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Energetics of Rice Cultivation in South-West Coastal Region of Bangladesh

M. Rahman[1] and M. Halder[2]
Environmental Science Discipline, Life Science School, Khulna University, Khulna-9208, Bangladesh
[1] Corresponding author; *E-mail: gkm.buet@gmail.com*; [2] *E-mail: mithun.es07@gmail.com*

ABSTRACT

This study attempts to analyse the energy flow in *boro* rice production in the south-west coastal region of Bangladesh during the dry season (November 2010 to May 2011). Structured questionnaire survey was made of target farmers of five farm sizes in randomly selected five coastal villages to collect step-wise and source-wise quantitative energy inputs and outputs. The energy from seed bed, land operation and maintenance, and harvesting and threshing were calculated as step-wise energy input, whereas energy from human labour, machinery, seed, irrigation, and fertilizer and pesticide applications were calculated as source-wise energy input. The output energy was estimated based on the main product (rice grains) and by-product (straw) of rice cultivation. Energy input, energy output and energy efficiency of rice cultivation were calculated in average of five coastal villages for each of the farm sizes. The results reveal that the average total energy input was estimated to be 44,520 MJ ha^{-1}, which varied from 29,283 MJ ha^{-1} on medium farmers to 72,339 MJ ha^{-1} on landless farmers. The total energy use in all steps decreases with an increase in size of farm holdings, except large farm. Seedbed stage consumes the highest energy following land operation and maintenance, and harvesting and threshing. Fertilizers accounted for a major share (63.3%) of energy input followed by seed, irrigation, machinery power, pesticides and manpower. In average farm situation, the total energy output produced from the field was 80,690 MJ ha^{-1}, which varied from 51,641 MJ ha^{-1} on large farm to 142,593 MJ ha^{-1} on landless farm. In the same situation, main product (rice grain) and by-product contribute respective 79.2% and 20.8% in the total output energy. Total energy output also decreased with the increase in farm size. The energy efficiency (output/input) from rice cultivation ranged from 1.5 on large farm to 2.0 on landless farm with an average of 1.8. The output-input ratio of energy was estimated to be in the sequence of landless > marginal > medium > small > large farm. Therefore, lower sized farms are more energy efficient than those of larger sized farms in rice production in the south-west coastal region of Bangladesh.

Key Words: Boro Rice, Structured Questionnaire Survey, Farmers, Energy Input, Energy Output, Energy Efficiency.

INTRODUCTION

Bangladesh is principally an agrarian and a riverine country. Its overall economic performance depends on agriculture and it contributes to 21.11% of the Gross Domestic Product (GDP), of which crop sector contri-utes to 72% (MoF 2007). Agriculture sector generates 51.69 % of the total employment. In addition, this sector employs about 90% of rural males as well as 80% of rural females of the country (WB 1998). The total land area of Bangladesh is 14.39 million hectares (Mha) of which 8.42 Mha are now under cultivation. Land, water and energy are usually the key resources for sustainable agricultural production. However, land and water productivity have been badly affected, which slowed down the race of socio-economic development particu-arly in the coastal region of Bangladesh. PDO-ICZM (2004) stated that the contribution of rice produced in the coastal areas to the total food grain production in the country has been declining due to decreased in acreage over the years, lowered in cropping intensity, decreased in soil fertility, increased in water and soil salinity, etc.

The relation between agriculture and energy is very close. The agriculture sector represents both consumers and producers of various forms of energy. Energy analyses in agriculture include computation of the energy content in inputs that go into crop production and comparison of the same with the energy content in the output. Agricultural productivity cannot hope to increase unless adequate energy inputs are available in a timely manner and applied judiciously. For the growth and development, energy inputs in crop agriculture can be divided into commercial (fuel, irrigation water, chemical fertilizer, machinery and pesticides) and non-commercial (solar radiation and wind) energy (Khan and Hossain 2007, Alam et al. 2005). Energy input pattern for crop production depends on economic, technological and social constraints. Energy input and output in Bangladesh agriculture were increased from 6.4 to 17.32 and 72.22 to 130.05 GJ ha^{-1} respectively, for a period from 1980-81 to 2000-01(Alam et al. 2005). However, energy efficiency declined from 11.28% to 8.1%, which indicates that the energy input increased faster than energy output. For tillage operation, use of power tiller increased significantly in Bangladesh. Use of fertilizer and pesticides increased from 0.87 to 3.3 and from 0.002 to 0.01 million MT, respectively, for the same period (GoB 2000).

