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Energy Efficiency and Economic Analysis of an Irrigated Rice Farming System in Ampara District of Sri Lanka: An Assessment for 2018/19 *Maha* Season

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ABSTRACT

This research presents the outcome of energy use efficiency and economic analysis of irrigated rice farming system in Ampara district, during 2018/19 *Maha* season, which will be useful for the farmers and decision makers. Primary data were collected from 80 farmers covering all the major irrigation schemes of Ampara district by using a structured questionnaire. The data collected on farm input and output volumes, and usage hours were converted to energy values using standard coefficients reported in literature. Economic analysis was done based on the regional cost information collected through the same questionnaire. Labor, machinery, fuel, agrochemicals, seeds and irrigation water were recognized as farm inputs, while rice yield and straw were considered as outputs. Total energy input and total energy output of rice production were 29,689±209.9 MJ/ha and 154,681±3,425.5 MJ/ha, respectively. The highest energy input was accounted by nitrogen fertilizer (44.76%). The system energy efficiency was 5.3±0.13 with a water productivity of 0.8±0.02 kg/m^3. The share of the non-renewable energy (67.29%) is higher than the renewable. The average value of total cost of production per hectare, gross return per hectare, benefit-cost ratio and productivity of rice production calculated to be Rs. 134,540.64, Rs. 212,316.36, 1.58 and 0.04 kg/Rs, respectively. The unit cost of production was Rs. 23.45 /kg. Although economic value of major inputs of materials (33.48%), labour (31.59%) and power (34.95%) equally contribute to the cost of production, the shares of these three major inputs in term of energy were 58.32%, 1.50% and 16.24%, respectively. The energy analysis is a convenient tool to quantify efficiency of different rice farming systems overcoming the issues arise from monetary escalations across time and regional boundaries in economic efficiency analysis.

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INTRODUCTION

Rice is the staple food for more than half the world's population which mainly lives in Asia (FAO, 2014). Rice has long been the staple food for Sri Lankans as well. However, the rice production in industrialized countries is heavily depended on intensive use of external inputs originate from fossil fuels, such as chemical fertilizers (Barker and Herdt, 1985); however, in Sri Lanka, use of external inputs remains comparatively low. Agriculture requires many other forms of energy inputs in addition to solar energy though it is a process of solar energy conversion in to food, feed and fiber through photosynthesis (Stout, 1990).

The primary objective of commercial agriculture is to maximize the profit; as a result, economic analysis is used to evaluate and compare agricultural systems in order to make decisions in selecting and starting up an efficient operation. This primary objective results intensive energy usage in agriculture with increasing human population and limited supply of arable lands. The intensive use of energy in agricultural systems has created many problems in public health and the environment (Rafiee *et al.*, 2010). The natural inputs from the environment to the production, such as land productivity, irrigation water, precipitation, solar energy are not considered in most of the economic analysis. So, the environmental overheads incurred due to degradation and depletion of land, water, and the biological resources remain unknown, hence there is a need of tools that can widely express the efficiency and sustainability of agricultural systems. Most of the inputs used in farming systems such as inorganic fertilizer, agrochemicals, fuel and machineries are not sourced locally but imports that makes paddy farming an external resource dependent farming systems (Gamage, 2002).

Energy Systems Theory (EST), which was first introduced by Odum in 1980s as a system analysis tool bridging the ecology and the economy (Lu *et al.*, 2010). Energy analysis is widely used for improving the energy efficiency and sustainability of agricultural systems (Lu *et al.*, 2010). The energy analysis indirectly provides information on both nonrenewable energy usage and indirect energy usage in crop production process, and it is not biased by the artificial changes in the price of inputs (Jones, 1989). Therefore, energy analysis can provide information on efficiency of farming systems that is useful for farmers and decision makers (Pervanchon *et al.*, 2002). The energy analysis is an appropriate tool to quantify and compare farming systems without influences from monetary escalations across time and regional boundaries.

