Indian J. Dryland Agric. Res. & Dev. 2015 30(2) : 84-92 DOI 10.5958/2231-6701.2015.00030.5

Different Levels of Energy Use and Corresponding Output Energy in Paddy Cultivation in North Bank Plain Zone of Assam, India

Prasanta Neog, P.C. Dihingia[1], P.K. Sarma, G.R. Maruthi Sankar[2], D. Sarmah, M.K. Sarmah, R. Rajbongshi, K. Sarmah, G.R. Chary[2], Ch. Srinivasa Rao[2] and P.K. Mishra[3]

All India Coordinated Research Project for Dryland Agriculture, BN College of Agriculture, Assam Agricultural University, Biswanath Chariali-784 176, Assam

[1]Farm Machinery Training and Testing Institute for North Eastern Region, Biswnath Chariali-784 176, Assam

[2]Central Research Institute for Dryland Agriculture, Hyderabad-500 059, Telengana

[3] Central Soil and Water Conservation Research and Training Institute, Dehradun- 248 195, Uttarakhand

Email: neogprasanta@rediffmail.com

ABSTRACT: Six levels of energy input were used to cultivate three *Sali paddy* varieties of different durations. Operation-wise as well as source-wise energy output, energy efficiency and energy productivity for different levels of energy input in paddy varieties were determined. Studies showed that with increase in the level of mechanization, the human and animal hour requirement for paddy cultivation was reduced from 795 to 350 and 352.5 to 22.5 hr/ha, respectively. Thus mechanization helped in a substantial reduction of drudgery of human and animals. Total energy requirement for paddy cultivation in the studied six levels of energy input ranged from 5630 to 8448 MJ/ha. Energy used in paddy cultivation could be reduced by 8 to 23% through increasing the level of mechanization. Under these six input energy levels and varieties, output parameters *viz.,* output energy, energy use efficiency and energy productivity ranged from 35456 to 85922 MJ/ha, 5.94 to 13.09 and 0.4 to 0.89 kg/MJ, respectively. For all the levels of energy input, higher values of output energy parameters were observed in the long duration variety *Ranjit* compared to other two varieties. The benefit-cost (B:C) ratio under different levels of energy input varied from 0.95 to 2.90.

Key words: *Sali* paddy, level of energy input, energy efficiency, energy productivity, benefit-cost ratio

Efficient use of the energy is important for increasing production, productivity and competitiveness of agriculture in general, and *rainfed* agriculture in particular (Srinivasarao *et al*., 2013). Agricultural productivity varies and is dependent on factors like improved seed, fertilizer, chemicals, irrigation and mechanization including management practices (Kalbande and More, 2008). Direct sources of energy like human and animal is required to perform various tasks related to crop production processes *viz.*, land preparation, irrigation, inter-culture, threshing, harvesting and transportation of agricultural inputs and farm produce (Singh, 2000). Indirect sources of energy in the form of fertilizer, seed, diesel, etc. are also utilized for crop production. The productivity of any crop would depend not only on the amount of input energy, but also on the efficiency with which they are utilized. Greater the value of the input energy, more is the natural capability of the system that can be achieved, but less would be the system become sustainable (Alipour *et al.,* 2012).

Agricultural productivity goes hand in hand with mechanization of different agricultural operations, which aims at achieving timeliness of operations, efficient use of inputs *viz.,* seed, fertilizer and chemicals, *etc.*, improvement in quality of produce, safety and comfort of farmers, reduction in the cost of produce and drudgery of farmers (Gulati and Singh, 2011). Mechanization would increase land and labour productivity and reduce drudgery of human and animals. In the changing climatic environment, frequency of destructive weather aberrations (like heat waves, heavy rainfall events, drought, flood, *etc.*) affects the agriculture sector more vulnerable. In such situations, timely completion of farm operations is very important which could be accomplished through the use of improved implements and machines. Thus, mechanization is the key for building climate resilient agriculture in the country (Srinivasarao *et al*., 2013)

