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Estimation of energy requirement in wheat crop production in the Tarai region of Uttarakhand

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Abstract
The majority of the cropped land in India (65%) is used for food grain crops, with the maximum food grain production expected in the years 2021–22 at 316.06 million tonnes. With the increase in power availability from 0.3 kW/ha in 1961–1962 to 2.76 kW/ha in 2020–2021, the average food grain productivity in the nation has increased linearly from 0.71 t/ha to 2.39 t/ha. India is the world's second-largest producer of wheat. The crop demands a significant input of energy. Direct energy and indirect energy make up the two main categories of the input energy needed for crops. Compared to the Uttarakhand's hilly regions, the Tarai region's agriculture is far more advanced. The cultivable land is about 7.41 lakh ha which is about 14% of total reported area of 56.72 lakh ha. Because of high energy input used in the district of Udham Singh Nagar, the wheat crop average yield is 3.8 t/ha. This paper discusses the energy requirements for growing wheat in the Tarai region of the state of Uttarakhand in the India. Energy equivalence expressed in MJ/ha was used to calculate the amount of energy required for the various activities carried out in wheat production. The average amount of energy used to produce a wheat crop is found to be 24304 MJ/ha and of these renewal energy contributed 2667 MJ/ha & while that of non-renewal energy contribution was 21637 MJ/ha. The highest total energy of 12148.28 MJ/ha is consumed in fertilizer operation and the lowest total energy consumption of 872.98 MJ/ha is observed in plant protection. The energy ratio and energy productivity were found as 6.77 and 0.22kg/MJ.

Keywords: Energy, farm operations, energy ratio, productivity, Tarai, Uttarakhand, wheat

1. Introduction
India's food grain productivity increased linearly from 0.71 t/ha to 2.39 t/ha as a result of an increase in power availability from 0.3 kW/ha in 1961–1962 to 2.76 kW/ha in 2020-2021 (Singh 2021) [4]. The country produced the most food grains, amounting to 316.06 million tonnes, in the years 2021–2022. India is only second to China in terms of producing wheat, rice, pulses, and sugarcane. Rice (40-45%) is the only crop that is grown in more area than wheat, which makes up around 25% of all cereal crop acreage.

Crop production energy requires Direct and indirect energy sources as the two categories used to categorise agriculture. Land preparation, irrigation, intercultural work, threshing, harvesting, transportation of agricultural materials, and other tasks involved in crop production processes all demand direct energy (Singh, 2002) [3]. Farms and fields use direct energy directly. On the other side, indirect energy includes the energy consumed in the production of machinery, agrochemicals, seed, and fertilisers. In crop production, agriculture necessitates a planned and efficient use of energy. It is pertinent to strike a balance between energy use and supply, particularly in the agricultural sector, so as not to negatively impact production. As a result, it's important to determine how much energy any crop will need. By counting the quantity of the input material and multiplying that number by the material's energy coefficients, one can calculate the energy input for a specific agricultural operation. The primary energy inputs in an agricultural production system include electricity, fertilisers, fuel, and machinery (Karimi, 2008) [1]. In light of the previous study, the current study was conducted to evaluate the amount of energy needed to produce wheat in the Tarai region of Uttarakhand.

2. Materials and Methods
The Tarai Region is situated in the Uttarakhand districts of Dehradun, Haridwar, and Udham Singh Nagar. Crop cycles including rice-wheat-rice, sugarcane-ratoon-rice, rice-rapeseed-sugarcane-ratoon-rice, and rice-rice-peas are often utilised in the Tarai region of Uttarakhand. The wet season lasts from mid-June to early October in the Tarai region, and the dry season runs from early October to mid-June. The maximum temperatures, 42 °C, are recorded in May and June, while the lowest, 4 °C are recorded in December and January. The relative humidity ranges from 54% in May to 97% in July. The majority of the 1400 mm of precipitation falls during the monsoon season, which lasts from June to September.

The majority of Tarai soils are mollisols, which are distinguished by their 1-4% organic content and dry, coloured surface. Soils often have a medium to coarse texture, are well drained, and are not very deep. By conducting in-person interviews with each chosen farmer and using a questionnaire, data on various aspects of wheat crop production in the area, such as how much time and labour were required for various farm tasks like tillage, sowing, bund making, irrigation, weeding, fertiliser and chemical application, harvesting, threshing, and transportation, farm power and machine use, etc., were gathered. To ensure that every farmer in the population had an equal chance of participating in the study, farmers were chosen at random from among several Tarai area blocks.