Number of studies were conducted on energy analysis and economic analysis of rice cultivation throughout the world but there is none reported in Sri Lanka with respect to energy analysis. Energy efficiency can be increased by reducing energy inputs without affecting the crop yield or by increasing the yield (Harchegani *et al.*, 2015). Alluvione *et al.*, (2011) found that balancing N fertilizer with actual crop requirements and adopting minimum tillage techniques are the most effective ways of reducing energy inputs thereby increasing energy efficiency. Rahman *et al.*, (2015) have shown that, fertilizers accounted for 59.98% of total energy input in Bangladesh. By practicing integrated pest management techniques in pest controlling would reduce the usage of pesticides (AghaAlikhani *et al.*, 2013). Analysis of energy consumption for the rice crop in Iran showed that energy use efficiency coefficient was as low as 1.53 (Komleh *et al.*, 2011). Powar *et al.*, (2017) also found a higher energy efficiency value from India as 2.22. Energy productivity and the specific energy of rice production in Iran was 0.09 kg/MJ and 11.09 MJ/kg, respectively (Komleh *et al.*, 2011). Higher net energy value indicates a higher solar radiation assimilation rate. Komleh *et al.*, (2011) found that Net energy value of rice production in Iran as 21,008 MJ/ha but in India it was 61,738.52 MJ/ha (Powar *et al.*, 2017).

Since these indicators are not yet known for Sri Lanka, the objective of this research was to estimate the energy values of inputs used in irrigated rice farming system such as machinery, human labour, irrigation water, chemical fertilizer, pesticides, fuels and seed paddy, the output that is paddy yield and the straw yield as a byproduct, and to conduct an economic analysis of the system.

METHODOLOGY

Study area

The Ampara district of the eastern province is selected for the study, because that is recognized as a high potential area of rice production and mechanization. Ampara district also has the highest extent of irrigated paddy that is 67,933 ha (COC, 2016). The total land area of the District is approximately 4495 km^2. The topography of the district varies from flat to undulating. The elevation ranges from sea level to 500 m. The dominant soil group (approximately 38% of the total extent of land) in the district is the Reddish

Brown Earth (RBE) with other soil groups as soil associations mainly in undulating terrain. The next dominant soil group is alluvial soils; it occupies about 16% of the total land area. Ampara district receives a mean annual rainfall of 1750 mm. Much of this rainfall is received between November and February during the period of the north–east monsoon. Most of the agricultural crops including paddy are cultivated during this season referred as *Maha* season. The mean annual temperature varies from 25 °C to 27 °C.

Data collection and sample selection

This study was carried out by collecting both primary and secondary data. A sample of 80 farm lands were selected from the Ampara district covering all the major irrigation schemes as explained by Cochran (1977). Number of total farm lands were taken as 67,933 assuming one farmer is having minimum of 1 ha.

Data collected from October 2018 to February 2019 (2018/19 *Maha* Season). Primary Data Collection were done by interview method using a structured questionnaire. Quantities of all the inputs used in rice production were in the form of chemical fertilizers (nitrogen, phosphorous, potassium and zinc sulphate), chemical biocides (herbicides, fungicides and insecticides), fuel (diesel and gasoline), manure, water for irrigation, human labor hours and machine hours were collected through the questionnaire. Output quantities were also collected through the same questionnaire which were rice (grain) as a product and rice straw as a byproduct. Questionnaires were filled by the extension officers of the Department of Agriculture by face to face interview with the respondent farmers. Questionnaire pre–testing was done with 10 farmers (Trial Survey) in order to confirm the survey questions operate well and gain information as expected.

Energy budgeting and energy analysis

All inputs and outputs used in rice production were transformed to energy equivalent (MJ/ha) by multiplying the quantity of the material used in the farms by the conversion factors of each material indicated in Table 1. Multiplying the quantity of the inputs used per hectare and quantity of output per hectare with their conversion factors gave the energy equivalents.