The requirement of energy input would vary with cropping pattern, farm activities and level of technology used in agriculture. Various research workers have studied the energy use pattern and energy productivity in different crops for different locations. The energy used in cultivation of greengram, pigeonpea, sunflower and sorghum in dryland areas in Karnataka varied from 1397 to 2797 MJ/ha (Guruswami *et al.*, 2001). From the field study, De and Babu (2004) found that paddy crop cultivation under irrigated farms consumed about 57 to 201% more input energy than the rainfed farms. They also reported that in irrigated, medium yielding irrigated and rainfed areas, highest energy productivity was obtained in (i) tractor farms (0.196 kg/MJ), (ii) animal + power tiller farms (0.306 kg/MJ) and (iii) animal + tractor farms (0.371 kg/MJ), respectively. The energy requirement of paddy cultivation in irrigated farms of Karnataka ranged from 13258 to 15593 MJ/ha and 20.58% of total energy utilized for all operations was consumed in ploughing (Prasanna kumar and Hugar, 2011). The energy consumption in the cultivation of *Sali* paddy in Golaghat district of Assam was assessed by Saikia *et al.,* 2007. The study revealed that the amount of input energy required for cultivation of *Sali* paddy in the farms of small and marginal farmers ranged from 5797 to 8933 MJ/ha. The study also confirmed that the preparatory tillage consumed maximum energy (68.01%) followed by threshing and cleaning operations (12.81%), harvesting (6.78%), transplanting (5.56%), seed bed preparation (4.74%), uprooting (1.46%), fertilization and manuring (0.29%), sowing (0.23%) and plant protection operation (0.10%).

Sali paddy is the major agricultural crop of Assam, occupying 66.63% of the total area of the state (Islam, 2012). Low yield is the characteristic feature of *Sali* paddy in the state due to occurrence of natural calamities, poor crop management and lack of mechanization. The energy input utilized in the paddy farms of the village was considerably lower than what is really necessary for production process of the crop. Low yield of *Sali* paddy was associated with low energy inputs (5681 MJ/ha) in bullock operated farms without use of chemical fertilizers. However, the potential yield of paddy (6000 kg/ha) could be achieved through increasing energy inputs (11,168 MJ/ha) comprising of human, animal, diesel and fertilizers as the major energy sources. By using chemical fertilizers, the average paddy yield in Assam could be increased from the existing 1976 kg/ha to 3165 kg/ha. The human and animal are the major energy sources under the existing practices contributing more than 70% of the total energy-input in paddy cultivation in Assam. The introduction of improved farm implements and machinery could reduce the demand of human and animal energy and increase productivity for animal-operated paddy farms in Assam (Baruah *et al*., 2004).

Understanding the energy use pattern in *Sali* paddy grown in Assam is very important. It is also necessary to study the impact of modernization and mechanization in terms of energy management on productivity and profitability of cultivation of *Sali* paddy. Keeping in view of these aspects, the present study was conducted to assess the operation-wise and source-wise energy inputs and their cost in *Sali* paddy cultivation. An attempt was also made to assess the energy use efficiency, energy productivity and economic analysis of *Sali* paddy cultivation in North Bank Plain Zone of Assam.

Materials and Methods

An assessment of energy requirement and energy output of *Sali* paddy was conducted during 2011 to 2013 in a selected village 'Chamua' situated at the North Bank Plain Zone of Assam. The village was adopted under 'National Initiative on Climate Resilient Agriculture (NICRA) administered by Assam Agricultural University, Biswanath Chariali under the All India Coordinated Research Project for Dryland Agriculture of ICAR for demonstration of climate resilient technologies on the use of improved farm implements and machinery for carrying out different agricultural operations. Paddy is the major crop of the village, and occupies 90% of the total cultivated area in the village. Most of the farmers of the village are small and marginal with size of land holding less than equal to 2.0 ha. Before start of the NICRA project, bullock and human were the main source of farm power for different agricultural operations. The farmers never used chemical fertilizers in paddy cultivation in the village. Women of the village were also engaged in carrying out various farm operations like uprooting of seedlings (40% of total human days), transplanting (100% of total human days) and harvesting (60% of total human days). The participant farmers of the village were supplied with various inputs like seed, fertilizer, farm implements, machinery, pesticides, *etc.* A custom hiring centre (CHC) was established in the village to provide improved farm implements and machinery to the farmers (Table 1).

