of 2,555 kg/ha [2]. Maize is produced by using energy source ranging from animal to human and farm machineries. Yield in crop is directly related to the amount and quality of energy invested during its production [3]. Thus, proper assessment is necessary for analyzing the appropriate energy inputs needed for optimum production of maize. Although, energy input in modern agricultural system is very high in comparison to the traditional agricultural system [4], increased input energy may not bring maximum profit because of timely increasing production cost [5]. Energy input and energy use pattern largely depends upon farming condition, crop season and farming system [6]. With the study of energy input system, it has also been equally important to study about Greenhouse Gas (GHG) Emission and Global Warming Potential (GWP) in agricultural production system. Agriculture shares 14% of the global CO₂ emissions [7]. Agricultural production system leads to the production of different Greenhouse Gases such as Carbon dioxide (CO₂), Methane (CH₄) and Nitrous Oxide (N₂O) [8]. Thus, effectively using the input energy helps in agricultural sustainability, reduce cost and finally decrease environment distortion. The study is carried out at Sundarharaincha Municipality of Morang District, in the rain-fed farming practiced farm, with the objective to the energy input-output analyze in maize production.
2. Materials and methods
A systematic procedure was followed to analyse energy use, GHG emission and GWP in maize production.

2.1 Study area
This research was conducted in Sundarharaincha municipality of Morang district, Nepal. It is located in the south-eastern part, having area of 1,855 km² and altitudes range from 60 m to 2,410 m. This district has total of 105,270 ha of agricultural land (56.7% of total lands) situating mostly in plain areas and having fertile soil [9].

Figure 1. Maps of Morang district of Nepal showing Sundarharaincha Municipality [9].
2.2 Data Collection
Sundarharaincha municipality ward no. 11 is chosen for study where farmers are growing maize in rain-fed conditions. The data were collected by face-to-face questionnaire method with 30 farmers. Farmers were selected according to cultivation area of maize, ranging from about 0.033 to 0.680 ha, having total area of about 8 ha.

2.3 Data processing and calculations
All the collected data were entered in the Excel sheet and inputs were transformed into energy value by multiplying the amounts of inputs with their respective energy equivalents (Table 1). In the output, this study has taken only maize grain that means it has excluded biomass residue though it is being used for cooking fuel and has potential raw materials for fuel pellet production [10]. The input energy was also categorized into Direct vs indirect. The direct energy (DE) includes diesel, human labor, water, and electricity and indirect energy (IDE) includes seeds, fertilizers, farmyard manure (FYM), pesticides and machineries.

Table 1. Energy equivalents of inputs and outputs in maize production system.

| Particulars | Unit | Equivalent (MJ) | Reference |
|-------------|------|-----------------|-----------|
| Inputs      |      |                 |           |
| 1. Human Labor | hr   | 1.96            | [11]      |
| 2. Machineries | hr   | 62.7            | [12]      |
| 3. Diesel   | ltr  | 51.33           | [12]      |
| 4. Fertilizers |      |                 |           |
| Nitrogen    | kg   | 66.14           | [5]       |
| Phosphorus  | kg   | 12.44           | [5]       |
| Potash      | kg   | 11.15           | [13]      |
| 5. FYM      | kg   | 3.8             | [14]      |
| 6. Chemicals| kg   | 120             | [15]      |
| 7. Water    | m³   | 0.63            | [16]      |
| 8. Electricity | kWh | 3.6             | [17]      |
| 9. Seeds    | kg   | 14.7            | [14]      |

The amount of output energy was calculated by multiplying maize yield (kg/ha) by maize energy equivalent (MJ/kg). The energy use efficiency, energy productivity and net energy were calculated by the three equations given below [18].

\[
\text{Energy use efficiency} = \frac{\text{Output Energy (MJ/ha)}}{\text{Input Energy (MJ/ha)}} \tag{1}
\]

\[
\text{Energy Productivity} = \frac{\text{Grain yield (kg/ha)}}{\text{Input Energy (kg/ha)}} \tag{2}
\]

\[
\text{Net Energy} = \text{Output Energy (MJ/ha)} - \text{Input Energy (MJ/ha)} \tag{3}
\]

