Auditing of Energy Use and Output of Different Cropping Systems in India

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ABSTRACT

The assessment of the energy requirements of the different cropping systems was carried out at the Research farm of Project Directorate for Cropping Systems Research, Modipuram, Meerut during the year of 2000-01 and 2003-04. Six cropping systems viz. rice-wheat, rice-mustard-greengram, rice-vegetable pea-wheat-greengram, maize-vegetable pea-wheat, pigeonpea-wheat and soybean-wheat were subjected to energy use and out put assessment, net return of energy and income. Results revealed that the total input energy utilization was highest in rice-veg. pea-wheat-greengram (65052 MJ/ha) followed by rice-wheat (50264 MJ/ha), maize-vegetable pea-wheat (46031 MJ/ha), rice-mustard-greengram (43614 MJ/ha) and soybean-wheat (30859 MJ/ha). The lowest energy use was in the pigeonpea-wheat system (29015 MJ/ha). The maximum energy was consumed in terms of chemical fertilizers followed by irrigation (diesel), machinery (diesel), plant protection, human labour and seed in all the cropping systems. The energy use by fertilizers represented the major part of total energy use accounting for 32.6 to 41.7 per cent in all the treatments. The net energy return was found highest in rice-wheat *(*102865 MJ/ha). It was at par with rice-mustard-greengram (102790 MJ/ha). The maize-vegetable pea-wheat (92869 MJ/ha) ranked third in energy return and was followed by the rice-vegetable pea-wheat-greengram (84871 MJ/ha), pigeonpea-wheat (80929 MJ/ha) and soybean-wheat (80365 MJ/ha). The net monetary return for maximum energy return system was higher in rice-mustard-greengram (Rs. 43328 /ha/year) than rice-wheat (Rs. 27976 /ha/year). The second most remunerative system was pigeonpea-wheat (Rs. 33442 /ha/year) followed by rice-vegetable pea-wheat-greengram (Rs. 26250 /ha/year) and maize-vegetable pea-wheat (Rs. 23517 /ha/year). The rice-mustard-greengram gained 54.9 per cent higher monetary benefit than that of rice-wheat system. However, it was 65.1 per cent more than rice-vegetable pea-wheat-greengram.

Keywords: Input energy use, output energy, net energy, cropping system

1. INTRODUCTION

Energy is one of the most valuable inputs in production agriculture. It is invested in various forms such as mechanical (farm machines, human labour, animal draft), chemical fertilizer, pesticides, herbicides), electrical, etc. The amount of energy used in agricultural production, processing and distribution should be significantly high in order to feed the expanding population and to meet other social and economic goals. Sufficient availability of the right energy and its effective and efficient use are prerequisites for improved agricultural production. It was realized that crop yields and food supplies are directly linked to energy (Stout, 1990). In the developed countries, increase in the crop yields were mainly due to increase in the commercial energy inputs in addition to improved crop varieties (Faidley, 1992). Bridges and Smith (1979) developed a method for determining the total energy input for agricultural practices. Numerous studies have been done to quantify energy consumption in agricultural production (Heslop and Bilanski 1989; Swanton *et al*. 1996; Vinten- Johansen *et al*. 1990 and Zentner *et al*. 1984). Lal *et al*. (2003), in their study on energy use and output assessment of food-forage production systems, reported sorghum (single cut)- berseem + mustard-maize+cowpea as most energy efficient and remunerative system among the five forage systems. The cropping systems were evaluated in terms of energy use, biomass production and gross income etc. The benefit-to-cost (B: C) ratio for the most energy efficient forage production was 1.37:1. The fertility of the soil could also be maintained by increasing organic carbon.

Particularly in developing countries, the primary objectives of mechanizing crop production are to reduce human drudgery and to raise the output of farm by either increasing the crop yield or increasing the area under cultivation. These can only be done by supplementing the traditional energy input i.e. human labour with substantial investments in farm machinery, irrigation equipment, fertilizers, soil and water conservation practices, weed management practices, etc. These inputs and methods represent various energies that need to be evaluated so as to ascertain their effectiveness and to know how to conserve them. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. Other benefits of energy analysis are to determine the energy invested in every step of the production process (hence identifying the steps that require least energy inputs), to provide a basis for conservation and to aid in making sound management and policy decisions. For example, proper management of weeds and operation of machinery or irrigation pumps reduce input energy.