Table 1 : Farm implements and machinery available at the custom hiring centre of Chamua village

1. Cultivator and harrow	11. MB plough
2. Water lifting pump	12. Ridger seeder
3. Self propelled Reaper	13. Sprayer
4. Thresher	14. Cultivator
5. Paddy weeder/wheel hoe	15. Disk plough
6. Dryland weeder	16. Power tiller
7. Rotavator	17.Paddy transplanter
8. Seed-cum-fertilizer drill (manual)	18. Manual fertilizer broadcaster
9. Power operated duster	19. Multi-crop seed drill
10. Maize Sheller	

Most of the implements and machinery supplied to the farmers were proved to be useful. The tractor drawn rotavator and cultivator were widely accepted for preparatory tillage which was earlier carried out by the bullock drawn traditional implements. Farmers generally use harvested rainwater in the natural farm ponds (during pre-monsoon months) in puddling operation for nursery-bed preparation. The traditional tools *viz. Leheti* and *Lahani* were used for lifting water for nursery-bed preparation. However, with the establishment of CHC in the village, much of traditional tools were replaced by the water lifting pumps (WLP). The thresher, which is operated by diesel engine (supplied under CHC) was also proved to be useful and was widely adopted by the farmers. The self propelled reaper was successful in harvesting short stature duration paddy varieties, but was not successful in case of medium and long duration tall paddy varieties. Farmers earlier never irrigated the *Sali* paddy. However, after implementation of the project, some of the farmers adopted scientific irrigation practice particularly during the occurrence of dry spells. Based on the adoption of various technologies like chemical fertilizer and improved implements and machinery by the farmers, the following levels of energy input were identified in the study.

Table 2 : Levels of input energy used for cultivation of Sali paddy in NICRA village Chamua

Levels of energy input	Name of the energy input level	Description
T_1	Farmers' practice	Not used fertilizer, improved implements and machinery
T_2	Use of fertilizer	Used fertilizer, but improved implements and machinery were not used
T_3	Use of fertilizer + Cultivator + Rotavator + water lifting pump (WLP)	Used fertilizer, cultivator (1time) and rotavator (2 times) for tillage operation and used water lifting pump for nursery-bed preparation
T_4	Use of fertilizer + Cultivator + Rotavator + WLP + Thresher	Used fertilizer, cultivator (1time) and rotavator (2 times) for tillage operation, used water lifting pump for nursery-bed preparation and thresher
T_5	Use of fertilizer + Cultivator + Rotavator + WLP + Thresher + Reaper	Used fertilizer, cultivator (1 time) and rotavator (2 times) for tillage, WLP for nursery-bed preparation, thresher and reaper
T_6	Use of fertilizer + Cultivator + Rotavator + WLP + Thresher + Reaper + Irrigation	Used fertilizers, cultivator (1 time) and rotavator (2 times) for tillage, WLP for nursery-bed preparation, thresher, reaper and irrigation

A total of 60 farmers of the village have participated in the NICRA study. Three improved winter paddy varieties of different crops duration *viz., Ranjit* (155 days), *Bashundhara* (140 days) and *Luit* (100 days) were studied. Each variety was cultivated with different level of energy input. One farmer was selected for one or more varieties cultivated with one or more levels of energy input. The study was conducted with three replications for each level of energy input and in three varieties. Data such as energy input in the form of seed, fertilizer, irrigation, human, animal, farm machinery and output in the form of grain yield were collected. Operation-wise energy use for different field operations in terms of human, animal and machine (hr/ha) were calculated following the procedures suggested by Pannu *et al.,* (1993). The physical data (inputs and outputs) were then converted to MJ/ha by multiplying the appropriate energy equivalent coefficients as reported by Mittal and Dhawan (1998). The energy use efficiency (energy ratio), energy productivity (Khan and Singh, 1996; Alipour *et al.*, 2012) and benefit-cost ratio analysis for different energy input levels in the cultivation of paddy varieties were determined.