The human energy was calculated by multiplying the number of man–hours (h/ha) by estimated conversion factor of human labor (MJ/h) from Table 1. The working day of agricultural worker is considered with an average 8 h work per day (Stout 1990). Total energy embodied in machinery included energy for raw materials, manufacturing, repairs and maintenance, and energy for transportation. By considering the total weight and the economic lifespan of machinery as used in practice, the energy required for each operation was calculated assuming that the all embodied energy of agricultural machinery get depreciated during their economical lifespan (Tabar *et al.*, 2010). The weight of machinery depreciated per hectare of paddy production during the production period was calculated as explained by Mousavi *et al.* (2011).

$$TW=(G \times W_h)/T \qquad \text{Eq -1}$$

Where TW is the depreciated machinery weight (kg/ha); G is the total machine weight (kg); W_h is the time that machine used per unit area (h/ha) and T is the economical lifespan of the machine (h).

The economic life for the machineries used in the study area was adopted from ASABE (2006) as follows: two-wheel drive tractor 12,000 h, self–propelled combine harvester 3,000 h, rotary tiller 1,500 h, threshers 3,000 h. Field capacity of the machines and fuel consumptions were obtained from Farm Mechanization Research Centre (FMRC) test reports (unpublished data). Weights of the machines were taken from operator manuals of the machines as two-wheel drive tractor 1,820 kg, tine tiller 285 kg, rotary tiller 430 kg and self–propelled combine 3620 kg.

Other inputs like fuel, seed, biocide and chemical fertilizers used in rice production were converted to energy value (MJ/ha) by multiplying the quantity of the material used by the farmers by the energy conversion factor of each material. For example fuel (diesel) energy consumption calculated by multiplying the amount of diesel usage (L/ha) by energy coefficient of diesel production (56.31 MJ/L from Table 1.); so the result is the energy consumption of diesel fuel (MJ/ha) in rice production. The energy contribution from irrigation water was estimated by assuming the total crop water requirement was supplied by the irrigation. The irrigation water requirement for LHG soil is taken as 1128 mm (DOA, 2019).

Table 1. Energy conversion factors used in converting inputs and outputs to energy values

Energy source	Conversion factor (Unit)	Reference
Human labour (h)	1.96 (MJ/h)	Gundogmus (2006)
Fertilizer (kg)		
N	60.60 (MJ/kg)	Gundogmus (2006)
P	11.10 (MJ/kg)	Gundogmus (2006)
K	6.70 (MJ/kg)	Gundogmus (2006)
Zinc Sulphate	20.9 (MJ/kg)	Gundogmus (2006)
Pesticide (kg)		
Insecticide	199 (MJ/kg)	Gundogmus (2006)
Fungicides	92 (MJ/kg)	Gundogmus (2006)
Herbicides	238 (MJ/kg)	Gundogmus (2006)
Diesel (L)	56.31 (MJ/L)	Gundogmus (2006)
Gasoline (L)	46.3 (MJ/L)	Gundogmus (2006)
Water (m^3)	0.63 (MJ/m)	Gundogmus (2006)
Machinery (kg)	62.70 (MJ/kg)	Gundogmus (2006)
Self–Propelled Combines (kg)	87.63 (MJ/kg)	Hetz (1992)
Tractors (kg)	93.61 (MJ/kg)	Hetz (1992)
Paddy (kg)	14.57 (MJ/kg)	Iqbal (2007)
Straw (kg)	12.50 (MJ/kg)	Iqbal (2007)

Table 2. Machinery data

Machine	Implement Used	Field Capacity (ha/h)	Fuel Consumption (L/h)
Two wheel drive tractor	Nine tine tiller	0.38	5.60
Two wheel drive tractor	Rotavator	0.40	6.01
Combine harvester		0.30	7.74

The amount of output energy (MJ/ha) estimated by multiplying the rice yield and the straw yield (kg/ha) by rice and straw energy coefficients (MJ/kg). The ratio of rice and straw production was taken as 1:1.

The total energy input is also classified into direct and indirect and renewable and nonrenewable forms of energy. The direct energy (DE) includes human labor, diesel fuel and gasoline, which are used in the production process and indirect energy (IDE) consists of machinery, chemical fertilizer, seed paddy and biocide energy. The renewable energy (RE) consists of human labor and seed, and nonrenewable energy (NRE) include machinery, diesel fuel, gasoline, biocides and chemical fertilizer.