Rice production incurs much higher inputs of commercial energy in Bangladesh including the coastal regions, mainly due to its high water and fertilizer requirements coupled with other practices like transplanting, harvesting and threshing (Khan and Hossain 2007). However, there has been rising concern over intensive agriculture through chemical fertilizers, as it may not be sustainable and might damage the environment or other productive sectors, such as fisheries (through water pollution) etc. (Ramachandra and Nagarathna 2001). Decisive conclusions here are possibly only after detailed analysis of energetics (energy flow and transformation) in rice production system at different farm sizes in the south-west coastal Bangladesh. In view of this, an investigation was undertaken to determine the energy flow and transformation in *boro* rice (BRRIdhan-29) cultivation for different classes of farmers in the study area.

MATERIALS AND METHODS

The study was conducted in the south-west of the coastal region that covers about 32% of the total area of Bangladesh and over 30% of the net cultivable area. The total population of the region amounts to 35.08 million living in 6.85 million households, and accounts for 28% of the total population of the country (BBS 2003). Coastal livelihood is more dominated by agrarian economy compared to rest of the country (BBS 2002). The economy is largely dependent on crop agriculture especially on rice that contributes to about 16% of the total rice production of the country. In coastal districts, *aman* is the dominant crop, covering about 70% of the total rice cropped area, *aus* covers 16% and *boro* 14% (PDO-ICZM 2004). The region has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, moderately warm temperatures, and high humidity. Several soil types occur in the coastal stretches, which are saline and non-calcareous, except for some soils of the Old Ganges and Meghna floodplain areas (PDO-ICZM 2004).

The coastal saline area lies about 1.5 to 11.8 m above the mean sea level. Out of total coastal and offshore land (2.85 million hectares), about 53% has been affected by varying degrees of salinity. About 1, 18, 37, 28 and 16% of this affected lands falls under S_1 (2.0-4.0 dS m^{-1}), S_2 (4.1-8.0 dS m^{-1}), S_3 (8.1-12.0 dS m^{-1}), S_4 (12.1-16.0 dS m^{-1}) and S_5 (>16.0 dS m^{-1}) soil salinity classes, respectively (Haque 2006, SRDI 2012). The coastal saline soils are distributed unevenly in 64 upazilas of 13 districts, covering portions of 8 agro-ecological zones (AEZ) of the country. The larger portion of saline land falls in the south-central and south-west coastal districts, whereas the smaller portion lies in the south-east coastal districts of Bangladesh. In general, the coastal regions of Bangladesh are quite low in soil fertility (PDO-ICZM 2004, Haque 2006). Thus, in addition to salinity, plant nutrients in soils affect plant growth.

Data Collection and Analysis

Both primary and secondary data were collected for achieving the aforesaid objective. For primary data collection, five villages were randomly selected from two districts of the south-western part of the coastal region of Bangladesh. The villages are: Krishnanagor of Charbaniari union under Chitalmari upazila of Bagerhat district, whereas Pankhali, Laxmikhola, Khatail of Chalna union and Gorkhali village of Tiladanga union under Dacope upazila of Khulna district. This selection was based on some homogenous features such as agro-ecological zone, soil types, climate and cropping patterns (SRDI, 2012). The farmers of landless (≤ 0. 20 hectare (ha)), marginal (0.21 - 0.60 ha), small (0.61 - 1.00 ha), medium (1.10 - 2.00 ha) and large (≥ 2.00 ha) farm sizes were then stratified from each village (Iqbal, 2007). The stratum was formed for a better estimate of the stratum mean of five villages (Bala, 1998). Total 125 farmers, five from each farm size of each village, were randomly selected finally based on the dedication to rice cultivation. The target farmers were then surveyed by using the structured questionnaire to collect step-wise and source-wise quantitative energy inputs and outputs in rice cultivation. Energy input, energy output, net return of energy and energy efficiency of rice cultivation were calculated in average of five coastal villages for each of the farm sizes.