Results and Discussion

Use of human, animal and mechanical energy in Sali paddy cultivation

The energy contributed (hr/ha) by human labour, draft animals and mechanical power (tractor, diesel engine and self-propelled reaper) to perform different farm operations were estimated for different levels of energy input used in the cultivation of *Sali* paddy. The operation- wise energy contributed by human, animal and machinery were also calculated in terms of MJ/ha. The analysis of data (Table 3) revealed that human hour requirement for cultivation of *Sali* paddy was maximum (795 hr/ha) in farms, where chemical fertilizers were applied without use of mechanical power (T_2). The human hours requirement in paddy cultivation was lesser in traditional farmers' practice (772.5 hr/ha). The human labour requirement decreased considerably when tractor drawn improved implements and other machinery were used for different farm operations like tillage, nursery-bed preparation, threshing, harvesting and other operations. The human labour requirement was minimum of 350 hr/ha in farms where the improved implements/machinery was used for tillage, nursery-bed preparation, threshing and harvesting along with the use of fertilizer (T_5). With an increase in the level of mechanization (T_3 to T_6), the human labour requirement was reduced by 26 to 56% as compared to the paddy farms using fertilizer, but did not use mechanical power for any farm operation (T_2). In case where mechanical energy was not used (T_1 and T_2), the human hours requirement was 60, 142.5, 180 and 210 hr/ha for nursery-bed preparation, harvesting, threshing and tillage, respectively. On the other hand, when cultivator, rotavator, WLP, reaper, thresher were used, the human hour requirement was reduced by 28, 114, 123 and 180 hr/ha for nursery-bed preparation, harvesting, threshing and tillage operation, respectively.

The draft animal hour requirement was maximum of 352.5 hr/ha in case of the use of traditional implements with or without fertilizer application (T_1 and T_2). Similar to human category, the number of animal hours required for different farm operations could be substituted by increasing the level of energy input by increasing the number of improved implements and machines.

Thus, increasing the use of machine hours resulted in a decrease of both human labour and draft animal hours to a

Table 3 : Operation-wise energy requirement (hr/ ha) in cultivation of Sali paddy under different levels of energy input

Farm operations	Farmers' practice			Use of fertilizer			Use of fertilizer + cultivator + rotavator + water lifting pump		Use of fertilizer + cultivator + rotavator + water lifting pump + thresher			Use of fertilizer + cultivator + rotavator + water lifting pump + thresher + reaper			Use of fertilizer + cultivator + rotavator + water lifting pump + thresher + reaper + irrigation		
	Man hr	Animal hr	Machine hr	Man hr	Animal hr	Machine hr	Man hr	Animal hr	Man hr	Animal hr	Machine hr	Man hr	Animal hr	Machine hr	Man hr	Animal hr	Machine hr
Tillage	210 (412)*	210 (2121)		210 (412)	210 (2121)		30 (59)		30 (59)		30 (1733)	30 (59)		30 (1733)	30 (59)		30 (1733)
Bund making and side cutting	75 (147)	-	-	75 (147)	-	-	75 (147)	-	75 (147)			75 (147)			75 (147)		
Nursery bed preparation and sowing	60 (118)	22.5 (227)	-	60 (118)	22.5 (227)	-	32 (63)	22.5 (227)	32 (63)	22.5 (227)	2 (114)	32 (63)	22.5 (227)	2 (114)	32 (63)	22.5 (227)	2 (114)
Uprooting of seedling	22.5 (42)		-	22.5 (42)		-	22.5 (42)		22.5 (42)		-	22.5 (42)		-	22.5 (42)		-
Transporting and distribution of seedlings	7.5 (15)	-	-	7.5 (15)	-	-	7.5 (15)	-	7.5 (15)	-	-	7.5 (15)	-	-	7.5 (15)	-	-
Irrigation (one)	-	-	-	-	-	-	-	-							16 (31)		15 (854)
Fertilizers application	-	-	-	22.5 (44)			22.5 (44)		22.5 (44)			22.5 (44)			22.5 (44)		
Transplanting	75 (147)	-	-	75 (147)	-	-	75 (147)	-	75 (147)	-	-	75 (147)	-	-	75 (147)	-	-
Harvesting	142.5 (248)	-	-	142.5 (248)	-	-	142.5 (248)	-	142.5 (248)	-	-	28.5 (56)		6 (264)	28.5 (56)	-	6 (264)
Threshing, cleaning and storage	180 (353)	120 (1212)	-	180 (353)	120 (1212)	-	180 (353)	120 (1212)	57 (112)		6 (286)	57 (112)		6 (286)	57 (141)		6 (286)
Total	772.5 (1482)	352.5 (3560)	-	795 (1526)	352.5 (3560)		587 (1118)	142.5 (1449)	464 (777)	22.5 (227)	38 (2133)	350 (685)	22.5 (227)	44 (2397)	366 (716)	22.5 (227)	59 (3251)

