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Energy Audit for Rice Production under Power Tiller and Bullock Farming Systems in Bangladesh

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Abstract: The energy expenditure under power tiller and bullock farming systems was studied to explore the energy requirement at different stage of rice production and to find out the activity contributed major share of energy. Energy was divided into direct energy and indirect energy. Direct energy included labour, animal and fuel consumption obtained by multiplying energy coefficient. The indirect energy included machinery use, seed, fertilizer, pesticides etc. The direct and indirect energy constituted the total energy requirement expenditure for both farming systems. Intercultural operation was the highest consumer of labour both farming systems as this operation was done manually. In land preparation, power tiller farming system consumed 3 times more energy than bullock farming system but there was a saving of 58% time thus requiring less labour during peak periods. Transplanting operation required energy of 143 MJ ha^{-1} and 125 MJ ha^{-1} respectively for power tiller and bullock farming system. Fertilizer and irrigation consumed largest (47-50%) and second largest (21-25%) energy in both the farming systems. Bullock farming system consumed more labour energy (1448 MJ ha^{-1}) than that of the power tiller farming system (1305 MJ ha^{-1}). Total energy requirement under power tiller farming system was 15,751 MJ ha^{-1} whereas 13,781 MJ ha^{-1} was consumed under bullock farming system i.e. 17.74% higher energy input was used in power tiller farming system than that of bullock farming system. The grain yield under power tiller and bullock farming systems were 4.87 t ha^{-1} and 4.12 t ha^{-1} respectively. The energy ratio of 9.39 and 9.26 were achieved under power tiller and bullock farming systems respectively.

Key words: Rice production, power tiller, bullock farming, energy audit

Introduction

Rice accounts for 95% of the food grain production and 90% of the population depends on rice for their daily diet. In the year 2002, the total food grain requirement of the country will be 25 million metric tons. (Das *et al.*, 1999). The energy input is one of the key factors for successful crop production. Energy input pattern for crop production depends on economic, technological and social constraints. Three prime movers are currently being used on rice farm in developing countries: human, animal and mechanical. Commercial and non-commercial energy are available in agricultural operation. Commercial energy inputs arrive on farm in many different forms e.g. diesel, irrigation water, chemical fertilizer, machinery, pesticides and herbicides. Non-commercial energy is available as solar radiation and wind (Kiamco and McMennany, 1979). For many developing countries, full supply of commercial energy inputs on farm is not possible due to many inherent factors but a slight increase in the energy in flow often results in a significant response in food production (Sarker *et al.*, 1981). Draught animal power is the main source of power for land preparation. Draught animals power decreases very rapidly from the year 1971 to 2000 and the number in 2000 is just one-third of 1971 (Hussain, 2000). The level of farm power utilization usually varies with farm size, crops grown, production practice and physical environment (Sarker, 2000). Annual crop production has a positive correlation with annual energy use per hectare and both direct and indirect components of annual energy use affected the crop production in same manner (Singh and Singh, 1991). Increase in productivity is mainly realized through commercial energy sources i.e. chemical fertilizer, diesel, and electricity (Bohra and Maheshwari, 1981). The cost of production (in terms of yield) can be minimized through judicial use of energy in different stage of crop production. The project deals with the energetics of rice production taking into account the cropping inputs like seed, fertilizer, chemicals and various farm operations carried out under power tiller and bullock operated equipment. The project was laid out to audit energy requirement under power tiller and bullock farming systems, to study the energy expenditure at different stages of rice production and to find out the activity contributes major share of energy in rice production.