Energy indices

System analysis and performance evaluation was done with the energy indices. The energy ratio (energy use efficiency) (Eq. 2), energy productivity (Eq. 3), specific energy (Eq. 4), net energy (Eq. 5) and water productivity (Eq.6) were calculated as follows (Rafiee *et al.*, 2010):

$$\text{Energy ratio} = \frac{\text{Energy Output (MJ/ha)}}{\text{Energy Input (MJ/ha)}} \quad \text{Eq-2}$$

$$\text{Energy Productivity} = \frac{\text{Paddy output (kg/ha)}}{\text{Energy input (MJ/ha)}} \quad \text{Eq-3}$$

$$\text{Specific Energy} = \frac{\text{Energy Input (MJ/ha)}}{\text{Rice Output(kg/ha)}} \quad \text{Eq-4}$$

$$\text{Net Energy} = \text{Energy output (MJ/ha)} - \text{Energy input (MJ/ha)} \quad \text{Eq-5}$$

$$\text{Water Productivity} = [\text{Grain Yield (kg/ha)}]/[\text{Amount of water used}(m^3/\text{ha})] \quad \text{Eq-6}$$

Economic analysis

The economic analysis was done based on the cost of each input, labor unit, machinery hours and farm gate price of paddy in the region. The cost of fertilizer was taken as Rs. 55.00/kg which is the subsidized price. Only the variable cost components were considered for analysis and farmer own inputs also considered as a cost. The net return (Eq. 7), gross profit (Eq. 8) and benefit to cost ratio (BCR) (Eq. 9) were calculated for wetland irrigated rice production system of the Ampara district as follows.

$$\text{Net Return} = \text{Total Production value (Rs./ha)} - \text{Total Production cost (Rs./ha)} \quad \text{Eq-7}$$

$$\text{Gross Profit} = \text{Total Production Value (Rs./ha)} - \text{Variable Production Cost (Rs./ha)} \quad \text{Eq-8}$$

$$\text{BCR} = \frac{\text{Total Production Value}}{\text{Total Production Cost}} \quad \text{Eq-9}$$

RESULTS AND DISCUSSION

Energy composition

Table. 3 displays the average energy composition of each input for rice production in Ampara District during the *Maha* Season of 2018/19.The total average energy consumption was 29,689.36 MJ/ha which is lower than the reported values by other researchers in the region (Komleh *et al.*, 2011 and Powar *et al.*, 2017). The highest energy use in rice production accounted by urea fertilizer which is 44.76% of total energy consumption. When compared to the region, proportion is much higher value due to high use of urea fertilizer: in Iran total chemical fertilizer accounts for 35.76% (Komleh *et al.*, 2011), in India 19.68% (Powar *et al.*, 2017). Komleh *et al.*, (2011) stated two considerable reasons for the high chemical fertilizer consumption. That is farmer's poor knowledge and subsidies price. He further stated the government subsidies price had significant effect on use of fertilizer. Soil and water pollution would be a result of using chemical fertilizer inefficiently. Energy used in the production of chemical fertilizer accounts for 40% of total energy used in agricultural production in developed countries (Singh *et al.* 1998). The situation in Sri Lanka is also similar, though the average fertilizer usage is little below the recommendation, there is a large variation. As an example, average Urea usage is 219.31 kg/ ha with a maximum value of 329.33 kg/ha. The seed paddy usage also accounted for 7.27% and it is also higher than the recommended seed rate (100 kg/ha). As reported by Department of agriculture, "*Manawari*" cultivation system (dry sawing) has a varying seed rate from 150 kg/ha to 300 kg/ha depending on the level of weed infestation (DOA, 2019). The amount of seed energy use can be reduced by applying recommended seed rate or practicing other crop establishment methods like seedling broadcasting. The required quantity of seed can be reduced by using high quality seeds. Moreover, quality seeds will help to reduce the chances of pest and weed infestation, the energy need in weeding and chemical application while increasing the yield. In this study, insecticide, herbicide and fungicide were collectively utilized with a share of 2.31%. Herbicides had the highest consumption value among biocides (2.04%) and followed by insecticides (0.22%) and fungicides (0.05%). Although, organic manure is the least demanding energy input among the whole specified inputs in rice production, it is very rarely used in rice farming. Human energy has been replaced by machinery energy which is 730.01 MJ/ha (2.46%) and human power is accounted only for 1.5% of total input energy.