Table 1. Energy co-efficients of various inputs and outputs (fom Bala 1998, Alam et al. 2005 and Khan and Hossain 2007)

Energy source		Energy co-efficient
Human labour		0.2014 MJ hr^{-1}
One pair of cow		1.0742 MJ hr^{-1}
Fertilizer:	Nitrogen (N)	60.10 MJ kg^{-1}
	Phosphorous (P)	10.35 MJ kg^{-1}
	Potassium (K)	11.10 MJ kg^{-1}
Pesticide		120 MJ kg^{-1}
Diesel		50.32 MJ kg^{-1}
petrol		50.00 MJ kg^{-1}
Paddy	Seed	14.57 MJ kg^{-1}
	Straw	12.50 MJ kg^{-1}

Total energy input and output for each of the farm holdings were estimated by using the respective energy co-efficient (Table 1) as suggested by many studies (Khan and Hossain 2007, Alam et al. 2005, Bala 1998). The energy from seed bed, land operation and maintenance, and harvesting and threshing were calculated as step-wise energy input, whereas energy from human labour, machinery, seed, irrigation, and fertilizer and pesticide applications were calculated as source-wise energy input. The energy input from conventional sources was ignored as this energy was coming from natural sources. The output energy was estimated based on the main product (rice grains) and by-product (straw) of rice cultivation. The net return of energy was calculated by subtracting input energy from output energy. The energetic efficiency (energy output to input ratio) was estimated by dividing the total energy generated from main product and by-product by the total energy used for raising the rice crop for each of the farm holdings. The energy input and output were computed as MegaJoule per hectare (MJ ha^{-1}) by the following formula (Khan and Hossain 2007, Halder and Rahman 2013):

Energy input (E_i) =

$$E_{hl} + E_{mp} + E_s + E_f + E_p + E_{irr} \qquad \text{(i)}$$

where,

E_{hl} = Energy from human labour; E_{mp} = Energy from machinery power; E_s = Energy from seed; E_f = Energy from fertilizer; E_p = Energy from pesticide; and E_{irr} = Energy from irrigation.

$$\text{Energy output } (E_o) = E_{mp} + E_{bp} \qquad \text{(ii)}$$

where,

E_{mp} = energy from main product and E_{bp} = energy from by-product

RESULTS AND DISSCUSSION

Energy Input in Rice Production

The step-wise energy use in rice cultivation among different size group of farms in the south-west coastal region of Bangladesh is shown in Table 2. The average total energy input in all steps of rice cultivation among all farms was estimated to be 44,520 MJ ha^{-1}, which varied from 29,283 MJ ha^{-1} on medium farmers to 72,339 MJ ha^{-1} on landless farmers. The landless farmer uses the highest amount of energy following marginal, small, large and medium for rice cultivation. It is seen that the total energy use in all steps decreases with an increase in size of farm holdings, except large. The most energy consuming phase of rice production system is land operation and maintenance in case of landless and marginal farmers, whereas the remaining classes of farmers use the highest energy in seedbed stage. However, average data shows that seedbed stage consumes the highest energy following land operation and maintenance, and harvesting and threshing. This might be due to the high amount of seed broadcasted in the seedbed. Seed accounted for a significant share of energy input in case of small, medium and large farm holdings (Table 3). In general, farmers of the coastal belt broadcasts seed repeatedly in the seed bed as the germination rate of seed is lower and mortality rate of seedlings is higher in saline environment. It was reported that seedling stage of rice is more sensitive to salinity (Zeng and Shannon 2000, Zeng et al. 2001). Moreover, farmers might have applied more fertilizer per unit area in the seed bed stage of rice cultivation. In the seedbed stage, the farmers falling under the medium farm size utilized the highest amount of energy followed by large, small, marginal and landless farmers, which likely to be the variation in seed application. The highest energy applied in land operation and maintenance was estimated for landless farmers following marginal, small, large and medium farmers. This might be attributed to the variation in fertilizer application to the farm (Table 3). In harvesting and threshing phase, both medium and large farmers used the same as well as the highest amount of energy whereas the lowest amount energy was estimated for landless farmers. Energy input from the manpower for harvesting and threshing might be responsible for the earlier statement.

