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Energy Input and Output Use Pattern in Wheat Crop Production System in South Western Zones of Punjab, India

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Abstract: The present study was carried out to assess and examine the input and output energy use pattern for the cultivation of wheat crops in the Muktsar district of Punjab, India. The local farmers were interviewed and information was collected for various inputs used in the wheat crop production system during the survey in the village. Based on the information received from local farmers, the various inputs used for raising wheat crops were identified and converted into energy with the help of standard energy equivalents. The results showed that the total energy expenditure was 28244.126 MJ/ha in the region for wheat crop production. The largest share was shared by diesel energy input of approximately 39 %. The total input energy in fertiliser and electricity was 32 % and 19 %. The total direct and indirect energy used for wheat cultivation was 19.57 and 14.39 %, respectively. The overall renewable energy used was 3 % and the rate of use of non-renewable input energy was 30.96 %.

Keywords: Wheat, Input energy use, Output energy, Energy ratio, Energy use pattern, Wheat crop, Specific energy

India is the second largest wheat producer in the world and the 10th largest wheat exporter in the world. In 2020, global wheat production reached 761 million tons, led by China, India, and Russia combined 38% of the total world. India's wheat production increased from 36 million tons in 1980 to 107 million tons in 2022. North India traditionally dominates wheat cultivation in India. The demand for Indian wheat in the world showed an upward trend. The country exported 7,239,366.80 metric tons of wheat to the world worth Rs 15,840.31 crores in the year 2021-22. Punjab contributes 15-20 % (Around 17.57 million tonnes) of total wheat production in India with an average growing rate of 2.36 per year (Anonymous 2022). Agriculture can be characterised as both a producer and an energy consumer. They use large amounts of locally available commercial and non-commercial energy including seeds, manure, and animal energy, as well as direct and indirect energy in the form of irrigation water, electricity, fertilizers, machinery, diesel, etc (Khalaj et al 2023). The efficient use of this energy contributes to increased production and productivity which contributes to the profitability and competitiveness of rural agriculture. The increase in energy use has brought with it several important problems for human health and the environment, therefore, the efficient use of inputs has become more important for sustainable agricultural production.

Energy plays an influential role in the development of important sectors of economic importance, such as agriculture, industry, and transportation. Many researchers are focusing their research on the energy management of various types of agricultural practices. Energy consumption for almost all agricultural activities in developing countries has increased very rapidly as a result of current economic growth and development (Saber et al 2020). Energy inputs and outputs are both very important factors in determining energy efficiency and its environmental impact on crop production systems. Energy use and production vary between crops, production systems, and the intensity of various management practices. However, the increased use of inputs in agricultural production may not maximize profits due to higher production costs. Energy, the economy, and the environment are interrelated. The profitability and productivity of the agriculture production system depend on energy consumption (Kashyap and Agarwal 2021). The amount of energy used depends on the level of mechanization, the amount of active agricultural work, and arable land. Hence, the main purpose of this study was to determine the energy flow pattern in the wheat cultivation process in the Muktsar region of Punjab, India.

MATERIAL AND METHODS

Study location description: Muktsar district lies in the south-western part of the state and lies between North Latitude 30°28'04.6" and East Longitude 74°29'17.9" which falls in the Ferozepur division. The climate of the region is dry and semi-humid and receives an average annual rainfall of

430.7 mm on 22 rainy days. The monsoon period contributes 79 % of annual rainfall and the remaining 21% occurs during the non-monsoon period. The main sources of irrigation in the region are canals and tube wells. The wheat crop is sown between late October to December, while it's harvesting usually starts in April.