Rice-wheat is the major cropping system in northern India covering about 10.5 M ha area contributing about 32 per cent to the national food basket. In fact, both rice and wheat are the two most important crops and the staple food of millions of people in India and other Asian countries. Therefore, their sustained high productivity is inevitable for national food security. In recent years, the rice-wheat has started suffering a production fatigue, stagnation or decline in productivity. Rice in general is grown using transplanting of seedlings under puddled field conditions. It requires huge amount of the input energy for the growing the seedlings, transplanting, puddling, irrigation etc. With the advancement in the technology and general agricultural developments, the use of the energy resources has increased markedly. Traditional, low energy farming is being replaced by modern one which require more energy use. The energy-agriculture relationship is therefore becoming more and more important with the intensification of the cropping systems, which is considered to be the only means of raising agricultural output in land scarce situations. Timely solving the problems and large scale implementing the approaches of developing the agricultural energy system will contribute to independence of energy supply for overcoming the energy crisis and reviving national farming, which will be a considerable input in ensuring the national food security.

Therefore the present study was undertaken with the following specific objectives:

1. To analyze the input, output and net return energy of different cropping systems.
2. To identify energy efficient cropping systems for satisfactory energy output.

2. MATERIALS AND METHODS

2.1 Site and Climate

The field experiments were carried out at the research farm of the Project Directorate for Cropping Systems Research, Modipuram, Meerut during year 2000-01 to 2003-04. The site is located at 29.40^0 N latitude, 77.4^0 E longitude and at 237 m above mean sea level, and categorized in hot-dry semi-arid subtropical climate with hot summers and cold winters. The mean annual rainfall of the site is about 837 mm and evapo-transpiration 1540 mm. The soil was sandy loam cosisting of 64, 19 and 17 per cent sand, silt and clay, respectively.

2.2 Experimental Details

The experiment was conducted in a randomized block design with four replications to estimate the input energy use , output energy obtained, net return of energy and income for six cropping systems (rice-wheat, rice-mustard-greengram, rice-vegetable pea-wheat-greengram, maize-vegetable pea-wheat, pigeonpea-wheat and soybean-wheat) were considered on comparative scale. The crops used were rice *(Oryza sativa L.*) cv. Saket-4, wheat (*Triticum aestivum* L. emend. Fiori and Paol*)* cv. PBW-343 while PBW-226 in four crop system , mustard (*Bassica nigra*) cv. Pusa bold, vegetable pea (*Pisum sativum*) cv. Arkel, greengram (*Phasolus radiatus*) cv. Pusa vishal, maize (*Zea mays*) cv. Naveen, pigeonpea *(Cajanus cajan*) cv. UPAS-120 and soybean (*Glycine max Merr.*) cv. PK. The crops were raised in a plot size of 6 m x 5 m. The net area under experiment was 0.096 ha (consisting of 32 plots having 6 m x 5 m size each). All these crops were raised following standard package of practices in the systems. The green foliage of greengram as residue after one and two pickings of pods in rice-mustard-greengram and rice-vegetable pea-wheat-greengram systems were incorporated and harrowed twice after 84 days of sowing. Thereafter, puddling was done for *kharif* rice crop. All plots were harrowed twice and tilled once with tiller followed by levelling and bund making. Thereafter, water was flooded to about 10-15 cm depth for 24 hours for the puddling in all treatments. For wheat crop, the field was harrowed twice, and tilled twice, planked & leveled for preparing good seedbed for sowing. Later bunds were made for easy irrigation. The seedbed for other crops was prepared by harrowing once and tilling once.