The source-wise energy input in rice field among different farm sizes is given in Table 3. In average farm situation, fertilizers accounted for a major share (63.3%) of energy input followed by the seed (24.9%), irrigation (6.0%), machinery power (3.3%), pesticides (1.8%) and manpower (0.7%). Nitrogen fertilizer is observed to be the most dominant source (58.1%) of energy input from fertilizers followed by poshphare (3.6%) and potassium (1.6%). It is seen that fertilizer use decreases with an increase in farm size in case of nitrogen and phosphorus, except large farm. However, potassium input sequence among the cultivators of different farm sizes is small > marginal > landless > large > medium. Larger farms apply less fertilizer than smaller farms, though they have better purchasing power. Energy intensive agriculture is practiced by lower sized farms as they try to produce more crops for their subsistence need. However, over and indiscriminate usage of fertilizer results in significant reduction in crop yield over a period of time and increases the pollution problems (Ramachandra and Nagarathna 2001). Table 3 shows medium farm size with

Table 2. Energy use (MJ ha^{-1})* in rice cultivation, by step and size of farms

Step of rice cultivation	Farm sizes					
	Landless	Marginal	Small	Medium	Large	All farms
Seed bed	25,261 (34.9)	21,321 (47.3)	21,797 (51.5)	24,515 (83.7)	27,737 (82.7)	24,126 (54.2)
Land operation and maintenance in field	46,927 (64.9)	23,452 (52.0)	20,153 (47.6)	4,463 (15.3)	5,485 (16.3)	20,096 (45.1)
Harvesting and threshing	151 (0.2)	310 (0.7)	387 (0.9)	305 (1.0)	340 (1.0)	298 (0.7)
All steps	72,339 (100.0)	45,083 (100.0)	42,337 (100.0)	29,283 (100.0)	33,562 (100.0)	44,520 (100.0)

* Figures in parentheses indicate the percentage of total energy inputs.

Table 3. Energy use (MJ ha^{-1}) in rice cultivation, by source and size of farms

Source	Farm sizes					
	Landless	Marginal	Small	Medium	Large	All farms
Seed	1,369 (1.9)	7,640 (17.0)	12,204 (28.8)	18,927 (64.6)	15,229 (45.4)	11,074 (24.9)
Manpower	562 (0.8)	290 (0.6)	250 (0.6)	230 (0.8)	295 (0.9)	324 (0.7)
Irrigation	2,503 (3.5)	6,290 (14.0)	4,497 (10.6)	15 (0.1)	0 (0)	2,661 (6.0)
Machinery power	1,478 (2.0)	1,126 (2.5)	1,429 (3.4)	2,134 (7.3)	1,215 (3.6)	1,477 (3.3)
Fertilizer						
N	60,548 (83.7)	25,785 (57.2)	20,916 (49.4)	6,750 (23.1)	15,318 (45.6)	25,864 (58.1)
P	4,139 (5.7)	1,672 (3.7)	1,354 (3.2)	361 (1.2)	576 (1.7)	1,620 (3.6)
K	1,080 (1.5)	733 (1.6)	933 (2.2)	385 (1.3)	456 (1.4)	717 (1.6)
Pesticides	660 (0.9)	1,547 (3.4)	754 (1.8)	481 (1.6)	473 (1.4)	783 (1.8)
All sources	72,339 (100.0)	45,083 (100.0)	42,337 (100.0)	29,283 (100.0)	33,562 (100.0)	44,520 (100.0)

*Figures in parentheses indicate the percentage of total energy inputs.

Table 4. Net return of energy (MJ ha^{-1}) and energy efficiency, by item and farm sizes

Item	Farm sizes					
	Landless	Marginal	Small	Medium	Large	All farms
Energy output from main product)	116,044 (81.4)	67,199 (79.3)	56,304 (78.7)	42,013 (79.3)	38,156 (73.9)	63,943 (79.2)
Energy output from by-product	26,549 (18.6)	17,516 (20.7)	15,245 (21.3)	10,941 (20.7)	13,485 (26.1)	16,747 (20.8)
Total energy output produced	142,593 (100.0)	84,715 (100.0)	71,549 (100.0)	52,954 (100.0)	51,641 (100.0)	80,690 (100.0)
Total energy input use)	72,339	45,083	42,337	29,283	33,562	44,520
Net energy return (output - input)	70,254	39,632	29,212	23,671	18,079	36,170
Energy efficiency (output/input energy)	2.0	1.9	1.7	1.8	1.5	1.8

* Figures in parentheses indicate the percentage of total energy outputs.