Methodology: The preliminary data was collected related to the different input sources used for wheat cultivation in the region from the farmers. The preliminary information included input sources such as various machinery systems used for cultivation from tillage activities to the harvest process. The energy consumption in production agriculture to grow a particular crop varies due to its climatic agricultural location, crop production, and management practices, agriculture machinery availability, mechanization status of the region, consumption pattern of different types of energy inputs in different forms, and other inputs used in raising the corresponding crops. Therefore, queries were made from the group of farmers related to sources of irrigation, and amount of water used, and types of fertilizer used by farmers. The number of human power and quantity of seeds, diesel, electricity, farm yard manure, chemicals, and fertilizers used per hectare were also considered for a better understanding of the cultivation practice. To determine the input and output energy for the overall cultivation process, the physical quantities of inputs and outputs were multiplied by their corresponding energy conversion equivalents to get the total energy used in megajoules per hectare. Energy production comes mainly from the products and by-products of crops. Some operations like transportation and disposal/removal of agricultural residues were not included in the evaluation. Therefore, the total estimated energy consumption applies to the crop production system before the post-harvest process. The study evaluated the energy inputs for wheat crops used only in the production process of wheat crops for one growing season and sources without considering the other natural resources such as annual rainfall, solar radiation, and wind. and the energy used for different operations from various sources was calculated by using the energy equivalent (Table 1). The use of human energy was assessed based on

Table 1. Energy equivalents for different inputs and outputs in wheat cultivation practice

Parameters	Unit	Energy equivalent	Source
Input parameters			
Human labour	h	1.96 MJ/h	Kumar et al 2018
Machinery	h	62.7 MJ/h	Kumar et al 2018
Combine	h	68.4 MJ/h	Sharma et al 2020
Tractor	h	68.4 MJ/h	Sharma et al 2020
Trolley	h	62.7 MJ/h	Sharma et al 2020
Disc harrow	h	62.7 MJ/h	Sharma et al 2020
Cultivator	h	62.7 MJ/h	Sharma et al 2020
Planker	h	62.7 MJ/h	Sharma et al 2020
Bund former	h	62.7 MJ/h	Sharma et al 2020
Straw Reaper	h	68.7 MJ/h	Sharma et al 2020
Reaper	h	62.7 MJ/h	Sharma et al 2020
Submersible pump (15 hp)	h	68.4 MJ/h	Sharma et al 2020
Knapsack sprayer	h	62.7 MJ/h	Sharma et al 2020
Electricity	kW/h	11.93 MJ/h	Kuswardhani et al 2013
Diesel	L	56.31 MJ/lit	Kumar et al 2018
Chemical fertilizers			
Topic	kg	120 MJ/kg	Kuswardhani et al 2013
Algrip	L	120 MJ/lit	Kuswardhani et al 2013
Tilt	L	120 MJ/lit	Kuswardhani et al 2013
Rogar	L	120 MJ/lit	Kuswardhani et al 2013
Fertilizers spraying			
Nitrogen	kg	60.60 MJ/kg	Shrivastava et al 2022
Phosphate	kg	11.1 MJ/kg	Mousavi-Avval et al 2011
Potash	kg	6.7 MJ/kg	Ziaei et al 2013
FYM	kg	0.30MJ/kg	Jin et al 2018
Wheat seed	kg	14.7MJ/kg	Ziaei et al 2013
Output parameters			
Wheat grain yield	kg	14.7MJ/kg	Shrivastava et al 2022
Wheat straw yield	kg	12.50MJ/kg	Shrivastava et al 2022

the time consumption of labour activity and the total number of people involved in each operational process. A labours' total energy spent was assessed by the multiple of the total number of hours of labour activity in a given unit process with the energy coefficient of labour for an hour worked per unit per operation including manual and mechanicals. The main input for fuel in wheat production was high-speed diesel used in agricultural machinery such as tractors, combine, reaper, and submersible pump sets. To calculate the reliable data on the fuel consumption by different operations with the help of the following relationship (Singh et al 2020).

$$F = (LCF \times RHP \times SFC) / 1000$$

Where “F” is the fuel consumption of fuel per unit of time (l/h), “LCF” is the load coefficient factor which is the ratio of actual load on the tractor system to maximum load for corresponding operation whereas “RHP” and “SFC” are rated horsepower in kilowatt (kW) and specific fuel consumption in milliliter per kilowatt (ml/kWh), respectively. The specific fuel consumption and rated horsepower of various agricultural machinery used for each corresponding operation used by farmers for a particular region were taken into consideration from the engine specification of the particular machinery used in the region. The Load coefficient factors used for the study are shown in Table 2. The electricity was mainly used for pumping and irrigation. Electric motors of different ratings were found to be used by different categories of farmers for irrigation purposes. The electricity consumption by electric motor was estimated by the following relationship. Electricity was used in electric motors for irrigation purposes. Electric motors of different classifications appeared to be used by different categories of farmers for irrigation purposes. The electricity consumption was estimated by the following relation.