Materials and Methods

The experiment was conducted at the farm of Bangladesh Rice Research Institute, Gazipur. Crops were raised in 1 ha of land during T.Aman season of 1999. Both experiments were conducted simultaneously to study the effect of practices on

Table 1: Energy coefficient for various inputs and machinery used

Equipment/input	Energy Co-efficient	
	MJ Kg^{-1}	MJ ha^{-}
Human energy	-	1.96
Bullock pair energy	-	14.05
Seed	14.7	-
Straw	14.58	
Fertilizer		
N	60.1	-
P	11.1	-
K	11.1	-
Agro-chemical	12.0	-
Diesel (including lubricants)	56.31 per litre	-
Power tiller	68.4	2.74
Rotavator	62.7	2.35
Thresher	62.7	10.03
Sickle	62.7	0.05
Diesel engine	64.8	1.03

Source: Mittal and Dhawan (1988)

Table 2: Energy input for cultivation of rice under power tiller farming system

Operation/input	Direct Energy						Total direct energy (MJ ha^{-1})	Indirect energy				Other indirect energy (MJ ha^{-1})	Total indirect energy (MJ ha^{-1})	Total energy (MJ ha^{-1})
	Labour		Animal		Diesel			Power tiller		Machinery				
	Man h ha^{-1}	EE* MJ ha^{-1}	h ha^{-1}	EE* MJ ha^{-1}	l ha^{-1}	EE* MJ ha^{-1}		h ha^{-1}	EE* MJ ha^{-1}	h ha^{-1}	EE* MJ ha^{-1}			
Seed bed preparation	41.42	81.18	-	-	-	-	81.18	-	-	27.34	1.37	-	1.37	83
Land preparation	24.70	48.42	7.55	76.23	33.90	1909	2033.65	17.15	47	17.15	40.31	-	87.32	2121
Transplanting	73.19	143.46	-	-	-	-	143.46	-	-	-	-	735	735	878
Irrigation	45.17	88.54	-	-	57.64	3245.67	3334.21	-	-	45.17	46.98	-	46.98	3381
Fertilizer	9.12	17.87	-	-	-	-	17.87	-	-	-	-	7434	7434	7452
Interculture	305.01	597.82	-	-	-	-	597.82	-	-	-	-	-	-	598
Harvesting, handling and transportation	149.31	292.65	-	-	1.2	67.57	360.22	-	-	149.3	99.76	-	99.76	460
Threshing	18.30	35.86	-	-	9.92	558.33	594.19	-	-	18.30	183.53	-	183.53	778
Total	666	1305	8	76	103	5781	7163	17	47	257	372	8169	8588	15751

*EE Energy equivalent ** This energy is for seed, fertilizer and agro-chemical

Table 3: Energy input for cultivation of rice under bullock farming system

Operation/input	Direct Energy						Total direct energy (MJ ha^{-1})	Indirect energy		Other indirect energy (MJ ha^{-1})	Total indirect energy (MJ ha^{-1})	Total energy (MJ ha^{-1})
	Labour		Animal		Diesel			Machinery				
	Man h ha^{-1}	EE* MJ ha^{-1}	h ha^{-1}	EE* MJ ha^{-1}	l ha^{-1}	EE* MJ ha^{-1}		h ha^{-1}	EE* MJ ha^{-1}			
eed bed preparation	41.42	81.18	-	-	-	-	81.18	27.34	1.37	-	1.37	83
Land preparation	57.84	113.36	57.84	584.14	-	-	697.50	57.84	38.17	-	38.17	736
Transplanting	63.85	125.14	-	-	-	-	125.14	-	-	735.00	735.00	860
Irrigation	45.17	88.54	-	-	57.64	3245.67	3334.21	45.17	46.98	-	46.98	3381
Fertilizer	10.99	21.53	-	-	-	-	21.53	-	-	6831.87	6831.87	6853
Interculture	270.52	530.22	-	-	-	-	530.22	-	-	-	-	530
Harvesting, handling and transportation	230.10	451.00	-	-	1.2	67.57	518.57	230.10	95.15	-	95.15	614
Threshing	18.66	36.60	-	-	8.89	500.60	537.20	18.66	187.13	-	187.13	724
Total	739	1448	58	584	68	3814	5846	379	369	7567	7936	13781

