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Study and Determination of Energy Consumption Pattern in Production of Paddy Crop in RS Pura Region of Jammu in J and K, India

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ABSTRACT

The study was conducted on the relationship between energy demand and energy input generated by rice production in RS Pura region of Jammu and Kashmir. Various agricultural processes, from land preparation to storage, were considered to determine the energy consumption in rice cultivation. The preliminary information was received from the local farmers of the particular region through a well-planned questionnaire. The energy consumption pattern for different operation in rice production system and their sources were determined by using energy equivalent. The energy calculation from different inputs included human labor, machinery system, diesel, electricity, seed, chemicals and fertilizers whereas output energy were calculated from the yield output including rice and straw. Specific energy, energy efficiency, energy productivity, energy intensity and water productivity were also calculated using the standard relations. The total input and output energy for paddy cultivation was found to be 30114.6 and 107700 MJ/ha, respectively. The highest input of energy was observed in irrigation (35 %) and fertilizer applications (27 %). The net energy was found to be 77585.4 MJ/ha.

Keywords Basmati rice, Energy ratio, Energy analysis, Specific energy, Energy efficiency.

INTRODUCTION

India is the world's second largest rice producer, after China. Rice is widely cultivated in India with an area of about 43.86 million hectare and an annual yield of 104.32 million tonnes, with an average yield of 2240 kg per hectare and an annual consumption of 85 million tons (Anon 2016). India is a major exporter of basmati rice to the world market and exported 3,948,161.03 million tons of basmati rice worth Rs 26,416.49 crores in 2021-22. The rice growing states in India is shown in Fig. 1. The economy of the state of Jammu and Kashmir is mainly based on agriculture, with about 70% of the population directly or indirectly engaged in agriculture and related occupations. It is believed that rice cultivation began simultaneously in many countries more than 6,500 years ago. The net cultivated and gross cultivated area of Jammu

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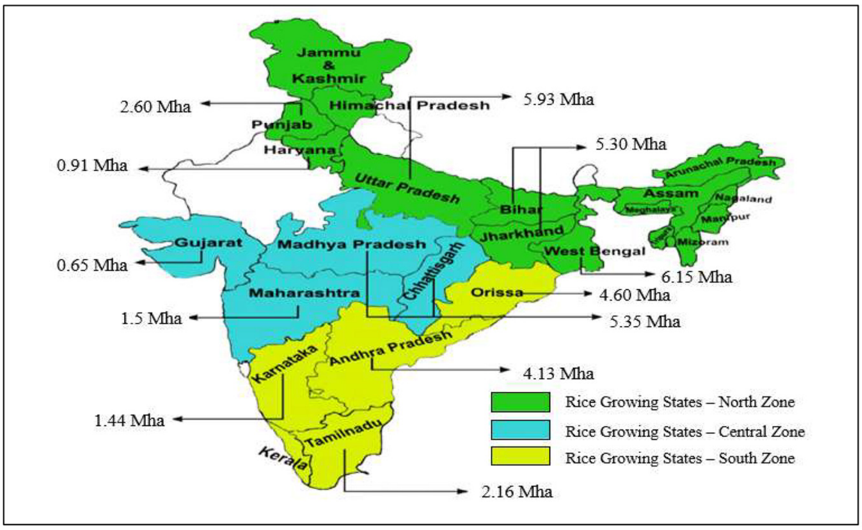

Fig. 1. Distribution of rice production state wise in India (Jena 2015).

region is 3.97 lakh ha and 7.15 lakh ha, respectively. The percentage of net irrigated area and small/marginal farmers is 24 and 92 %. Rice is grown mainly in irrigation belts of Jammu region such as Jammu, Ranbir Singh Pura, Bishnah, Hiranagar, Samba, Mara, and Kathua Tehsils of Jammu Division. The rice crop season runs from mid-June to the end of November for almost 175 days (Anon 2022).

Local basmati along with basmati 370 are the most common varieties sown in Jammu region of J and K. Both these varieties are best known for its aroma and cooking quality and matures generally 10 to 14 days earlier than other varieties sown in the region. The other varieties of basmati rice grown in region include Ranbir basmati, Sanwal Basmati, Pusa Sughandha, No. 1 Pusa Basmati, RR-564 and Pusa Basmati 1121. These varieties mature in 135-140 and maximum up to 175 days. These are well suited to rice, wheat and legumes system. In the financial year 2021, India's northernmost state of Jammu and Kashmir produced more than 500,000 tons of rice as shown in Fig. 2.

