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Energy Assessment of Rice- Wheat Cropping Systems in Agro-Climatic Zone-1 of Haryana State

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Authors' contributions

This work was carried out in collaboration among all authors. Authors PS and Y designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KV and YKY managed the analyses of the study. Author R managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The aim of study to examined the operation-wise and source wise energy use in wheat and rice crop production. Present study was conducted in four districts of Haryana namely Kurukshetra, Karnal, Kaithal and Sonipat, which are situated at the bank of Yamuna canal and comes under agro climatic zone-1. In this study total 1080 farmers from 120 villages in different categories (360 from each group) were interviewed and information on various input in wheat and rice crop production was collected during winter and rainy seasons consecutive two years i.e. 2018-19 and 2019-20. Based on the collected information, all the cultural practices in wheat and rice crop production were identified and converted into energy by using standard energy equivalents. Results showed that total operation-wise energy expenditure by large, medium and small farmer's was 43693.82, 42557.21 and 41915.70 MJ/ha respectively in rice crop production. In case of wheat crop cultivation total operation-wise energy consumed by large, medium and small farmer's was 26472.74, 26576.39 and 25644.18 MJ/ha respectively. In both the crop production irrigation and fertilizer share more than 75 % of the total energy. Fertilizer alone accounted approximately 40 % 0f total energy followed by irrigation and it was also estimated that large group farmer's consumed more energy as compared to medium and small categories farmers in cultivation of rice and wheat crop. Total source-wise energy expenditure by large, medium and small farmer's was 39402.40, 36579.49 and

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36332.21.70 MJ/ha respectively in rice crop production. In case of wheat crop cultivation total source-wise energy consumed by large, medium and small farmer's was 19969.47, 20486.03 and 20180.73 MJ/ha respectively. From the study it was concluded that energy consumption has a positive relationship with the yield.

Keywords: Wheat and rice crop; energy auditing; energy productivity; Haryana.

1. INTRODUCTION

We all know, Agriculture sector not only provides the bread, fodder and other raw material (as feedstock for industries) to nation, this sector also helping in enhancing the living standard of majority of Indian population. India's economy is classified into three sectors - Agriculture & allied; Industry; and Services. Agriculture sector includes Agriculture (Farming & Livestock), Forestry & Logging, Fishing and related activities [1,2]. After independence, the agriculture sector continues the backbone of Indian economy. Before green revolution, our nation was suffering from shortage of food grain. At that time, all agricultural experts as well as bureaucrats of India has focused primarily on raising agricultural output and improving good security [3,4].

After green revolution the share of rice and wheat production in the country have been consistently increasing. Around 40-45 percent production increase in rice and 70-74 percent production increase in wheat. Rice and wheat are the major cereals crops in the country as well as in the state of Haryana and are the cornerstones of national food security. Haryana and Punjab accounts for 53 percent of total area under rice and wheat crops. In Haryana, rice was grown over an area of 1.38 mha with total production of 4.45 Mt and productivity 3450 kg/ha during 2016-17 [5]. Based on Ministry of Agriculture and Farmers Welfare of India statistics, India produced about 98.38 million tonnes of wheat in 2016-17. Out of 8.9 percent of wheat growing area of the country, the contribution of Haryana is nearly 13.3 percent towards national production of wheat with an average productivity approximately 4.0 tonnes per hectare. In Haryana wheat was grown over an area of 2.52 mha and productivity 4624 kg/ha during 2016-17 [5].

In modern era, agriculture crops especially rice and wheat are directly depends on high yielding verities, mechanization, chemical fertilizers, as well as on other energy input viz. fuel, electricity and weedicide [6]. The excessive use of agricultural inputs consumed more energy in form of human, animals and machinery etc [7]. For production of rice and wheat crop, more energy is used in comparisons to other cereal crops as well as legume crops. The input energy used pattern to raise a particular crop depends on many factors like size of land holding of farmers, availability of farm power at the farmer filed, agro-climatic location and management practices [8-10]. In India, farmer are categorized based on their land holding. In present study, farmers are categorized as small, medium and large according to their land holding. The objective of this study is to audit the energy use pattern of different category of farmers in cultivation of rice-wheat cropping system, which will be helpful to identify the energy intensive operation in rice-wheat cropping pattern.