Direct energy and indirect energy

DE and IDE were also investigated in this study (Figure 1). The results showed that the share of direct input energy was 15.3% (4,537.12±57.43 MJ/ha) in the total energy input compared to 84.7% (25, 152.24±213.62 MJ/ha) for the IDE. In comparison, in Iran it gives a contradictory result with 49.3 % DE and 50.7% IDE consumption in rice production systems (Komleh *et al.*, 2011) that is mainly due to the high electrical and fossil fuel energy usage for irrigation water pumping operations. Practically, it was seen that, the fuel was used for machineries in various operations in various quantities. Replacing human energy with machineries has increased the fuel usage.

Renewable and non-renewable energy

RE and NRE contributed to 32.7% (9,710.08 MJ/ha) and 67.3% (19,929.28 MJ/ha) of the total energy input, respectively (Figure 2). This result is comparable with Powar *et al.*, (2017); RE and NRE used for the rice cultivation in India is 13,791.2 MJ/ha (27.14%) and 37,027.3 MJ/ha (72.86%) respectively. But in Iran RE and NRE usage in rice cultivation are 4,411 MJ/ha (11%) and 34,922 MJ/ha (89%), respectively (Komleh *et al.*, 2011).

Table 3. Energy composition

Input energy category	Quantity (Unit)	Total energy equivalent MJ/ha	Energy % of the total
Total Machinery		730.01±16.69	2.46
Total Human	226.69 (h/ha)	444.30±5.36	1.50
Urea	219.31 (kg/ha)	13,289.89±218.24	44.76
MOP	53.28 (kg/ha)	591.43±7.83	1.99
TSP	55.32 (kg/ha)	370.64±4.95	1.25
Zink Sulphate	0.99 (kg/ha)	20.65±4.65	0.07
Manure	782.53 (kg/ha)	199.55±40.97	0.67
Herbicide	2.54 (L/ha)	605.15±33.69	2.04
Fungicide	0.15 (L/ha)	13.38±3.68	0.05
Insecticide	0.33 (L/ha)	65.76±8.15	0.22
Diesel	71.18 (L/ha)	4,008.36±60.91	13.50
Petrol	1.82 (L/ha)	84.46±18.83	0.28
Seed Paddy	148.21 (kg/ha)	2,159.37±54.46	7.27
Water	11,280.00 (m^3/ha)	7,106.40±0.00	23.94
Total		29,689.36±209.85	100.00

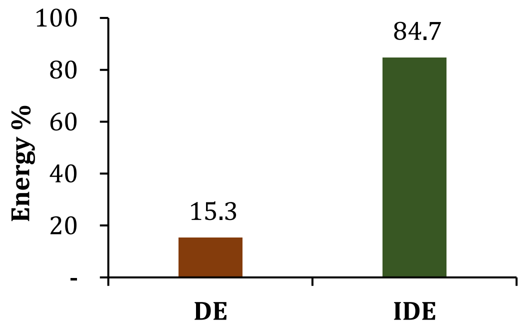

Figure 1: Energy composition as direct energy (DE) and indirect energy (IDE)

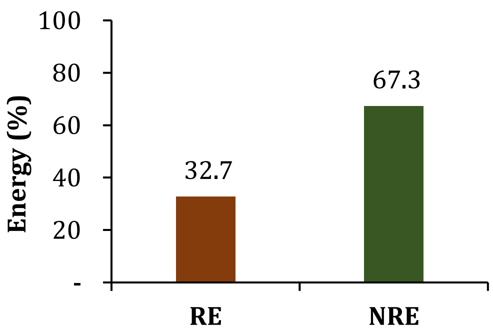

Figure 2: Energy composition as renewable energy (RE) and nonrenewable energy (NRE)

The higher figure of NRE represent the fuel and electricity usage in water pumping. It is clear that the proportion of IDE and NRE use in surveyed rice fields were very high. The results of this research clearly showed that the rice production is mainly dependent on IDE and NRE in the study area.