In the field survey, it was found that to supply Nitrogen, Phosphorous and Potash farmers are used Urea, Diammonium Phosphate (DAP) and Potassium Chloride (MOP), respectively. As per their composition, nitrogen, Phosphorous and Potash were calculated. Urea contains 46% nitrogen, DAP contains 46% phosphate (P₂O₅), and MAP contains 60% potash (K₂O) [19] Greenhouse Gas Emission is calculated from chemical inputs. CO₂, N₂O and CH₄ emissions coefficient of chemical inputs are given in Table 2. The amount of GHG emissions from chemical inputs used in maize production system were calculated by using those emission coefficients. Each of the GHG are responsible for Global Warming potential. GWP is the warming potential of the gases with relate to that of Carbon
dioxide. The emissions are measured in terms of reference gas, CO$_2$ [16]. Total emission of greenhouse gases is determined by given equation [20].

\[
\text{Greenhouse effect} = \sum GWP_i \times M_i
\]

(4)

where, $M_i$ represents the mass of the emission gas. Global warming Potential is expressed in terms of CO$_2$ equivalents.

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

| Input               | Unit   | CO$_2$   | N$_2$O | CH$_4$ | Ref.  |
|---------------------|--------|----------|--------|--------|-------|
| Diesel              | liters | 3,560.00 | 0.70   | 5.20   | [20]  |
| Nitrogen            | kg     | 3,100.00 | 0.03   | 3.70   | [21]  |
| Phosphate           | kg     | 1,000.00 | 0.02   | 1.80   | [21]  |
| Potash              | kg     | 700.00   | 0.01   | 1.00   | [21]  |
| GWP (CO$_2$eq)      | kg     | 1.00     | 310.00 | 21.00  | [22]  |

During the survey cost per unit inputs were recorded from farmers. Farmers may say the unit rate or total overall cost. From the data provided by farmers, cost of items can be calculated as:

\[
\text{Cost of items} = \frac{\text{Total Price (Rs)}}{\text{Amount of items (Number, hours, day, Kg, Ltr)}}
\]

(5)

Cost of production per hectare and the cost of production of per kg Maize can be calculated as:

\[
\text{Cost of production per hectare} = \sum \text{Cost of input items per hectare}
\]

(6)

\[
\text{Cost of production of 1 kg maize} = \frac{\text{Cost of production per hectare}}{\text{Production per hectare}}
\]

(7)

Profit per kg = Selling price of 1 kg maize – Cost of production of 1 kg maize

Profit per hectare = Profit per kg × Production of maize per hectare (kg/ha)

\[
\text{Profit (\%)} = \frac{\text{Profit per Kg}}{\text{Cost of production of 1 kg maize}}
\]

(8)

3. Results and discussion

Energy inputs for maize production in the studied area have been presented in Table 3. The total energy requirement for producing the maize was 10,999.61 MJ/ha, FYM contribution was found the highest (50.07%). After FYM, nitrogen occupies second position in highest energy uses (1,874.81 MJ/ha). Chemical input contribution was found lowest (18.81 MJ/ha). Thus, it can be clearly seen that use of chemicals is not much in that area.

Total output grain was 3,095.34 kg/ha or 45,501.52 MJ/ha (in terms of energy). Energy use Efficiency in this agricultural system was calculated 4.14, which is higher than in Iran (1.86) [23], which can be considered good. Total energy productivity was 0.28 kg/MJ and Net Energy was 34,501.91 MJ/ha, which is higher than national average productivity of maize. Energy use efficiency can further be made more by increasing the yield in production and reducing the energy inputs.
Table 3. Energy inputs and outputs in maize production system