*EE Energy equivalent ** This energy is for seed, fertilizer and agro-chemical

Table 4: Energy budget for rice production Farming system

Farming system	Energy input (MJ ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Energy output (MJ ha^{-1})	Energy ratio
Power tiller	15751	4.87	5.23	147842	9.39
Bullock	13781	4.12	4.6	127632	9.26

yield. Rice variety BRRI dhan 31 was established in both farming systems. Implements used in power tiller farming system were rotavator, traditional ladder, sickle, power thresher, tractor & trolley. Country plow, traditional ladder, sickle, power thresher, tractor and trolley were used in bullock farming system. During the experiment the time spent for human, animal and power tiller with fuel, lubricant and machinery used per unit time were also recorded. The operation for puddling, irrigation and application of insecticides were kept uniform for both the systems. Seeds, fertilizer and agrochemical were used as per recommended agronomic practices. For the calculation of energy input, the observed time and fuel consumption was multiplied by energy coefficient. This energy was put down under direct energy. The indirect energy included machinery use, seed, fertilizer and pesticides etc. The direct and indirect energy (Mega Jule) constituted the total requirement of energy input for both farming systems. For auditing rice energy equivalence of various energy inputs including machinery use and outputs as suggested by Mittal and Dhawan (1988) were used (Table 1). The energy input from non-commercial sources was ignored because this energy was coming from natural source. The energy output/input ratio was worked out by dividing the total energy generated from the main product and by product by the total energy used for raising crop in the unit area.

Results and Discussion

Energy input at different stages of rice production such as seedbed preparation (ploughing, laddering), transplanting, irrigation, fertilizer, intercultural operation, harvesting, carrying and threshing under power tiller and bullock farming systems were presented in Table 2 and Table 3. Operation wise analysis showed that in land preparation almost 3 times more energy was consumed under power tiller farming system than that of bullock farming system. Although more energy was consumed under power tiller farming system but there was a savings of 58% time in land preparation. This implies that land preparation in power tiller farming system was faster than bullock farming system and would be able to command a larger area under the resource constraints. The draft power available from animals for tillage requiring longer time. During peak period farmers can hire power tiller for land preparation. Bala (1980) reported that peak time labour requirement makes the farmers justify the introduction of tractor and power tiller for selective mechanization.

Intercultural operation included weeding, spraying, put tap in cross wise and around the field for birds' scare. Intercultural operation was the highest consumer of labour i.e. 305 h ha^{-1} equivalent to 598 MJ ha^{-1} and 270 h ha^{-1} equivalent to 530 MJ ha^{-1} respectively for power tiller and bullock farming system. Introduction of mechanical weeder and sprayer can increase labour utilization efficiency. Transplanting of HYV Aman was major farm operation and includes seedling uprooted, cleaning, carrying and transplanting seedling in row wise. The total labour energy requirement was 143 MJ ha^{-1} and 125 MJ ha^{-1} respectively for power tiller and bullock farming system. The contribution of fertilizer energy was 47% and 50% of the total energy for power tiller and bullock farming systems respectively. Fertilizer contributed the largest energy input in both the systems. The contribution of irrigation energy was 21% and 25% of the total energy expenditure respectively for power tiller and bullock farming systems. Irrigation consumed the second largest energy input for both the systems. The results were in conformity with the findings of Singh *et al.*, 1987, Bala, 1992 and Sarker, 2000. The application of organic fertilizer or apply fertilizer as an USG form or liquid form may increase fertilizer efficiency. Irrigation was essential for high yielding varieties and water stress significantly affects the yield. Irrigation was done by the diesel engine. So the energy requirement was seemed to be higher. Electric motor of same horsepower can increase the command area which in turn reduce the irrigation energy. Efficient pumping and water uses are the most important energy conservation concerns for irrigation. Bullock farming system consumed more labour energy (1448 MJ ha^{-1}) than that of the power tiller farming system (1305 MJ ha^{-1}). This implies that more labour is needed under bullock farming system. In the peak season shortage of labour influence the delayed in land preparation as well as transplanting which in turn reduce the yield. In Power tiller farming system, diesel fuel requirement in land preparation, carrying and threshing operation was 103 l/ha whereas in bullock farming system fuel requirement in carrying and threshing operation was 68 l/ha. From these findings policy makers can predict how much diesel fuel is to be imported in a year if the whole cultivable land are gone under power tiller farming system.