*Figures in parentheses represent the operation-wise energy requirement (MJ/ha) great extent in the *Sali* paddy cultivation (Figure 1). In other words, increasing the level of mechanization in *Sali* paddy cultivation is essential for increasing the labour productivity as well as reducing the drudgery of human and animals. The use of improved implements and machines might also help in reducing the migration of labour from agriculture which is a big problem in Assam.

Energy consumption in Sali paddy cultivation

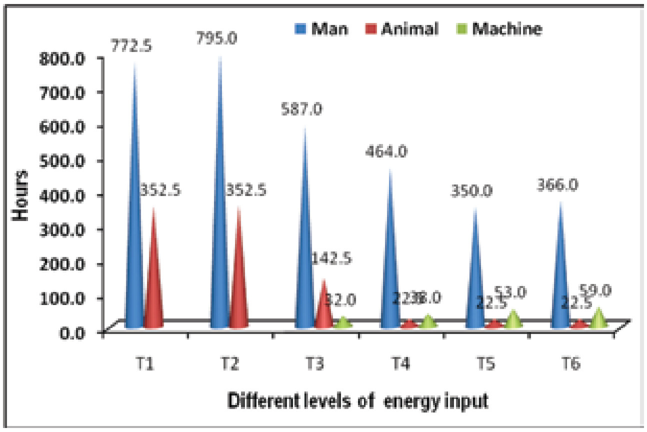

Fig. 1 : Human, animal and machine hours required for different farm operations in cultivation of Sali paddy under different levels of energy input

The total energy used in different agricultural operations in paddy cultivation ranged from 5630 to 8448 MJ/ha under different cases as described in Table 4. The farms following the farmers' practice (T_1) were found to have the lowest total energy input of 5630 MJ/ha. With the addition of fertilizer component total input energy used increased to 8448 MJ/ha. This result is in agreement with earlier report that the lower energy-input (5681 MJ/ha) was the characteristic feature of farms not using the fertilizer in contrast to higher energy input (9290 MJ/ha) of fertilizer-used paddy farms in Assam (Barua *et al*., 2004).

The total energy consumption in paddy cultivation was reduced by 8 to 23% in cases T_3 to T_6 as compared to the farms using chemical fertilizers, but not using improved implements (T_2). The total human and animal energy requirements for different farm operations were between 1482 - 1526 MJ/ha and 3560 MJ/ha, respectively in the farms where only traditional implements (T_1 and T_2) were used. However, the requirement of human and animal energy was reduced up to 685 MJ/ha (T_5) with an increase in the level of energy input in terms of addition of chemical (diesel and kerosene) and mechanical (improved implements and machines) energy.