| Particulars | Quantity per ha | Energy (MJ/ha) | % Contribution |
|-------------|----------------|----------------|----------------|
| **A. Inputs** | | | |
| 1. Human Labor (h) | 279.99 | 548.78 | 4.99 |
| 2. Machineries (h) | 6.21 | 389.40 | 3.54 |
| 3. Diesel (Ltr) | 36.52 | 1,874.81 | 17.04 |
| 4. Fertilizers | | | |
| Nitrogen (kg) | 27.70 | 1,832.19 | 16.66 |
| Phosphorus (kg) | 18.11 | 225.32 | 2.05 |
| Potash (kg) | 9.06 | 101.04 | 0.92 |
| 5. FYM (kg) | 1,449.27 | 5,507.23 | 50.07 |
| 6. Chemicals (kg) | 0.15 | 17.81 | 0.16 |
| 7. Water (m³) | 0.00 | 0.00 | 0.00 |
| 8. Electricity (kWh) | 0.00 | 0.00 | 0.00 |
| 9. Seeds (kg) | 34.22 | 503.04 | 4.57 |
| **B. Output** | | | |
| 1. Maize (kg) | 3,095.34 | 45,501.52 | |
| **Total Energy Input (MJ/ha)** | | | 10,999.61 |
| **Total Energy Output (MJ/ha)** | | | 45,501.52 |
| **Energy use efficiency** | | | 4.14 |
| **Energy productivity (kg/MJ)** | | | 0.28 |
| **Net energy (MJ/ha)** | | | 34,501.91 |

It was found that the indirect energy contribution is higher (77.97%) than that of direct energy (22.03%), as shown in Table 4.

Table 4. Total energy input in form of direct, indirect, biological and Industrial for maize production system

| Indicators | Quantity (MJ/ha) | % Contribution |
|------------|-----------------|----------------|
| Direct energy | 2,423.59 | 22.03 |
| Indirect energy | 8,576.20 | 77.97 |

Amount of GHG emissions of CO₂, N₂O and CH₄ from chemical inputs were calculated and shown in Table 5. Total CO₂ emission was 163.24 kg/ha. Similarly, emission amount of N₂O and CH₄ were 0.03 Kg/ha and 0.33 Kg/ha respectively. Global GWP which resembles the CO₂ equivalent was calculated to be 178.58 kg CO₂eq/ha. Highest share in GWP of chemical input was due to diesel fuel that was 79.48%. Lowest share in GWP was due to Potash (3.67%).

Table 5. Gaseous emissions per ha from chemical sources and their GWP in maize production systems

| Input | CO₂ (kg) | N₂O (kg) | CH₄ (kg) | GWP (kg CO₂eq) | % Share (GWP) |
|-------|----------|----------|----------|----------------|---------------|
| Diesel | 130.03 | 0.03 | 0.19 | 141.94 | 79.48 |
| Nitrogen | 8.75 | 0.00 | 0.10 | 11.16 | 6.24 |
| Phosphate | 18.11 | 0.00 | 0.03 | 18.91 | 10.59 |
| Potash | 6.34 | 0.00 | 0.01 | 6.57 | 3.78 |
| **Total** | **163.23** | **0.03** | **0.33** | **178.58** | **100** |

The average cost of production per hectare was found United States Dollar (USD) 301.35 and the cost of production per kg was USD 0.0974. According to market value and survey conducted among farmers, selling price of maize was found about USD 0.1854 at the time of harvest. Hence, about USD 0.0880 per kg profit is calculated, and in a ha a farmer was made USD 272.26 profit. The respective cost is shown in Table 6.
Table 6. Cost of production for each input.