2. MATERIALS AND METHODS

The study was conducted in four districts of Haryana namely Kurukshetra, Karnal, Kaithal and Sonipat, which are situated at the bank of Yamuna canal and comes under agro climatic zone-1 as presented in Fig. 1. The above said districts selected based on the spread of area under rice-wheat cropping system and the farmer's livelihood. This agro climatic zone is considered important for rice and wheat cropping due to its higher productivity in comparison with to national average. The farmer's were grouped in to three categories small (0-2 ha), medium (2-10 ha) and large (> 10 ha) based on their land holding. The following classification was used in accordance with the classification used by the Indian Council of Agricultural Research (ICAR) [11]. Total 1080 farmers from 120 villages in different categories (360 from each group) were interviewed during rabi and kharif seasons consecutive two years i.e. 2018-19 and 2019-20.

The information regarding various cultivation operations of rice- wheat crop production was collected by face to face interviewed with each selected farmer using pre-designed questionnaire. The questionnaire was formatted in such a manner that it includes all details regarding all unit operations in rice and wheat crops production as well as information about

inventory of all resources use. It mainly includes information on size of land holding, availability of farm power, agro-climatic location, and management practices, fertilizers, agrochemical used and farm yard manure, machinery used and grain and straw yield of crops. Energy efficiency, energy productivity, specific energy and net energy gain for rice and wheat production were also calculated using the equations as suggested in literature [12,13]. Total output energy was determined based on the energy value associated with paddy grain (14.7 MJ/kg dry grain) and straw (13.75MJ/kg dry straw). Crop input was grouped in to two categorized direct and indirect energy source. Direct energy sources included fuel energy, electrical energy and human energy andindirect energy sources are fertilizers, chemicals , farm yard manure, high yielding varieties used in both crops etc. In order to estimate the energy use in crop production operations, information on amount, frequency and duration of unit operations and energy inputs was collected and quantified using the energy coefficient as suggested by Mittal et al. [11] and Kitani [14].

3. RESULT AND DISCUSSION

3.1 Operation-wise Energy use Pattern in Rice and wheat Crop Cultivation

The operational energy use pattern of rice and wheat crop is presented in Table 1. For production of wheat crop; sowing, land preparation, irrigation, weeding, fertilizer, harvesting, threshing and straw management operations are performed. If we talk about the agro-climate zone-1, where irrigation is concerned for any operation, large farmers spent much energy on the other hand medium and small farmers spent munch energy in the fertilizer operation. The total operation wise energy consumption of large, medium and small farmers was found to be 26472.74 MJ/ha, 26576.39 MJ/ha and 25644.18 MJ/ha, respectively in wheat crop production. It can be seen from

Fig. 1. Agro climatic zone of Haryana

Table 1 that in wheat medium and small farmer consumed more energy in fertilizer operation while large farmer consumed more energy in irrigation operation. Sowing, land preparation, weeding, harvesting and straw management contributed 2150.55 MJ/ha, 1649.00 MJ/ha, 33.29 MJ/ha, 665.06 MJ/ha and 1401.47 MJ/ha in case of large farmer in wheat. Sowing, land preparation, weeding, harvesting and straw management contributed 2217.08 MJ/ha, 1376.45 MJ/ha, 43.75 MJ/ha, 783.94 MJ/ha and 1499.47 MJ/ha in case of medium farmer in wheat crop. Sowing, land preparation, weeding, harvesting and straw management contributed 2289.69 MJ/ha, 1502.83 MJ/ha, 47.04 MJ/ha, 176.4 MJ/ha and 1046.59 MJ/ha in case of small farmer in wheat crop. On the other hand the total operation wise energy consumption of small, medium and large farmers was found to be 41,915.70 MJ/ha, 42,557.21 MJ/ha and 43,019.82 MJ/ha respectively in rice crop production. Table-3 depict that in rice cultivation among all operations, Irrigation contributed maximum energy which was 23,397.32 MJ/ha, 23,869.21 MJ/ha and 23,898.46 MJ/ha, respectively followed by fertilizers among all category of farmers. Puddling, land preparation, seedling preparation, transportation, harvesting and threshing, transplanting and weeding contributed 3263.73 MJ/ha, 2462.97 MJ/ha, 837.80 MJ/ha, 741.07 MJ/ha, 650.00 MJ/ha, 626.44 MJ/ha and 42.03 MJ/ha, respectively in case of small farmers. Puddling, land preparation, land development, seedling preparation, green manuring, transportation, harvesting and threshing, transplanting and weeding contributed 3647.69 MJ/ha, 2626.21 MJ/ha, 1104.21 MJ/ha, 787.21 MJ/ha, 787.21 MJ/ha, 733.94 MJ/ha, 678.96 MJ/ha, 632.96 MJ/ha and 45.08 MJ/ha, respectively in case of medium farmers. Puddling, land preparation, land development, seedling preparation, green manuring, straw management, transportation, harvesting and threshing, transplanting and weeding contributed 3,717.90 MJ/ha, 2762.78 MJ/ha, 1201.73 MJ/ha, 829.75MJ/ha, 352.92 MJ/ha, 739.84 MJ/ha, 739.84 MJ/ha, 683.81 MJ/ha, 652.78 MJ/ha and 47.87 MJ/ha, respectively in case of large farmers. It also depicts from the Table-1 that medium and small farmers did not adopt straw management in their cultivation practices for rice. Zero energy in green manuring and land development operation in case of small farmers indicated that they did not include green manuring and land development operation in their rice cultivation practice.