2.3 Method of Energy Calculation

2.3.1 Evaluation of Manual Energy Input

Manual energy (Em) expended was determined using the following formula:

$$E_m = 1.96\, N_m\, T_m \text{ MJ}$$

Where, N_m = Number of labour spent on a farm activity

T_m= Useful time spent by a labour on a farm activity, h

Table 1 shows the energy coefficients used in the calculations. The total manual labour was recorded in each operation with working hours which was converted in man-hour. All other factors affecting manual energy were neglected

2.3.2 Evaluation of Mechanical Energy use

Mechanical energy input was evaluated by quantifying the amount of diesel fuel consumed during the tillage, sowing, threshing and winnowing, etc (Umar, 2003). The total time spent was also recorded. Diesel consumption in pump was also recorded during irrigation. Hence, for every farm operation, the diesel fuel energy input was determined by:

$E_f = 56.31\ D$ MJ

Where, 56.31 = unit energy value of diesel, MJL^{-1}

D= amount of diesel consumed, L

2.3.3 Other Inputs

The inputs used for different operations in various crop sequences and outputs obtained in terms of yield were used for calculating energetics of systems. For the calculation of input energy, all inputs in the form of the labour, diesel, seed, chemical fertilizer, plant protection (insecticides/pesticides/herbicides) used in all different operations were taken into consideration with the use of energy conversion factor (Table 1). The different field operations performed for completion of each activity in the experiment were measured in terms of time taken for human, machinery and fuel consumption and expressed as energy input in mega joules (MJ) using corresponding conversion factors as detailed in Table 1. The farm production (grain yield) was also converted in terms of energy output (MJ) using four years average yield under different crops of selected sequences. The energy use was calculated operations namely, (i) land preparation (ii) puddling (iii) nursery raising & transplanting (iv) sowing/planting (v) interculture/weeding (vi) crop management (vii) harvesting and threshing. The energy input sources were from human, tractor and pumping units. The energy use inputs were also calculated based on input-wise given source during crop period namely, (i) seed (ii) FYM (iii) chemical fertilizers (iv) plant protection (insecticides/pesticides/herbicides) (v) pump (diesel) (vi) machinery (diesel) (vii) electricity (viii) human labours etc. The farm production (*i.e.* yield) was assessed in economic terms in Indian Rupees.

3. RESULTS AND DISCUSSION

3.1 Operation-wise Energy Utilization Pattern

The energy utilization was highest in crop management operation which varies from 19432 MJ/ha in pigeonpea–wheat system to 43476 MJ/ha in rice-vegetable pea-wheat-greengram followed by seedbed preparation (3729 to 7161 MJ/ha), harvesting and threshing (1986 to 3813 MJ/ha), puddling (2878 MJ/ha) and sowing /planting (1082 to 4986 MJ/ha) (Table 2). The energy use by crop management represented the major part of total energy use accounting for 66.37 to 68.4 per cent in all treatments. The higher input energy used in crop management was due to the higher quantity of diesel consumed in irrigation and energy use through chemical fertilizers and plant protection etc. The seed bed preparation has got second rank in energy consumption accounting about 7.9 to12.7 per cent of the total input energy (ranging from 3729 MJ/ha in pigeonpea–wheat & soybean-wheat (both case) and 7161 MJ/ha in rice-vegetable pea-wheat-greengram). The harvesting and threshing consumed about 6 per cent of total energy use of the system. The maximum energy use was 3813 MJ/ha in rice-vegetable pea-wheat-greengram and minimum was 1986 in pigeonpea–wheat & soybean-wheat (both case).

Table1. Energy conversion factors used

Power source	Units	Equivalent energy (MJ)
Human labour (Adult)	human-hour	1.96
Diesel	litre	56.31
Chemical fertilizers		
Nitrogen (N)	kg	60.60
Phosphorus (P)	kg	11.10
Potash (K)	kg	6.70
Plant protection (superior)		
Granular chemical	kg	120
Liquid chemical	ml	0.102
Crop produce (grain)		
Rice	kg	14.70
Wheat	kg	15.70
Vegetable pea	kg	3.91
Greengram	kg	14.03
Maize	kg	15.10
Mustard	kg	22.72
Pigeonpea	kg	14.07
Soybean	kg	18.14