| SN | Input and Output | Quantity per Hectare | Cost per unit (NPR)* | Total Cost per Hectare (USD)* |
|----|------------------|----------------------|----------------------|------------------------------|
| A  | Input            |                      |                      |                              |
| 1  | Labor (h)        | 279.99               | 50                   | 129.75                       |
| 2  | Machines (h)     | 6.21                 | 1000                 | 57.55                        |
| 3  | Diesel fuel (L)  | 36.52                | 90                   | 30.46                        |
| 4  | Nitrogen-N (kg)  | 27.70                | 25                   | 6.42                         |
| 5  | Phosphorous- P₂O₅ (kg) | 18.11            | 120                  | 20.14                        |
| 6  | Potassium-K (kg) | 9.06                 | 45                   | 3.78                         |
| 7  | FYM (kg)         | 1,449.27             | 1.5                  | 20.15                        |
| 8  | Chemicals (kg)   | 0.15                 | 1000                 | 1.39                         |
| 9  | Electricity (kWh)| 0.00                 | 3.5                  | 0.00                         |
| 10 | Seeds (kg)       | 34.22                | 100                  | 31.71                        |
| B  | Output           |                      |                      |                              |
| 1  | Maize (kg)       | 3,095.34             | 20                   | 573.74                       |

Cost of Production (USD/ha) 301.35
Cost of Production (USD/kg) 0.0974
Selling cost (USD/kg) 0.1854
Profit (USD/kg) 0.0880
Profit (USD/ha) 272.26

*USD 1 = 107.90 Nepalese Rupee (NPR) as 15 June 2018, per Nepal Rastra Bank exchange rate.

4. Conclusions

In this study, energy input-output analysis and economics of maize production were done in Sundarharaincha Municipality, Morang District, Nepal. Following conclusions are drawn from this study:

1. Maize Production System consumed 10,999.61 MJ/ha energy and produced output energy 45,501.52 MJ/ha with the highest share of energy input by FYM (50.07%) and diesel (17.04%). This shows that in Nepal still farmers use FYM as fertilizers in huge amount in maize production systems.
2. Energy use efficiency, energy productivity and net energy were calculated as 4.41, 0.28 kg/MJ and 34,501.91 MJ/ha, respectively. Higher energy efficiency may be due to fertilize farmlands.
3. The share of direct and indirect form of energy were calculated about 22.03% and 77.97%, respectively.
4. Total emission of CO₂, N₂O and CH₄ from maize production system were estimated 163.24 Kg/ha, 0.03 kg/ha and 0.33 kg/ha, respectively. Diesel with 79.48% accounted share in GHG emissions followed by phosphate (10.59%).
5. The total GHG emission was calculated about 178.58 kg CO₂eq /ha
6. The average input cost for production of maize and profit gained per ha were calculated USD 301.35 and USD 272.26, respectively. By cultivation of maize in large scale and use of machineries may increase the profit to the farmers.
7. Through the analysis of result, it is concluded that good management and proper use of energy can reduce the input and maximize the output, ultimately increases the profit to the farmer. Reducing the chemical fertilizers by the use of FYM saves the outflow of money and reduces the GHG emissions.
References

[1] MoF. (2016) Economic Survey 2017/18. Ministry of Finance, Government of Nepal, Kathmandu, Nepal.

[2] MoAD. (2018) Statistical Information on Nepalese Agriculture 2016/17. Ministry of Agriculture Development, Government of Nepal, Kathmandu, Nepal.

[3] Mani I and Patel SK. (2012) Energy consumption pattern in production of paddy crop in haryana state in India. AMA, Agricultural Mechanization in Asia, Africa and Latin America, 43(2), 39–42.

[4] Lorzadeh SH, Mahdavidamghani A, Enayatgholizadeh MR, and Yousefi M. (2012) Reasearch of Energy use efficiency for maize production systems in Izeh, Iran. Acta agriculturae Slovenica, 99(2), DOI: 10.2478/v10014-012-0013-4

[5] Erdal G, Esengiin K, Erdal, and Gündüz O. (2007) Energy use and economical analysis of sugar beet production in Tokat province of Turkey. Energy, 32(1), 35–41.

[6] Hormozi MA, Asoodar MA, Abdeshahi A, and Barauah DC. (2014) Energy use pattern of paddy production systems : Case study for Khuzestan province , Iran. Proc. 6th Int. Conf. Appl. Energy, 787, 0–3.