Data analysed as shown in Table 2, revealed that in case of farmers' practice of cultivating *Sali* paddy, the energy consumption in different agricultural operations is in the decreasing order of magnitude from tillage (2533 MJ/ha), threshing (1565 MJ/ha), nursery-bed preparation (345 MJ/ha), harvesting (248 MJ/ha), transplanting and bund making (147 MJ/ha) and seedling uprooting, transport and distribution (57 MJ/ha). Earlier, Saikia *et al.,* (2007) reported that nursery-bed preparation required less energy compared to harvesting and transplanting. This could be with rain dependent paddy cultivation and might not be with irrigation condition. Both human and animal energy requirement for different agricultural operations was reduced to a significant extent by increasing the levels mechanization. The human energy input for tillage, nursery-bed preparation, threshing and harvesting were decreased by 86, 47, 77 and 89%, if tractor drawn cultivator and rotavator, WLP, reaper and thresher were used in the place of traditional practice, respectively. Similarly, the animal energy for different farm operations could be totally replaced for tillage operation and reduced in the seed-bed preparation, harvesting and threshing due to increasing levels of mechanization. Irrigation is one of the high energy-consuming farm operations. One irrigation alone consumed 885 MJ/ha of energy. Generally, Sali paddy

Table 4 : Source-wise energy consumption in Sali rice cultivation under different levels of energy input

Source of energy	T_1 (MJ/ha)	T_2 (MJ/ha)	T_3 (MJ/ha)	T_4 (MJ/ha)	T_5 (MJ/ha)	T_6 (MJ/ha)
Direct Sources						
Human	1482	1526	1118	777	685	716
Animal	3560	3560	1449	227	227	227
Diesel	-	-	1591	1873	1873	2721
Kerosene	-	-	-	-	259	259
Indirect Sources						
Machinery	-	-	255	260	265	271
Seed	588	588	588	588	588	588
Fertilizer	-	2774	2774	2774	2774	2774
Total energy input (MJ/ha)	5630	8448	7776	6499	6671	7556

Table 5 : Energy input, output, energy efficiency and energy productivity in cultivation of *Sali* paddy varieties - *Ranjit, Basundhara* and *Luit* grown with different levels of energy input

Levels of energy input	Energy Input (MJ/ha)	*Sali paddy varieties*											
		Ranjit				*Basundhara*				*Luit*			
		Yield (kg/ha)	Output energy (MJ/ha)	Output-Input energy ratio	Energy productivity (kg/ MJ)	Yield (kg/ha)	Output energy (MJ/ha)	Output-Input energy ratio	Energy productivity (kg/ MJ)	Yield (kg/ha)	Output energy (MJ/ha)	Output-Input energy ratio	Energy productivity (kg/ MJ)
Farmers' practice	5630	3752	55154	9.80	0.67	2741	40293	7.16	0.49	2412	35456	6.30	0.43
Use of fertilizer	8448	5841	85863	10.16	0.69	3944	57977	6.86	0.47	3412	50156	5.94	0.40
Use of fertilizer + cultivator + rotavator + water lifting pump	7776	5845	85922	11.05	0.75	3925	57698	7.42	0.50	3373	49583	6.38	0.43
Use of fertilizer + cultivator + rotavator + water lifting pump + thresher	6499	5787	85069	13.09	0.89	3895	57257	8.81	0.60	3311	48672	7.49	0.51
Use of fertilizer + cultivator + rotavator + water lifting pump + thresher + reaper	6671	-	-	-	-	-	-	-	-	3405	50054	7.51	0.51
Use of fertilizer + cultivator + rotavator + water lifting pump + thresher + reaper + Irrigation	7556	-	-	-	-	4325	63578	8.41	0.57	3661	53817	7.12	0.48
Mean	7097	5306	78002	11.3	0.75	3766	55360	7.73	0.53	3230	47478	6.70	0.45
SD	1019	1037	15237	1.47	0.10	599.4	8810	0.84	0.07	433.5	184846	0.67	0.05
CV (%)	14.35	19.53	19.53	13.37	13.24	15.91	15.91	10.83	10.64	13.29	150.33	9.88	10.10