maximum energy input from seed of 18,927 MJ ha^{-1} (64.6%) followed by large (45.4%), small (28.8%), marginal (17.0%) and landless (1.9%). The large variation in energy sourced from seeds across farms was attributed to larger quantities of seed used to compensate for losses caused by birds, salinity, etc. The energy contribution from manpower was estimated to be the highest in large farm size. The same amount of energy from labor force (0.8 MJ ha^{-1}) was estimated for both landless and medium farm sizes. Marginal and small farm sizes also use the same labor force (0.6 MJ ha^{-1}) for rice cultivation, which is the lowest contribution of energy from the said source across the farms. In case of irrigation, the highest energy input was estimated for marginal farm followed by small, landless and medium farms. Irrigation was not performed by the farmers of large farm sizes as their field is usually watered and dewatered during flood and ebb tides. The use of mechanical power for rice cultivation in the coastal region of Bangladesh increases with the increase in farm size, except large (Table 3). This might be due to the variations in social acceptability of mechanized agriculture as well as in capacity to afford cost incurred on mechanization. It is found that marginal farm size apply the maximum energy for plant protection chemicals (pesticides) following small, medium, large and landless farms.

Energy Output and Efficiency of Rice Cultivation

In average farm situation, total energy output produced from the field was 80,690 MJ ha^{-1}, which varied from 51,641 MJ ha^{-1} on large farm to 1,42,593 MJ ha^{-1} on landless farm (Table 4). In case of main product, total energy output was estimated to be 63,943 MJ ha^{-1}, which varied from 38,156 MJ ha^{-1} on large farm to 1,16,044 MJ ha^{-1} on landless farm. Total energy output from by-product was 16,747 MJ ha^{-1}, which ranged from 10,941 MJ ha^{-1} on medium farmer to 26,549 MJ ha^{-1} on landless farmer. It is observed that total energy output produced and energy output from main product decrease with increase in farm size. Output energy from by-product also decreases with increase in farm size but upto medium farm as output energy in large farm is found to be higher than medium one. The highest value of energy output was estimated in landless farm, which might be attributed to the maximum input of energy in rice farm (Table 3) as well as the increased productivity of water and soil in the study area. In addition, landless farmer applied the highest amount of nitrogen and phosphate fertilizers. Alam et al. (2005) claimed that total agricultural output will be increased if the increase of input energy continues. The lowest energy output was found in large farm, which could be due to the absence of irrigation (Table 3), or the decrease in soil and water productivity.

In the same function, net return (output - input) of energy from the rice field was 36,170 MJ ha^{-1}, which varied from 18,079 on large farm to 70,254 MJ ha^{-1} on landless farm (Table 4). It is observed that net return of energy decrease with increase in farm size in the study area. The highest and lowest energy returns from the rice farm was calculated in landless and large farms, respectively, which might be cause of the significant variation in energy input and energy output. The energy efficiency (output/input) from rice cultivation was also estimated and it ranged from 1.5 on large farm to 2.0 on landless farm with an average of 1.8. The output-input ratio of energy was estimated to be in the sequence of landless > marginal > medium > small > large farm. Therefore, lower sized farms are more energy efficient than those of larger sized farms in rice production in the south-west coastal region of Bangladesh.

CONCLUSION

The step-wise and source-wise energy inputs in rice cultivation were found to be variables with different farm sizes in the south-west coastal region of Bangladesh. Land operation and maintenance phase consume the highest energy in case of landless and marginal farms, whereas the remaining classes of farmers use the highest energy in seedbed stage. However, in average farm situation, seedbed stage consumes the highest energy following land operation and maintenance, and harvesting and threshing. In source-wise, fertilizers accounted for a major share (63.3%) of energy input followed by seed, irrigation, machinery power, pesticides and manpower. Nitrogen fertilizer is observed to be the most dominant source (58.1%) of energy input from fertilizers followed by phosphate and potassium. The landless farmers use the highest amount of total energy followed by marginal, small, large and medium for rice cultivation. Total energy output produced from the field decreases with increase in farm size. Similarly, main product (rice grain) and by-product contribute respective 79.2% and 20.8% in the total output energy. The average output-input ratio of energy was found to be 1.8, which varied from 1.5 on large farm to 2.0 on landless farm. The output-input ratio of energy was estimated to be in the sequence of landless > marginal > medium > small > large farm. Therefore, lower sized farms are more energy efficient than those of larger sized farms in rice production.

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