The available direct and indirect energy were 7163 MJ ha^{-1} (45%) and 8588 MJ ha^{-1} (55%) respectively for Power tiller farming system whereas 5846 MJ ha^{-1} (42%) and 7936 MJ ha^{-1} (58%) respectively for bullock farming system. Total energy requirement under power tiller farming system was 15,751 MJ ha^{-1} whereas 13,781 MJ ha^{-1} was consumed under bullock farming system i.e. 17.74% higher energy input was used in power tiller farming system than that of bullock farming system. Higher energy input in power tiller system was due to the use of high quality energy source i.e. diesel. This is in line with the concept that the energy input for production in agriculture increases with the level of mechanization (Bohra *et al.*, 1990).

Total energy expenditure for different farming operation and total energy output from grain yield and straw yield for both farming systems are mentioned in Table 4. The grain yield under power tiller and bullock farming systems were 4.62 t ha^{-1} and 4.12 t ha^{-1} respectively. The higher yield in power tiller farming system might be due to timeliness of critical operation that can be effected by mechanization. The energy ratio of 9.15 and 9.26 were achieved under power tiller and bullock farming systems respectively. Though there was higher energy input under the power tiller system; but there was a little difference in the output-input energy ratio mainly due to increased yield under power tiller farming system. Sarker *et al.* (1981) supported that higher yield of paddy mainly contributes for the increased energy output in mechanized cultivation.

Based on the above findings, the following conclusions were made that intercultural operation was the highest consumer of labour i.e. 305 h ha^{-1} or 598 MJ ha^{-1} and 270 h ha^{-1} or 530 MJ ha^{-1} respectively for power tiller and bullock farming system. In land preparation almost 3 times more energy was consumed under power tiller farming system than that of bullock farming system but 58% time was saved in land preparation. The total labour energy requirement for transplanting operation was 143 MJ ha^{-1} and 125 MJ ha^{-1} respectively for power tiller and bullock farming system. Fertilizer contributed the largest energy input i.e. 47% and 50% of the total energy for power tiller and bullock farming systems respectively. Irrigation consumed the second largest energy i.e. 21% and 25% of the total energy expenditure respectively for power tiller and bullock farming systems. Bullock farming system consumed more labour energy (1448 MJ ha^{-1}) than that of the power tiller farming system (1305 MJ ha^{-1}). Peak time labour requirement initiated the farmer for mechanized cultivation. Fuel requirement was 103 l/ha and 68 l/ha for power tiller and bullock farming system respectively. Direct and indirect energy consumed 45% and 55% respectively of the total energy expenditure in power tiller farming system whereas in bullock farming system consumed 42% and 58% respectively of the total energy expenditure. Total energy requirement under power tiller farming system was 15,751 MJ ha^{-1} whereas 13,781 MJ ha^{-1} was consumed under bullock farming system i.e. 17.74% higher energy input was used in power tiller farming system than that of bullock farming system. The grain yield under power tiller and bullock farming systems were 4.87 t ha^{-1} and 4.12 t ha^{-1} respectively. Higher yield from mechanized cultivation will generate enough capital for small farmers to supply them with increased energy inputs through power tiller and tractor. The energy ratio of 9.38 and 9.26 were achieved under power tiller and bullock farming systems respectively. The more will be the energy output/input ratio the more will be the benefit to farmers from a particular crop.

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