Energy is the basic driving force in human development. The history of civilization is largely a story of man's progress in harnessing energy, i.e., to convert energy to a more useful form. In agriculture, energy is important in terms of crop production and agro-processing for value adding. Since the efficient use of energy resources is essential to increase yields, productivity, agricultural competitiveness and sustainability of rural life, energy audit is one of the most common ways to examine the energy efficiency and its environmental effect on production systems. Therefore, it enables the researchers to determine the corelation between the input and output energy and its relation with yield and production (Nandan *et al.* 2021).

To accomplish farming smarter and increased yield production, the energy inputs in variation cultivation practices like seed bed preparation with tractor, tillage implements, spraying fertilizers and

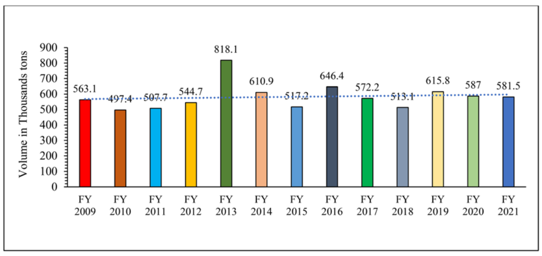

Fig. 2. Volume of rice production in Jammu and Kashmir (Anon 2023)

Fig. 3. Site of study location.

pesticides, Irrigation, and harvesting with manual methods, thresher or combine harvester. The energy used directly at farms/field in these various operations is called direct energy whereas the energy used in manufacturing, packaging and transporting of crop seeds, fertilizers and agricultural machinery implements is termed as indirect energy (Rabbani *et al.* 2022).

Objective

The purpose of this study was to determine energy flow pattern in paddy cultivation in RS Pura region of Jammu region in the union territory of Jammu and Kashmir, India.

Study site

The study was carried out in RS Pura region of Jammu district where the basmati-370 rice is the main crop and source of income for the farmers (Fig. 3). The paddy crop of basmati-370 is a *kharif* crop which is sown in May to June and harvested in October to November. This rice zone of Jammu region has subtropical climate where summer has hot and dry climates, and cold climate during winter season. The night temperature is are generally cooler than those around Punjab as it lies under the foothills of mountains. The minimum and maximum temperature is approximately 4°C and 47°C respectively. The rainy season usually starts in late June or early July. The average rainfall in the region is about 1246 mm.

MATERIALS AND METHODS

The data was collected from Haripur village located in the RS Pura tehsil of Jammu district. The preliminary information was collected by interviewing the paddy growing farmers. The other information needed for the study was collected from the state department of agriculture and recommended cultivation practicing manual by SKUST-Jammu. The energy needs of paddy crops are met using various types of energy, both direct and indirect. Direct energy comprises of human, diesel, natural gas, gasoline and electricity energy used in the production process which starts from seed bed preparation to harvesting, while indirect energy comprises of machinery, fertilizer, seed and biopesticide energy. The other category of energy is renewable and non-renewable. The renewable energy includes human labor and seed whereas non-renewable energy includes diesel, natural gas, electricity, fertilizers and machinery. Renewable energy, used

Table 1. Estimation of energy input in different modes of energy sources.

Direct energy	Human, animal, petrol, diesel, electricity, irrigation water from canal
Indirect energy	Seeds, fertilizers, farmyard manure, chemicals, machinery
Renewable energy	Human, animal, seeds, farmyard manure, canal
Non-renewable energy	Petrol, diesel, electricity, chemicals, fertilizers, machinery.
Commercial energy	Petrol, diesel, electricity, chemicals, fertilizers seeds, machinery
Non-commercial energy	Human, animal, farmyard manure, canal

Table 2. Energy equivalents for different inputs and outputs in paddy production.

Sl. No.	Parameters	Unit	Energy equivalent	Source
		Input parameter		
1	Human labor	h	1.96 MJ/h	Kumar *et al*. (2018)
2	Machinery	h	62.7 MJ/h	Kumar *et al*. (2018)
3	Electricity	kW/h	11.93 MJ/h	Gundogmus (2006)
4	Diesel	L	56.31 MJ/lit	Kumar *et al.* (2018)
5	Chemical fertilizers			
	a) Monocil	L	120 MJ/lit	Gundogmus (2006)
	b) Tilt	L	120 MJ/lit	Gundogmus (2006)
	c) Stomp	L	120 MJ/lit	Gundogmus (2006)
	d) Algrip	kg	120 MJ/kg	Gundogmus (2006)
6	Fertilizers spraying			
	a) Nitrogen	kg	60.60 MJ/kg	Esengun *et al.* (2007)
	b) Phosphate	kg	11.1 MJ/kg	Mousavi-Avval *et al*. (2011)
	c) Potash	kg	6.7 MJ/kg	Khan *et al.* (2004)
	d) FYM	kg	0.30MJ/kg	Demircan *et al.* (2006)
7	Paddy seed	kg	14.7MJ/kg	Khan *et al*. (2004)
	Output parameters			
1	Grain	kg	14.7MJ/kg	Esengun *et al.* (2007)
2	Straw	kg	12.50MJ/kg	Esengun *et al.* (2007)

to describe the complementary energy of natural processes on a sufficiently fast time scale (Satish and Nagesha 2017). The modes of source of energy for different production process is shown in Table 1.