3.2 Source-wise Energy use Pattern in Rice and wheat Crop Cultivation

The source wise energy consumption pattern of rice and wheat is presented in Table 2. It is observed from the table that the share of each sources of energy varied with a category of farmer. Total energy consumption for wheat production of small, medium and large were found to be 19,969.47 MJ/ha, 20,486.03 MJ/ha and 20,180.73 MJ/ha respectively. For cultivation of wheat crop, fertilizer contributed as a major source of energy consumption i.e. contribution of fertilizer energy as a source was in range of 9,798.32 to 11,747.10 MJ/ha followed by electricity (4,095.24 – 3,485.31 MJ/ha), diesel (3,586.58 – 2,727.48 MJ/ha), seed (1,764.00 – 1,911.00 MJ/ha), machinery (496.54 – 188.94 MJ/ha) and human (228.79 - 393.90 MJ/ha) (Table 2). On the other hand the source wise energy consumption for rice production were 36,332.21 MJ/ha, 36,579.49 MJ/ha and 39,402.40 MJ/ha for small, medium and large farmers, respectively. For cultivation of rice crop, it is found that, among all the sources of energy, electricity (20441.06, 20735.51 and 20930.06 MJ/ha) was found to be the major source in small, medium and large farmers, respectively (Table 2). It accounts to 56.0-57.11% in all three category of farmers. The next energy consuming operation was fertilizer which contributed 26.90, 20.88 and 22.34% followed by diesel (10.05, 12.45 and 15.90%), machinery (4.59, 7.24 and 6.54%), human (1.68, 1.16 and 1.11 %) and seed (0.50, 1.58 and 1.11 %) in small, medium and large farmers respectively.

3.3 Energy Inputs and Variation of Indicators of Energy Usage Efficiency for Different Category of Farmers

Table 3 present different indicators of energy usage efficiency like net energy gain, energy ratio, specific energy, energy productivity etc. These would help in analysis of energy use efficiency during rice and wheat crop production. For production of wheat crop medium farmer had the highest energy input requirement followed by the large farmer. On the other hand for production of rice crop larger farmer used highest energy input and small farmer used lowest energy amongst all farmer's group [15,16]. Direct energy inputs include human labour and fuel, whereas, indirect energy inputs include machinery, seed, fertilizer and pesticide for rice and wheat production. Direct and indirect energy

Table 1. Operation-wise energy use pattern in Rice - wheat cropping production

Operation performed under wheat	LF Zone-1 MJ/ha	MF Zone-1 MJ/ha	SF Zone-1 MJ/ha	Operation performed under rice	LF Zone-1 MJ/ha	MF Zone-1 MJ/ha	SF Zone-1 MJ/ha
Sowing	2150.55	2217.08	2289.69	Seedlings	829.75	787.21	837.80
Land Preparation	1649	1376.45	1502.83	Green Manuring	352.92	787.21	0.00
Irrigation	10772.97	10133.75	9105.55	Land Development	1201.73	1104.21	0.00
Weeding	33.29	43.75	47.04	Land Preparation	2762.78	2626.21	2462.97
Fertilizer	9800.4	10521.95	11476.08	Puddling	3717.90	3647.69	3263.73
Harvesting	665.06	783.94	176.4	Transplanting	652.78	632.96	626.44
Straw Management	1401.47	1499.47	1046.59	Irrigation	23898.46	23869.21	23397.32
				Weeding	47.87	45.08	42.03
				Fertilizer	8805.96	7644.53	9894.34
				Harvesting & Threshing	683.81	678.96	650.00
				Transportation	739.84	733.94	741.07
				Straw Management	739.84	0.00	0.00
Total Input Energy	26472.74	26576.39	25644.18				
				Total Energy (MJ/ha)	43693.82	42557.21	41915.70