Source: Gopalan *et al*. (1978) and Binning *et al*. (1983)

Table 2 Input energy use in field operations of different cropping systems (MJ//ha)

Cropping systems	Seedbed Preparation	Puddling	Nursery Raising & Transplanting	Sowing/ Planting	Interculture /Weeding	Crop Management	Harvesting/ Threshing	Green Manuring	Total Input Energy, MJ/ha
Rice-wheat	3955	2878	1347	2826	1411	34817	3030	0.0	50264
Rice-mustard-greengram	4252	2878	1347	1082	1098	30111	2847	5546	43614
Rice-vegetable pea-wheat-greengram	7161	2878	1347	4572	1803	43476	3813	5311	65052
Maize-vegetable pea-wheat	5578	0.0	0.0	4986	1333	31913	2221	0.0	46031
Pigeonpea -wheat	3729	0.0	0.0	2770	1098	19432	1986	0.0	29015
Soybean-wheat	3729	0.0	0.0	3718	1098	20328	1986	0.0	30859

The puddling, nursery raising and transplanting were accomplished in three cropping systems for rice crop only which consumed 2878 MJ/ha and 1347 MJ/ha of energy, respectively. The interculture and weeding operation consumed least amount of energy use in all treatments which varied from 1098 to 1803 MJ/ha only. However, among six cropping systems, rice-vegetable pea-wheat-greengram was found to be more energy consuming system in all operations followed by rice-wheat, rice-mustard-greengram, maize-vegetable pea-wheat. The lowest energy was consumed in soybean-wheat and pigeonpea-wheat system in all operations. The higher energy use in rice-veg. pea-wheat-greengram was due to high intensity of cropping sequence. However, in two green manuring systems, rice-mustard-greengram and rice-vegetable pea-wheat-greengram, the total input energy use was 43614 MJ/ha and 65052 MJ/ha in which 5546 MJ/ha and 5311 MJ/ha energy was consumed for green manuring crop in greengram as input (grain + crop residue use), respectively.

3.2 Source-wise Energy Utilization Pattern

The energy use for cultivation of crops was more in rice-vegetable pea-wheat-greengram (65052 MJ/ha) followed by rice-wheat- (50264 MJ/ha), maize-vegetable pea-wheat (46031 MJ/ha) and rice-mustard-greengram (43614 MJ/ha), pigeonpea-wheat (29015 MJ/ha) and soybean-wheat (30859 MJ/ha) systems (Table 3). Further, it was revealed that the maximum energy was consumed in terms of chemical fertilizers followed by irrigation (diesel), machinery (diesel), plant protection, human labour and seed in all the cropping systems. The energy use by fertilizers represented the major part of total energy use accounting for 32.6 to 41.7 per cent in all treatments (Chaudhary *et al.*, 2004 a & b). Among six cropping systems, rice-vegetable pea-wheat-greengram used maximum energy by chemical fertilizer (21231 MJ/ha). It was due to more number of crops in the system. This was followed by maize-vegetable pea-wheat (19173 MJ/ha), rice-wheat (16680 MJ/ha) and rice-mustard-greengram (15690 MJ/ha), soybean-wheat (11314 MJ/ha) and pigeonpea-wheat system (11011 MJ/ha). However, in case of diesel consumption for irrigation of crop, the energy use in pumping varied from 18.1 to 31.5 per cent of total energy use in all treatments. It was highest in rice-vegetable pea-wheat-greengram (17625 MJ/ha) in comparison to others systems. This was followed by in rice-wheat (15823 MJ/ha), rice-mustard-greengram (13683 MJ/ha) and maize-veg. pea-wheat (8334 MJ/ha). The least amount of diesel energy for irrigation was required as soybean-wheat (6532 MJ/ha) and pigeonpea-wheat (6082 MJ/ha) systems. It was due to less requirement of irrigation in soybean and pigeonpea crops.