$$E = RHP \times T$$

where “E” is the electricity expenditure in kilowatts per hour (kWh), “RHP” is the rated horsepower of the electric motor in Kilowatt (kW), and “T” is the total time used for irrigation (h). The energy consumption of the agricultural types of machinery such as tractors, combines and straw reaper for the wheat production system was determined based on the weight of particular machinery, service lifespan, and average working hours for one year. The energy input of the machinery system by using the following formula

$$ME = (G \times E)/ TC_{ef}$$

where “ME” is the machine energy in megajoules per hectare (MJ/ha), and “G “is the total weight of the corresponding machinery system in kilograms (kg). “E” is the total energy consumed by agricultural equipment in megajoules per kilogram (MJ/kg) whereas “T” is the total service lifespan of the machine in hours (h) and “C_{ef}“ is the actual field capacity of the agricultural machinery used in the wheat production system in hectare per. (ha/h). After the estimation of total energy input and output, the energy efficiency, specific energy, water productivity, energy productivity, energy intensity, and net energy were determined by using the different relations (Kumar et al 2017) as shown below:

i. Specific energy = Total energy input (MJ/ha) – Grain yield (kg/ha).
ii. Energy efficiency = Total energy output (MJ/ha) – Total energy input (MJ/ha).
iii. Energy productivity = Grain yield (kg/ha) – Total energy input (MJ/ha).
iv. Energy intensity = Total energy input (MJ/ha) – Total energy output (MJ/ha).
v. Energy productivity = Grain yield (kg/ha) – Amount of water applied (MJ/ha).

Net energy = Energy output (MJ/ha) – Energy input (MJ/ha).

RESULTS AND DISCUSSION

The total input and output energy for the cultivation of wheat crops was 28244.126 and 115795 MJ/ha. The total of human energy in all operations including tillage, sowing, bund making, irrigation, fertilizer and chemical spraying, and harvesting was found to be 201.39 MJ/ha. The total of different types of machinery inputs during form operations was found to be 602.986. The total energy consumed by electricity was 5368 MJ/ha. The largest share was contributed by diesel energy around 11136.99 MJ/ha. The total input energy for chemicals and fertilizers used in the study was 227.76 and 1617 MJ/ha whereas the total input energy for wheat seeds was 9090 MJ/ (Table 3). The specific

Table 2. Load coefficient factor (LCF) for different unit operations from various power sources

Power source	Type of work	LCF
Stationary diesel engine	Threshing	0.8
	Water-lifting	0.6
Tractor	Heavy work such as primary tillage	0.6
	Medium work such as secondary tillage, sowing intercultural operations, etc.	0.5
	Light work such as transport, water-lifting, etc.	0.4

Table 3. Input and output energy use pattern per unit hectare in wheat production