The conversion of physical units of different inputs and outputs into energy units using their conversion factors, i.e., energy equivalents (Singh and Mittal1992). The associated energy equivalents are listed in Table 2. Specific energy (Singh and Mittal 1992), energy efficiency (Mandal *et al*. 2002), energy productivity (Khan *et al.* 2004), energy intensity (Singh and Mittal 1992), water productivity (Alipour *et al.* 2012), and net energy (Singh and Mittal 1992) were calculated by using following.

$$\text{Specific energy}=\frac{\text{Total energy input (MJ/ha)}}{\text{Grain yield (kg/ha)}} \quad (1)$$

$$\text{Energy efficiency}=\frac{\text{Total energy output (MJ/ha)}}{\text{Total energy input (MJ/ha)}} \quad (2)$$

$$\text{Energy productivity}=\frac{\text{Grain yield (kg/ha)}}{\text{Total energy input (MJ/ha)}} \quad (3)$$

$$\text{Energy intensity} =\frac{\text{Total energy input (MJ/ha)}}{\text{Total energy output (MJ/ha)}} \quad (4)$$

$$\text{Water productivity}=\frac{\text{Grain yield (kg/ha)}}{\text{Amount of water applied (MJ/ha)}} \quad (5)$$

$$\text{Net energy} =\text{Energy output (MJ/ha)}-\text{Energy input (MJ/ha)} \quad (6)$$

RESULTS AND DISCUSSION

In agricultural production system, direct and indirect forms of energy are required for efficient functioning of production process. The instantaneous energy of the current study includes both living (animate) and non-living energies (inanimate). Over the past few decades, the use of animal energy in agriculture has declined significantly. Therefore, the mobile energy component includes only human energy, which is necessary for all operations of the crop production unit, including those that are carried out using machines or electric energy. The energy input and output values were determined by multiplying the energy equivalents of the associated source. The ratio of input and output energy was determined from both direct and indirect source of energy used in the production of paddy cultivation up to yield output with rice and straw. The direct energy was higher than the indirect energy with a share of 55.02 and 44.96%, respectively whereas the commercial energy shared larger share of 74.16%. However, lower energy share was observed in non-commercial energy of approximately 26%. The energy input source wise in the form of direct and indirect, renewable and non-renewable, and commercial and non-commercia for cultivation of paddy crop is shown in Fig. 4 and Table 3.

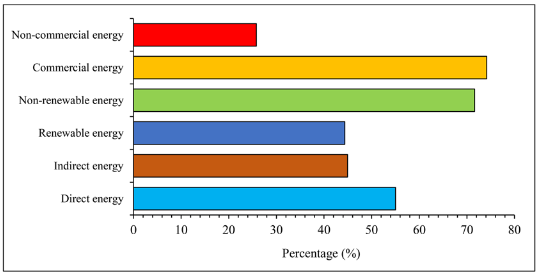

Fig. 4. Energy input (MJ/ha) in different modes of energy source in paddy production.

Table 3. Total energy input in the form of direct, indirect, renewable and non-renewable energies for paddy production.

Type of energy	Paddy crop MJ/ha	Percentage share (%)
Direct energy	16570.49	55.02
Indirect energy	13539.22	44.96
Renewable energy	13365.46	44.38
Non-renewable energy	21571.97	71.63
Commercial energy	22333.47	74.16
Non-commercial energy	7776.24	25.82
Total energy input	30,114.6	100

The total energy consumed for various operations in paddy cultivation during farm operation was in the 137814.6 MJ/h which included 30,114.6 MJ/h energy as input sour and 1,07,700 MJ/h as output source as shown in Table 4. The input energy in seed, chemicals and human labor was approximately 2% whereas diesel input for the production system for 6%. The machinery input energy was 3% and electricity input energy was 23%. The highest input energy was observed in water for irrigation (35%) and fertilizers (27%) as shown in Fig. 5. The input energy of human labor and machinery had a contribution of 576.24 and 1348.05 MJ/ha in paddy cultivation process followed by diesel energy input of 8.086 MJ/ha. The irrigation

Table 4. Analysis of input-output energy use in rice production system in RS Pura, J and K, India.