Energy output and the energy indices

Table 4. Shows the energy indices and energy output of the rice farming system. Total energy output of the system is 154,680.98±3,425.46 MJ/ha and out of that 83,245.60±1,843.70 MJ is from the main product of paddy and remaining 71,426.39±1,581.76 MJ is from the byproduct of straw. The energy output from the main product is relatively high compared to the results of the other researches. That is mainly due to higher average yield of paddy in Ampara district (5,738.28±126.54 kg/ha).

Energy ratio or energy efficiency is one of the best energy index that shows the efficient use of energy in rice production. The results indicated that the average energy ratio of 5.25 with respect to total output and 2.80 with respect to main product of rice. Which is a very good value when compared with the values in the region. The reported values in Iran (Komleh e. al., 2011), India (Powar *et al.*, 2017) and Bangaladesh (Alam *et al.*, 2005) are 1.53, 2.22 was and 1.87, respectively. This is mainly due to the higher paddy yield compared to the other countries and lower external energy input in Sri Lanka. Energy productivity, specific energy and net energy of rice production are 0.19±0.00 kg/MJ, 5.41±0.13 MJ/kg and 124,991.62±3,485.58 MJ/ha, respectively. Better management practices with less energy input and producing more energy output are the two main reasons of reaching higher indices. Water productivity also calculated as 0.8±0.02 kg/m^3 which is a higher figure in the region. In India it is 0.4 (Powar *et al.*, 2017), in Iran it is 0.16 (Komleh *et al.*, 2011) where they use high amount of water (18,487.4 m^3/ha). The water productivity can be further improved by using efficient water management strategies like alternate wetting and drying (AWD) method

The Economic analysis of irrigated rice production

Cost components can be divided into three categories as machinery (34.93%), labour (31.59%), and input (33.48%). Unit cost is Rs. 23.45/kg and in 2017/18 "*Maha*" it was Rs. 22.11/kg including imputed costs (COC, 2018). The BCR which can be used to compare the profitability of rice production with other countries is 1.58 which is a much higher value compared to Iran (1.3) (Komleh *et al.*, 2011) and much lower than Pakistan (2.7) (Khan *et al.*, 2009).

Table 4. Energy output and energy indices

Item	Units	Average value
Output		
Paddy output	MJ/ha	83,254.60±1,843.7
Straw Output	MJ/ha	71,426.39±1,581.76
Total Output	MJ/ha	154,680.98±3,425.46
Energy Indices		
Net Energy	MJ/ha	124,991.62±3,485.58
Specific Energy	MJ/kg	5.41±0.13
Energy Productivity	Kg/MJ	0.19±0.00
Water Productivity	Kg/m^3	0.80±0.02
Energy Ratio		5.25±0.13

Table 5. Economic analysis of rice production

Economic indicators (units)	Average values
Average paddy yield (kg/ha)	5,738.28±126.54
Average farm gate price of Paddy (Rs.)	37.00±0.58
Gross income (Rs./ ha)	212,316.36±4,696.75
Gross profit (Rs./ ha)	77,775.72±4,920.25
Unit cost (Rs./kg)	23.45±0.56
Benefit cost ratio (BCR)	1.58±0.04
Productivity (kg/Rs.)	0.04±0.00