[7] Ipc. (2007) Climate Change 2007: impacts, adaptation and vulnerability: contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel.

[8] Flessa H, Ruser R, Dörsch P, Kamp T, Jimenez MA, Munch JC, and Beese F. (2002) Integrated evaluation of greenhouse gas emissions (CO2, CH4, N2O) from two farming systems in southern Germany. Agriculture, Ecosystem & Environment, 91, 175–189. DOI:10.1016/S0167-8809(01)00234-1.

[9] CBS. (2017) Local level profile of Morang district 2074. Available at: http://cbs.gov.np/wp-content/uploads/2018/12/Local-Level-Profile-of-Morang-2074-1.pdf

[10] Kafle S, Parajuli R, Euh SH, Oh KC, Choi YS, Adhikari K, Oh JH, and Kim DH. (2016) Potential biomass supply for agro-pellet production from agricultural crop residue in Nepal. Energy Sources, Part A Recovery, utilization and environmental effects, 38. DOI:10.1080/15567036.2014.1043474.

[11] Singh H, Mishra D, Nahar NM, and Ranjan M. (2003) Energy use pattern in production agriculture of a typical village in arid zone India: Part II. Energy Conversion and Management, 44, 1053–1067.

[12] Samavatean N, Rafiee S, Mobli H, and Mohammadi A. (2011) An analysis of energy use and relation between energy inputs and yield, costs and income of garlic production in Iran. Renewable Energy, 36, 1808–1813.

[13] Mohammad Y and Ali M. (2011) Economical analysis and energy use efficiency in alfalfa production systems in Iran. Scientific Research Essays, 6, 2332–2336.

[14] Memon SQS, Mirjat MSM, Mughal AQ, and Amjad N. (2012) Evaluationof inputs and outputs energy for majiye grain yield. Sarhad Journal of Agriculture, 28 (3), 387-393.

[15] Demircan V, Ekinci K, Keener HM, Akbolat D, and Ekinci C. (2005) Energy and economic analysis of sweet cherry production in Turkey: A case study from Isparta province. Energy Conversion and Management, 47, 1761–1769.

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

[17] Rafiee S, Avval SHM, and Mohammadi A. (2010) Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy, 35(8).

[18] Mandal KG, Saha KP, Ghosh PK, Hati KM, and Bandyopadhyay KK. (2002) Bioenergy and economic analysis of soybean-based crop production systems in central India. Biomass and Bioenergy, 23, 337–345.

[19] Yara. (2018). Yara Fertilizer Industry Handbook. Available at: https://www.yara.com/siteassets/investors/057-reports-and-presentations/other/2018/fertilizer
industry-handbook-2018-with-notes.pdf/

[20] Kramer KJ, Moll HC, and Nonhebel S. (1999) Total greenhouse gas emissions related to the Dutch crop production system. Agriculture, Ecosystem & Environment, 72, 9–16. DOI: 10.1016/S0167-8809(98)00158-3.

[21] Snyder CS, Bruulsema TW, Jensen TL, and Fixen PE. (2009) Review of greenhouse gas emissions from crop production systems and fertilizer management effects. Agriculture, Ecosystems & Environment, 133(3-4), 247-266.

[22] Tzilivakis J, Warnera DJ, May M, Lewisa KA, Jaggard K, Warner DJ, May M, Lewis KA, and Jaggard K. (2004) An assessment of the energy inputs and greenhouse gas emissions in sugar beet (Beta vulgaris) production in the UK. Agricultural Systems, 85(2), 101-119.

[23] Lorzadeh SH, Mahdavidamghani A, Enayatgholizadeh MR, and Yousefi M. (2011) Agrochemical Input Application and Energy Use Efficiency of Maize Production Systems in Dezful, Iran. Middle-East Journal of Scientific Research, 9(2), 153-156.

Acknowledgement
This study is supported by Purwanchal Campus, Institute of Engineering, Tribhuvan University, Dharan, Sunsari district, Nepal.