The diesel used in farm machinery was highest in rice-vegetable pea-wheat-greengram (10699 MJ/ha) and lowest (4955 MJ/ha) in soybean-wheat and pigeonpea-wheat systems. It varied from 14.4 to 17.1 per cent of the total energy used in diesel. The more machinery used in seedbed preparation and other operations for intensive cropping system caused higher energy consumed in rice-vegetable pea -wheat-greengram.

Table 3 Source wise energy use in different cropping systems (MJ/ha)

Energy Source	Rice-wheat			Rice-mustard-greengram				Rice-vegetable pea-wheat-greengram					Maize-vegetable pea-wheat				Pigeonpea -wheat			Soybean-wheat		
	Rice	Wheat	Total	Rice	Mustard	Green-gram	Total	Rice	Veg. pea	Wheat	Green-gram	Total	Maize	Veg. pea	Wheat	Total	Pigeon-pea	Wheat	Total	Soybean	Wheat	Total
Seed	588	1884	2472	588	182	279	1049	588	1058	1884	279	3810	906	1058	1884	3848	141	1884	2025	1088	1884	2972
Fertilizers	8340	8340	16680	8340	5426	1924	15690	8340	2627	8340	1924	21231	8206	2627	8340	19173	2671	8340	11011	2974	8340	11314
Pesticides	2106	1928	4034	2106	255	128	2489	2106	2085	1928	128	6246	128	2085	1928	4140	255	1928	2183	383	1928	2310
Pump (Diesel)	11093	4730	15823	11093	1689	901	13683	11093	901	4730	901	17625	2703	901	4730	8334	1351	4730	6082	1802	4730	6532
Machinery (Diesel)	3942	3660	7602	3942	1295	1295	6532	3942	1802	3660	1295	10699	1295	1802	3660	6757	1295	3660	4955	1295	3660	4955
Human Labour	2352	1301	3653	2352	800	1019	4171	2352	1004	1301	784	5441	1474	1004	1301	3779	1458	1301	2760	1474	1301	2775
Total Energy	28421	21843	50264	28421	9647	5546	43614	28421	9477	21843	5311	65052	14711	9477	21843	46031	7172	21843	29015	9016	21843	30859

Plant protection was one of the energy consuming inputs for cultivation of crops accounting from 5.7 to 9.6 per cent of the total input energy in all cropping systems. While, in case of human energy, the higher energy was found to be in rice-vegetable pea-wheat-greengram (5441MJ/ha) followed by rice-mustard-greengram (4171 MJ/ha). More energy in greengram was consumed because of the human labours used in one or two pickings of pods and threshing. The least human energy was required in soybean-wheat (2775 MJ/ha) and pigeonpea-wheat (2760 MJ/ha). The energy used in seed varied from 2024 MJ/ha to 3810 MJ/ha with similar pattern as other inputs.

3.3 Energy Output and Economic Return Pattern

The total output energy was highest in rice-wheat system *(*153126 MJ/ha) followed by rice-vegetable pea-wheat-greengram (149922 MJ/ha), rice-mustard-greengram (146403 MJ/ha) and maize-vegetable pea-wheat (138901 MJ/ha) as detailed in Table 4 and Fig. 1. The lowest output energy was given by soybean-wheat *(*111224 MJ/ha) and pigeonpea-wheat *(* 109944 MJ/ha).

The net energy return was highest in rice-wheat *(* 102862 MJ/ha) which was at par with rice-mustard-greengram (102790 MJ/ha) followed maize-vegetable pea-wheat (92869 MJ/ha) and rice-vegetable pea-wheat-greengram (84871 MJ/ha). It was because of the intensification of crops in a year of growing period consumed higher input energy than the obtained output energy. The vegetable pea and greengram contributed only 6.6 and 3.7 per cent to the total output energy of the system, whereas, the input energy used was taken as 14.6 and 8.3 per cent of total input energy of system, respectively. The net return energy of rice-mustard–greengram and rice-wheat systems were similar because of the mustard crop taking about 22.1 per cent input energy and giving about 45.1 per cent output energy of total system energy. The greengram was grown for dual purpose as green manuring and grain yield, it showed that about 4.3 per cent in rice-mustard-greengram and 3.7 per cent energy in rice-veg. pea-wheat-greengram was contributed into total output energy of system through grain. So, it is clear that about 2.96 per cent and 4.29 per cent higher output energy was obtained in succeeding rice crop after green manuring by greengram after due pickings of pods as compared to other systems.