Sl. No.	Parameters	Unit	Energy coefficient (MJ/unit)	Energy consumed (MJ/ha)	Total energy (MJ/ha)	Percentage (%)
			Input parameters			
1	Human labor	h	1.96 MJ/h	294 Man/h	576.24	1.910
2	Machinery (Seedbed preparation, nursery raising and transplanting, bund making, and harvesting)	h	62.7 MJ/h	21.5	1348.05	4.480
3	Diesel	L	56.3 MJ/lit	43.25 lit	2434.97	8.086
4	Seed	kg	14.7 MJ/kg	45 kg	661.5	2.197
5	Irrigation water	m^3	10000	0.45 m^3	4500	45.179
	Electricity	(kWh)	11.93	759.37	9059.28	
	Submersible pump (15 hp)	h	68.4	0.0675	46.17	
6			Chemical spraying			
	a) Insecticide	L	120 MJ/lit	1.5 lit	180	2.507
		L	120 MJ/lit	0.5 lit	60	
	b) Herbicide	L	120 MJ/lit	2.5 lit	300	
		kg	120 MJ/kg	0.75 kg	90	
	c) Fungicide	L	120 MJ/lit	1lit	120	
	d) Knapsack sprayer		62.7 MJ/h	0.0781	4.89	
7	Fertilizer spraying					
	a) N	kg	60 MJ/kg	120 kg	7200	35.64
	b) P_20_5	kg	11.1 MJ/kg	60 kg	666	
	c) K_20	kg	6.7 MJ/kg	25 kg	167.5	
	d) FYM	kg	0.30 MJ/kg	9000 kg	2700	
	Total input energy (MJ/ha)				30,114.6	
			Output parameters			
1	Rice	kg	14.7 MJ/kg	3500 kg	51450	47.77
2	Straw	kg	12.5 MJ/kg	4500 kg	56250	52.23
	Total output energy (MJ/ha)				107,700	

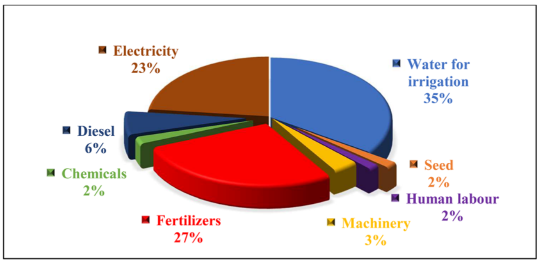

Fig. 5. Energy input (MJ/ha) share percentage from different energy source in paddy production.

process which requires almost 9 irrigations consumed 4500 MJ/ha followed by electricity (9059.28 MJ/ha) and submersible pump (46.17 MJ/ha). The input energy in chemical spraying for insecticide, herbicide and fungicide was found to be 240, 390 and 120 MJ/ha. The energy consumed in praying chemicals with knapsack sprayers was found to be very less i.e., 4.89 MJ/ha. The other energy share in fertilizer spraying includes N (7200 MJ/ha), P_2O_5 (666 MJ/ha), k_2O (167.5 MJ/ha), and F.Y.M. (2700 MJ/ha). The specific energy and energy efficiency was found to be 2.09 (MJ/ha) and 3.58, respectively, whereas the energy productivity and energy intensity was found to be 1.71 (kg/MJ) and 0.28, respectively. The water productivity was 11.43 (kg/MJ) and net energy was 77585 (MJ/ha). The output energy of the final output of the paddy crop for rice was found to be 51450 MJ/ha and straw was 56250 MJ/ha.

CONCLUSION

The study used energy analysis to assess the energy flow of paddy cultivation production system in RS Pura region of Jammu district of J and K. The results showed that the energy input of rice production system was 30114.6 MJ/ha. Energy inputs related to water, fertilizer and electricity account for the largest share of total energy inputs in rice production systems. Direct energy accounts for 55.02% of the total energy input of traditional systems, and non-renewable energy accounts for 71.63% of the total energy input. The results showed that the net energy value of traditional rice production system was low. The use of energy in rice production system in the research area is not efficient and environmentally safe in order to use huge inputs. On the other hand, excess use of inputs can cause adverse effect on ecosystems, which may cause degradation due to overuse of non-renewable resources. It is necessary to use today's modern technologies and new harvesting machines for production, so as to reduce the high input energy sources in rice production system. There is a wide scope and requirement of small-scale agricultural machineries in the region to reduce the human drudgery during operations with heavy implements and manual tools. Based on the energy analysis, it can be concluded that the irrigation, electricity, and fertilizer are quite higher than desired for rice production system. The objective of the study is not to decrease the energy input but it emphasises on its efficient utilization.

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