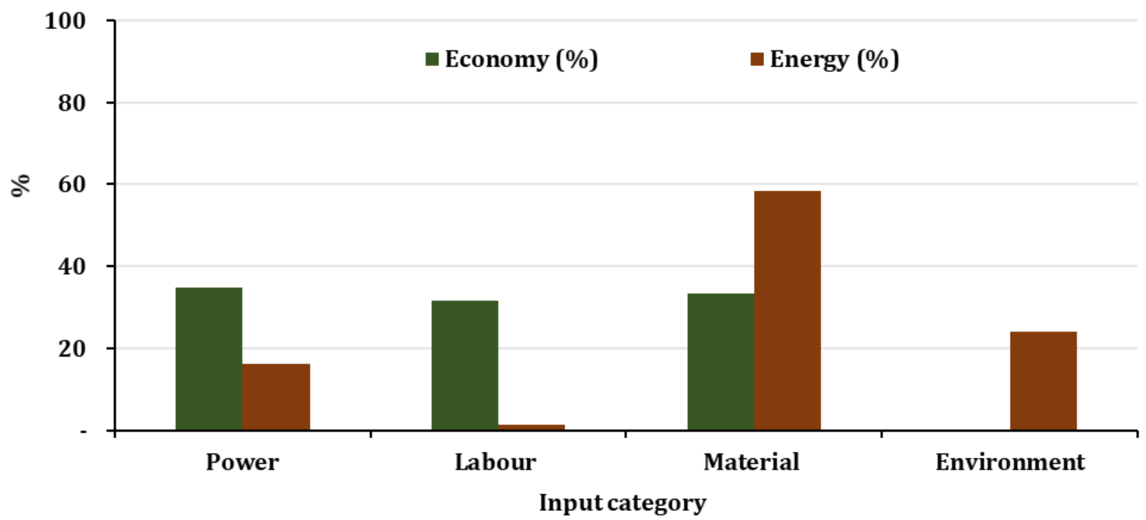

Figure 3. Composition of energy and economic input categories

The most important motivating factor to remain farmers in the agricultural system is to make profits. Hence economic analysis is used to evaluate the system which gives clear and meaningful indication about the economic survival of the system and farmer retention. Energy analysis is widely used for improving energy efficiency and the sustainability of the system. Also it gives an idea in fossil fuel conservation and financial saving. The environmental contribution to the economic production like irrigation water are not included in the economic analysis (Figure 3). Figure 3. shows the contribution of the environment as 23.94 % (energy) on rice production which is not considered in economic analysis. Though the economic analysis gives almost equal contribution from material (33.48%), labour (31.59%) and power (34.95%), energy analysis give huge variation as 58.32 %, 1.50 % and 16.24 % respectively. Which is a clear indication of masking the real contribution due to the financial and political system of the region.

CONCLUSION

Energy efficiency of the irrigated rice production system of the Ampara district was five. Nitrogen fertilizer (Urea) is the biggest energy consumer (44.76% of total energy usage). Human energy is discovered as one of the least demanding energy input (1.5%). The irrigated rice production system in Ampara district of Sri Lanka is heavily dependent on the nonrenewable energy sources which is a clear indication of the system dependency on external input supplies. Energy management should be considered as an important field in terms of efficient, sustainable and economical use of energy in future studies and for policy making. It is essential to use modern technologies in input usage and new efficient machineries for operations to decrease high energy usage in rice production. Educating farmers on the lesser input usage and its effect on the environment and the cost of production is a vital factor of sustainability in rice farming in the future.

In perspective, the energy efficiency analysis is found to be a good indicator to quantify the productivity of rice farming systems across a wider range of ecological and political boundaries as the energy analysis is not influenced by cost escalations.

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REFERENCES

AghaAlikhani, M., Kazemi, P.H. and Habibzadeh, F. (2013). Energy use pattern in rice production: A case study from Mazandaran province, Iran. Energy Conversion and Management, 69, 157-162.

Alam, M.S., Alam, M.R. and Islam, K.K. (2005). Energy flow in agriculture: Bangladesh. American Journal of Environmental Sciences, 1(3), 213-220.

Alluvione, F., Moretti, B., Sacco, D. and Grignani, C. (2011). EUE (energy use efficiency) of cropping systems for a sustainable agriculture. Energy, 36(7), 4468-4481.

ASABE (2006). American Society of Agricultural and Biological Engineers, 2950 Niles Road, St. Joseph, USA.