The output-input ratio was highest in pigeonpea-wheat (3.8) followed by soybean-wheat (3.6), rice-mustard-greengram (3.4), rice-wheat and maize-vegetable pea-wheat (3.0 in both the systems). The pigeonpea-wheat and soybean-wheat systems were more efficient due to lower input and higher output energy. The lowest output-input ratio was noticed in rice-vegetable pea-wheat-greengram (2.3). Numerically, maximum net energy was found in rice-wheat and rice-mustard-greengram than other systems. The rice-wheat system gained 27.7, 21.2 and 10.8 per cent higher net return energy than soybean-wheat and pigeonpea-wheat systems, rice-vegetable pea-wheat-greengram and maize-vegetable pea-wheat systems, respectively.

Table 4 Input and output energy of different cropping system

Particulars	Rice-wheat			Rice-mustard-greengram				Rice-veg. pea-wheat-greengram					Maize-veg. pea-wheat				Pigeonpea -wheat			Soybean-wheat		
	Rice	Wheat	Total	Rice	Mustard	Green-gram	Total	Rice	Veg. pea	Wheat	Green-gram	Total	Maize	Veg. pea	Wheat	Total	Pigeon-pea	Wheat	Total	Soybean	Wheat	Total
Input energy, MJ/ha	28421	21843	50264	28421	9647	5546	43614	28421	9477	21843	5311	65052	14711	9477	21843	46031	7172	21843	29015	9016	21843	30859
	(56.5)	(43.5)	(100)	(65.2)	(22.1)	(12.7)	(100)	(43.7)	(14.6)	(33.6)	(8.2)	(100)	(32.0)	(20.6)	(47.5)	(100)	(24.7)	(75.3)	(100)	(29.2)	(70.8)	(100)
Output energy, MJ/ha	71957	81169	153126	74088	66002	6314	146403	75044	9834	59503	5542	149922	70291	9892	58718	138901	24693	85251	109949	27936	83289	111224
	(47.0)	(53.0)	(100)	(50.6)	(45.1)	(4.3)	(100)	(50.1)	(6.6)	(39.7)	(3.7)	(100)	(50.6)	(7.1)	(42.3)	(100)	(22.5)	(77.5)	(100)	(25.1)	(74.9)	(100)
Net energy return, MJ/ha	43536	59326	102862	45667	56355	768	102790	46623	357	37660	231	84871	55579	416	36875	92869	17521	63408	80929	18920	61445	80365
Output-input ratio	2.5	3.7	3.0	2.6	6.8	1.1	3.4	2.6	1.0	2.7	1.0	2.3	4.8	1.0	2.7	3.0	3.4	3.9	3.8	3.1	3.8	3.6
Net return, Rs./ha/year	9798	18178	27976	10581	31795	952	43328	10932	3375	11761	182	26250	8626	3450	11441	23517	13600	19842	33442	1956	19042	20998

The averages data for four years are shown. The figures in parenthesis show the percentage of input and output energy to the total system energy.