Table 6 : Economic analysis of different levels of energy input used in cultivation of Sali paddy varieties

Level of energy input	Cost of Cultivation (₹/ha)	*Sali* paddy varieties											
		Ranjit				Basundhara				Luit			
		Yield (kg/ha)	Gross income (₹)	Net income (₹)	B:C ratio	Yield (kg/ha)	Gross income (₹)	Net income (₹)	B:C ratio	Yield (kg/ha)	Gross income (₹)	Net income (₹)	B:C ratio
Farmers' practice	22734	3752	33768	11034	1.49	2741	24669	1935	1.09	2412	21708	-1026	0.95
Use of fertilizer	25504	5841	52569	27065	2.06	3944	35496	9992	1.39	3412	30708	5204	1.20
Use of fertilizer + cultivator + rotavator + water lifting pump	21926	5845	52605	30679	2.40	3925	35325	13399	1.61	3373	30357	8431	1.38
Use of fertilizer + cultivator + rotavator + water lifting pump + thresher	17970	5787	52083	34113	2.90	3895	35055	17085	1.95	3311	29799	11829	1.66
Use of fertilizer + cultivator + rotavator + water lifting pump + thresher + reaper	16958	-	-	-	-	-	-	-	-	3405	30645	13687	1.81
Use of fertilizer + cultivator + rotavator + water lifting pump + thresher + reaper + Irrigation	18758	-	-	-	-	4325	38925	20167	2.08	3661	32949	14191	1.76
Mean	20642	5306	47756	25723	2.21	3766	33894	12516	1.62	3262	29361	8719	1.46
SD	3284	1037	9329	10207	0.59	599.3	5394	7045	0.40	433.4	3901	5860	0.34
CV (%)	15.910	19.534	19.534	39.679	26.778	15.914	15.914	56.289	24.905	13.286	13.286	67.207	23.460

is grown under rainfed condition under normal weather situation. However, application of 5 cm irrigation water 3 days after disappearance of ponding water is recommended in medium and heavy soils under aberrant weather condition.

Energy efficiency and energy productivity in paddy cultivation

The amount of output energy derived from the grain yield was in the range of 55154 - 85922, 40293 - 63578 and 35456 - 53817 MJ/ha in *Ranjit, Basundhara* and *Luit* varieties cultivated with different levels of energy input, respectively (Table 5). The mean output energy was highest in *Ranjit variety* (78002 MJ/ha), followed by *Basundhara* (55360 MJ/ha) and *Luit* (47478 MJ/ha) variety in all levels of energy input. Among different levels of energy input, the lowest yield was recorded in farmers' practice for all cultivars. The use of fertilizer significantly increased the paddy yield and hence energy output across all varieties, irrespective of use of different levels of energy input. There was no significant difference in the output energy for the same variety in the farms using chemical fertilizer with or without use of improved implements or machinery (T_2 to T_5). However, with addition of one irrigation (T_5), a substantial increase of output energy in paddy varieties was observed. In the irrigated farms, highest output energy of 63578 MJ/ha and 53817 MJ/ha were recorded in *Basundhara* and *Luit* varieties, respectively.

The energy efficiency (energy ratio) was found to increase with an increase in grain yield. Energy ratio was highest and lowest in growing *Ranjit* (11.3) and *Luit* (6.7) varieties, respectively (Table 5). Irrespective of cultivars, the lowest energy ratio was observed in the farmers' practice. As the level of energy input increased (T_2 to T_6), energy efficiency was found to increase. This was due to increase in the grain yield, in all varieties. Highest energy ratios 13.09 and 8.81 registered in case of '*use of fertilizer + rotavator +cultivator + WLP + thresher*' (T_4). In *Ranjit* and *Basundhara* varieties, respectively. However, in *Luit* variety*, the* highest energy ratio (7.51) was found when reaper was added to above level of energy input (T_5).