Table 2. Source-wise (MJ/ha) energy use pattern for wheat and rice crop

Source	Wheat			Rice		
	LF	MF	SF	LF	MF	SF
Seed	1764.00	1852.20	1911.00	383.75	580.35	184.75
Human	228.79	230.89	393.90	437.87	425.02	611.91
Diesel	3586.58	3502.19	2727.48	6266.81	4548.81	3652.18
Machinery	496.54	503.39	188.94	2579.93	2648.79	1668.05
Fertilizer	9798.32	10519.95	11474.10	8803.98	7641.00	9774.26
Electricity	4095.24	3877.41	3485.31	20930.06	20735.51	20441.06
Total	**19969.47**	**20486.03**	**20180.73**	**39402.40**	**36579.49**	**36332.21**

Table 3. Energy inputs and Variation of indicators of energy usage efficiency for different category of farmers

Energy analysis	Wheat			Rice		
	LF	MF	SF	LF	MF	SF
Direct MJ/ha	3815.37	3733.07	3121.39	6704.68	4973.83	4264.09
Indirect MJ/ha	22580.51	22771.25	22465.35	32697.72	31605.66	32068.12
Yield Wheat /Rice grain (kg/ha)	6700.00	6620.00	6515.00	5300.00	5240.00	4930.00
Yield Wheat/Rice (kg/ha)	2960.00	2810.00	2754.00	5500.00	5400.00	5130.00
Wheat/Rice grain (MJ/ha)	98490.00	97314.00	95770.50	77910.00	77028.00	72471.00
Wheat/Rice straw (MJ/ha)	37000.00	35125.00	34425.00	68750.00	67500.00	64125.00
Total input energy (MJ/ha)	26472.74	26576.39	25644.18	43693.82	42557.21	41915.70
Total output (MJ/ha)	135490.00	132439.00	130195.50	146660.00	144528.00	136596.00
Energy ratio	5.12	4.98	5.08	3.36	3.40	3.26
Specific energy (MJ/kg)	3.95	4.01	3.94	8.24	8.12	8.50
Net energy gain (MJ/ha)	109017.26	105862.61	104551.32	102966.18	101970.79	94680.30

was calculated by the procedure adopted by Parmod et al. (2019). In case of indirect energy inputs per hectare, the relative energy used by SF and LF were 1.34 and 0.83 %, respectively as compared to MF for production of wheat crop. In case of direct energy inputs per hectare, the relative energy used by MF and SF were 2.15 and 18.18 %, respectively as compared to LF category for production of wheat crop. In wheat and rice cultivation net energy gain varied from 109017.26-104551.32 MJ/ha and 102966.18-94680.30 MJ/ha respectively among all categories of farmers. Specific energy of large, medium and small category framers was 3.95, 4.01, and 3.94 MJ/ha, respectively in wheat crop. This indicated that energy input per kg of product was quite high in case of medium farmers. On the other hand in rice cultivation the specific energy of large, medium and small category farmers was 8.24, 8.12 and 8.50 MJ/ha respectively, this indicated that energy input per kg was quite high in case of small farmers. Energy productivity varied between 0.14 to 0.15 kg/MJ among all categories.

4. CONCLUSION

In this study energy consumption in rice-wheat crop production for three categories (Large, Medium and Small) of farmer in agro climatic zone-I of Haryana region analyzed. It was conclude that after the present study in rice-wheat cropping pattern electricity and fertilizer are the most significant energy inputs followed by fuel. Therefore, to reduce input energy of rice and wheat crop farmer's need to focus on more on fuel, fertilizer and electricity in crop cultivation compared to other factors. The excessive energy consumption can be controlled by applying recommended dose of fertilizer and can be achieved by adopting crop management practices such as use of farm yard manure, snowing of nitrogen enrich crop (legume crop) , adoption of conservation tillage and adequate rate and timing of applying fertilizer when crop absorb maximum amount of nutrients. The consumption of fuel in rice wheat cropping pattern can be reduce by using efficient tillage method i.e. adopting the zero tillage or minimum tillage method in their cultural practice . During the study, it was found that in rice-wheat cultivation farmers irrigate their fields with electrical motor operated tube well. So electrical energy can be minimized by using solar operated tube well and used of modern irrigation technology i.e. drip and sprinkler irrigation. So appropriate management of resources can reduce energy use in rice wheat cropping pattern on farm and can improve energy efficiency

CONSENT

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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