Parameters	Energy equivalent (MJ/unit)	Energy consumed (MJ/unit)	Total energy consumed (MJ/ha)	Total share (%)
Input parameters				
Human labour (Includes all operations)	1.96 MJ/h	102.75 man/ha	201.39	0.71
Machinery				
Combine	68.4 MJ/h	1.5	42.68	2.14
Tractor	68.4 MJ/h	25	342	
Trolley	62.7 MJ/h	6.25	78.375	
Disc harrow	62.7 MJ/h	5	36.366	
Cultivator	62.7 MJ/h	3	9.405	
Planker	62.7 MJ/h	3.5	16.458	
Bund former	62.7 MJ/h	1	2.069	
Straw Reaper	68.7 MJ/h	2.5	41.22	
Reaper	62.7 MJ/h	1	3.135	
Submersible pump (15 hp)	68.4 MJ/h	40	27.36	
Knapsack sprayer	62.7 MJ/h	25	3.918	
Electricity	11.93 MJ/h	450	5368 MJ/ha	19.01
Diesel	56.31 MJ/lit	197.78	11136.99	39.43
Chemical fertilizers				
Topic	120 MJ/kg	0.5 kg/ha	60	0.81
Algrip	120 MJ/lit	0.025 lit/ha	3	
Tilt	120 MJ/lit	1 lit/ha	120	
Rogar	120 MJ/lit	0.373 lit/ha	44.76	
Fertilizers spraying				
Nitrogen	60.60 MJ/kg	120 kg	7272	32.18
Phosphate	11.1 MJ/kg	60 kg	666	
Potash	6.7 MJ/kg	60 kg	402	
FYM	0.30MJ/kg	2500 kg	750	
Wheat seed	14.7MJ/kg	110 kg	1617	5.72
Total input energy (MJ/ha)			28244.126	
Output parameters				
Wheat grain yield	14.7MJ/kg	4850 kg	71295	61.57
Wheat straw yield	12.50MJ/kg	3560 kg	44,500	38.42
Total output energy (MJ/ha)			115795	

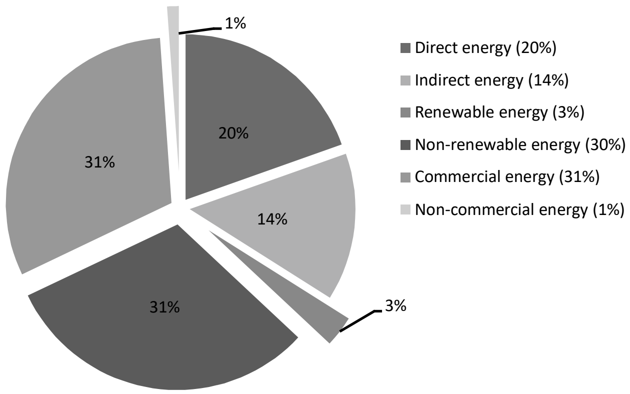

Fig. 1. Energy input (MJ/ha) in different modes of energy source in wheat crop

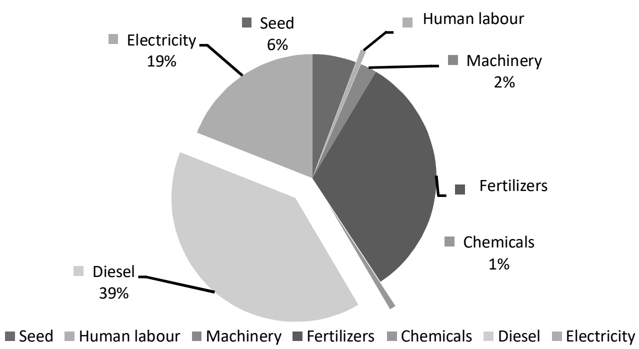

Fig. 2. Energy input (MJ/ha) share percentage from different energy sources in wheat crop

energy and energy efficiency were 0.4 and 4.1 MJ/ha, respectively. The energy productivity and energy intensity were 2.52 kg/MJ and 0.24, respectively. And the net energy was 87550.87 MJ/ha. Direct and indirect energy was found to be accounting 20 and 14% of energy inputs. The largest share was contributed by commercial and non-renewable energy whereas a very less percentage of non-commercial and renewable energy (Table 4; Fig. 1). The energy input (MJ/ha) share percentage from the different energy sources in wheat crops is shown in Figure 2.

CONCLUSION

Energy use efficiency in wheat crop production systems varies from region to region depending upon many factors. The total input energy consumption for raising wheat crops was 28244.126 MJ/ha. The largest share was consumed by diesel, fertiliser and electricity. Therefore, need to focus more on fuel consumption, fertilizers, and electricity to reduce energy consumption in growing crops compared to other factors. More improved wheat crop management practices and procedures must be followed to increase the efficiency of nitrogen use. It is also necessary to educate the farmers about a zero-tillage system and other energy-saving agricultural machinery that can save a large amount of energy to reduce farm energy consumption and improve energy efficiency.

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