The energy productivity index was calculated for different levels of energy input in the three paddy varieties. The average energy productivity for *Ranjit, Basundhara* and *Luit* were 0.75, 0.53 and 0.45 kg/MJ respectively (Table 5). Among different levels of energy input, energy productivity was found to be the lowest in the farmers' practice in all the three varieties.

Benefit-cost ratio under different levels of energy input

The cost of cultivation, gross income, net income and benefit-cost ratio for different levels of energy input used for cultivation of paddy varieties were assessed and are given in Table 6. The cost of cultivation incurred for the three paddy varieties was equal for the same level of energy input used. It ranged from ₹ 16958 to ₹ 25504/ha with an average cost of ₹ 20624/ha for different treatments. The cost of cultivation was the highest (₹ 25504/ha) when chemical fertilizer was applied without use of improved implements (T_2). It was higher by ₹ 2770/ha as compared to the farmers' practice. As the level of input energy increased from T_3 to T_6, the cost of cultivation reduced substantially and became minimum (₹ 16958/ha) in the farms using *fertilizers + cultivator + rotavator + WLP + thresher + reaper* (T_5). However, when irrigation was added to T_5, the cost of cultivation increased to ₹ 18758/ha.

Both the gross and net income was found to be lowest with farmer's practice, even negative net income (i.e. loss) was observed in *Luit* (₹ 1026/ha). As the level of energy input increased from T_1 to T_6, the net income was found to increase in all the cultivars. Irrespective of use level of input energy, net income accrued was the highest in *Ranjit* (₹ 25723/ha), followed by *Basundhara* (₹ 12516/ha) and *Luit* (₹ 8719/ha).

The benefit-cost ratio under different levels of energy input use varied from 1.49 to 2.90, 1.09 to 2.08 and 0.95 to 1.81 in *Ranjit*, *Basundhara* and *Luit* varieties, respectively. The highest benefit-cost ratio of 2.90 and 1.95 in *Ranjit* and *Basundhara* was recorded in the energy input level of T4. However, in case of *Luit,* the highest benefit-cost ratio (1.81) registered in the energy input level of T_5. In the three varieties of paddy, the lowest benefit-cost ratio was observed with farmers' practice. Therefore, high input farms using higher level of energy input appeared to be in a better position in both energy use efficiency and benefit-cost ratio than the farms with no mechanization and use of fertilizes.

Conclusions

It was found that with an increase in the level of mechanization, the human and animal hour requirement for paddy cultivation was reduced from 795 to 350 and 352.5 to 22.5 hr/ha as compared to farmers' practice. Thus, mechanization helped to reduce drudgery of human and animals. The total energy requirement for paddy cultivation in different levels of energy input ranged from 5630 to 8448 MJ/ha. The energy used in paddy cultivation could be reduced by 8 to 23% through increasing the level of mechanization. Under different levels of energy input, the output energy, energy use efficiency and energy productivity ranged from 35456 to 85922 MJ/ha, 5.94 to 13.09 and 0.4 to 0.89 kg/MJ, respectively. For all the levels of energy input, higher values of energy parameters registered in *Ranjit* compared to other two varieties. The benefit-cost ratio under different levels of energy input varied from 1.49 to 2.90, 1.09 to 2.08 and 0.95 to 1.81 in *Ranjit*, *Basundhara* and *Luit* varieties of paddy, respectively. Hence, it could be concluded that the farms using higher level of energy input are in a better position from the viewpoint of both energy use efficiency and benefit-cost ratio than that of farms without mechanization and fertilize use.

Acknowledgement

Authors acknowledge the financial support provided by Indian Council of Agricultural Research (ICAR), New Delhi for carrying out the study under NICRA project and also thank the participant farmers of NICRA village Chamua, Lakhimpur, Assam.

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Received: May 2015; Accepted: September