Barker, R. and Herdt, R.W. (1985). The Rice Economy of Asia; Resources for the Future. The Johns Hopkins University Press, Washington.

COC 2016, Cost of cultivation of Agricultural Crops, Socio Economic and Planning Centre, Department of Agriculture, Peradeniya.

COC 2018, Cost of cultivation of Agricultural Crops, Socio Economic and Planning Centre, Department of Agriculture, Peradeniya.

Cochran, W.G. (1977), Sampling Techniques, Third Edition, New York: John Wiley & Sons.

DOA (2019). Rice Research and Development Institute: (Accessed on 28.04. 2019). https://www.doa.gov.lk/rrdi/index.php?option=com_sppagebuilder&view=page&id=42&lang=en.

FAO (2014). FAO Statistical Year book, Asia and the Pacific. Food and Agriculture; FAO Regional

Office for Asia and the Pacific, Bangkok, Thailand.

Gamage, D. (2002). some issues related to sustainability of Farming Systems in the central highland region of Sri Lanka. Hector Kobbakaduwa Agrarian Research and training Institute, Colombo, Sri Lanka.

Gundogmus, E. (2006). Energy use on organic farming: a comparative analysis on organic versus conventional apricot production on small holdings in Turkey. Energy Conversation Management, 47, 3351-3359.

Harchegani, T.M., Ebrahimi, R. and Mahmoodi, E.M.M. (2015). Almond production in Iran: An analysis of energy use efficiency (2008-2011). Renewable and Sustainable Energy Reviews, 41, 217-224

Hetz, E.J. (1992). Energy utilization in Chilean agriculture. Agriculture Mechanization in Asia, Africa and Latin America, 23(2), 52–56.

Iqbal, T. (2007). Energy input and output for production of Boro rice in Bangladesh. Electronic Journal of Environmental, Agricultural and Food Chemistry, 7, 2717-2722.

Khan, M.A., Awan, I.U. and Zafar, J. (2009). Energy requirement and economic analysis of rice production in western part of Pakistan. Soil and Environment, 28 (1), 60-67.

Komleh, S.H.P., Safeepari, P. and Rafee, S. (2011). Energy and economic analysis of rice production under different farm levels in Guilan Province of Iran. Energy, 36, 5824-5831.

Lu, H., Bai, Y.U., Ren, H. and Campbell, D. E. (2010). Integrated emergy, energy and economic evaluation of rice and vegetable production systems in alluvial paddy fields: Implications for agricultural policy in China. Journal of Environmental Management, 91, 2727-2735.

Mousavi, A.S.H., Rafee, S., Jafari, A. and Mohammadi, A. (2011). Energy flow modeling and sensitivity analysis of inputs for canola production in Iran. Journal of Cleaner Production, 19, 1464-1470.

Pervanchon, F., Bockstaller, C. and Girardin, P. (2002). Assessment of energy use in arable farming systems by means of an agro-–ecological indicator: the energy indicator. Agricultural Systems, 72(2), 149-172.

Powar, R.V., Shahare, P.U., Aware, V.V. and Deogirikar, A.A. (2017). Energy audit of paddy cultivation practices in Kokan region of Maharashtra. International Journal of Agricultural Engineering, 10(2), 647-654.

Rafiee, S., Avval, S.H.M. and Mohammadi, A. (2010). Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy, 35(8), 3301-3308.

Rahman, M., Halder, M., Hassan, N. and Haque, F. (2015). Energy input-–output analysis of rice cultivation in the coastal region of Bangladesh. Songklanakarin Journal of Science and Technology, 37 (4), 455-464.

Singh, S., Singh. S., Mittal, J.P. and Pannu, C.J.S. (1998). Frontier energy use for the cultivation of wheat crop in Punjab. Energy Conversion and Management, 39(5/6), 485-491.

Stout, B.A. (1990). Handbook of Energy for World agriculture. Elsevier Applied Science, London.

Tabar, B.I., Keyhani, A., and Rafee, S. (2010). Energy Balance in Iran’s agronomy (1990-2006). Renewable and Sustainable Energy Reviews, 14, 849-855.