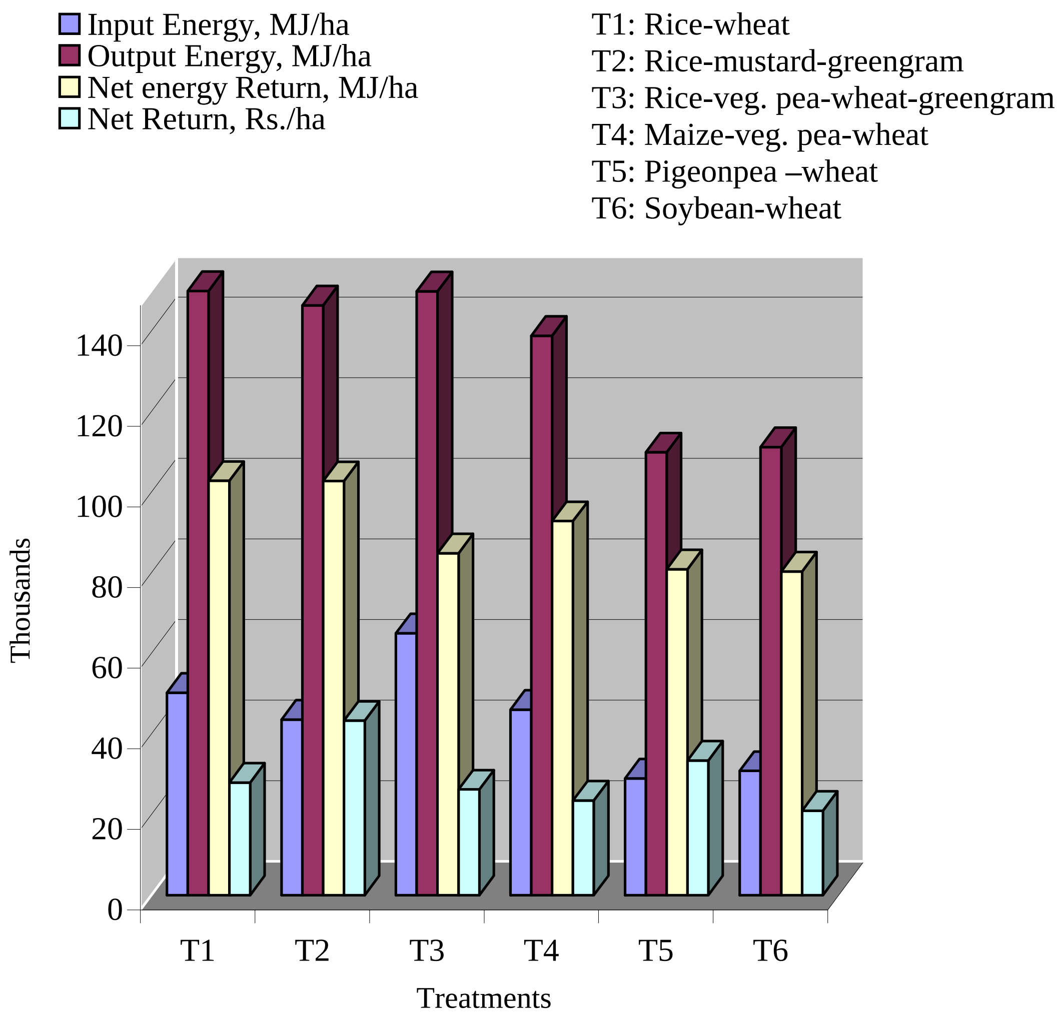

Figure 1 Input, output and net return/ energy of different cropping systems

The net monetary return was highest in rice-mustard-greengram (Rs. 43328 /ha/year) followed by pigeonpea-wheat (Rs. 33442 /ha/year), rice-wheat (Rs. 27976 /ha/year), rice-vegetable pea-wheat-greengram (Rs. 26250 /ha/year) and maize-vegetable pea-wheat (Rs. 23517 /ha/year) system (Table 4 and Fig. 1). The rice-mustard-greengram gained 54.9 per cent higher monetary benefit than that of rice-wheat, however, it was 65.1 per cent more than rice-vegetable pea-wheat-greengram which consumed highest input energy.

4. CONCLUSION

It may be concluded that the net energy and monetary return of cropping systems can be quantified and stratified for sound planning of sustainable systems. The highest net return energy was in rice-wheat *(*102862 MJ/ha). It was at par with rice-mustard-greengram (102790 MJ/ha) followed maize-vegetable pea-wheat (92869 MJ/ha). The total output energy was highest in rice-wheat *(*153126 MJ/ha) followed by rice-vegetable pea-wheat-greengram (149922 MJ/ha) and rice-mustard-greengram (146403 MJ/ha). Among six cropping systems evaluated, the overall performance of rice-mustard-greengram system was adjudged to be most efficient and profitable.

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