2.1 Total energy inputs

The total input energy was determined by the sum of the input elements multiplied by the appropriate energy co-efficient (Gupta, 2004) for each as indicated in Table 1.

$$E = \sum (A_i * C_i)$$

Where,
E = Energy input
A_i = Input factors
C_i = Energy Equivalent for input factor

Table 1: Energy equivalents of different inputs

SI. No.	Source	Unit	Energy Equivalent (MJ)
1.	Human	Man-hour	1.96 1 adult women = 0.8 adult man 1 child = 0.5 adult man
2.	Animal	Pair-hour	10.10
3.	Diesel	Litre	56.31
4.	Electricity	Wh	16.93
5.	Seed	Kg	14.70
6.	FYM	Kg	0.3
7.	Fertilizer N P K	Kg	 60.6 11.1 6.7
8.	Agro chemical Inferior chemicals	Kg	120 100
9.	Machinery Electric Motors Prime Mover Farm Machinery	Kg	 64.80 68.40 62.10

Calculation of Direct, indirect and total Energy Consumption

The total energy consumption in a farm operation is the sum of human energy, animal energy, fuel, electricity, seed energy, fertilizer energy, machine energy and agro chemical energy. The various energy inputs were calculated using the following expressions.

Estimation of Direct energy use

$$DE = HLH \times 1.96 + BPH \times 10.10 + FC \times 56.31 + EC \times 11.93 \quad \ldots (3.1)$$

Where,
DE = Direct Energy, (MJ)
HLH = Human labor hours used, (h/ha)
BPH = Bullock pair hours used, (h/ha)
FC = Fuel consumption, (l/ha)
EC = Electricity consumption, (kWh/ha)

Estimation of Indirect energy use

IE = (C x WM x HUM x OA) + FYM X 0.3 MJ/kg + S x 14.7 MJ/kg + Ch. x 120 MJ/l x

Fertilizer (N X 60.0 X P X 11.1 X K x 6.7) … (3.2)

Where,
IE = Indirect energy input from machinery, (MJ)
C = Energy coefficient, (MJ/Kg)
WM = Weight of machinery used per hour, (Kg)
HUM = Hours use of machinery, (h)
OA = Operational area, (ha)
FYM = Farm Yard Manure, (Kg/ha)
S = Seed, (Kg/ha)

Estimation of Total energy use

TE = DE + IE … (3.3)

Where,
DE = Direct Energy, MJ,
IE = Indirect Energy, MJ

$$\text{Energy Productivity, kg/MJ} = \frac{\text{Crop Yield, kg/ha}}{\text{Total Energy Input, MJ/ha}} \quad \ldots (3.4)$$

$$\text{Energy Ratio} = \frac{\text{Total Energy Output, MJ/ha}}{\text{Total Energy Input, MJ/ha}} \quad \ldots (3.5)$$

3. Results and Discussion

A study was conducted to estimate the energy consumption pattern for wheat crop production in Tarai region of Uttarakhand and the same has been discussed as under:

3.1 Energy in wheat crop production

Large and medium categories of farmer use seed cum ferti drill for sowing operation and normally the seed is applied at a rate of 100 kg/ha. Small and semi-medium categories of farmers generally broadcast the seed manually and adopt a high seed rate of 110 kg/ha.

The energy used in wheat crop production was calculated and presented in the form of renewable and non-renewable energy sources used in all unit operations by average of all categories of farmers is presented in Table 2.

Table 2: Average Renewable and non-renewable energy values of renewal and non-renewal energy of all categories of farmers

	Renewable energy (MJ/ha)			Non-renewable energy (MJ/ha)					
Category of farmers	**Human**	**Seed**	**Total**	**Fuel**	**Electricity**	**Fertilizer**	**Agro-chemical**	**Machinery**	**Total**
Average	212	2455	2667	5335	3265	12148	482	407	21637

It is illustrated from the Table 2, that the average total renewable energy used by all category of farmers was 2667 MJ/ha. Similarly, average total non-renewable energy used by all category of farmers in the wheat crop production was 21637 MJ/ha. In the category of renewable energy, human energy's contribution is 212 MJ/ha (7.94%) while that of seed

energy contribution is 2455 MJ/ha (92.05%). Of the non-renewable sources, the highest contribution was by fertilizer 12148 MJ/ha (56.14%) followed by fuel 5335 MJ/ha, electricity 3265 MJ/ha, agro-chemical 482 MJ/ha and machinery 407.44 MJ/ha. Total 10.97% energy consumed in wheat crop production was renewable energy and remaining 89.03% energy consumed was non-renewable energy sources by average of all categories of farmers. The agro-climatic conditions increase or decrease the level of energy requirement depending upon the type of soil, crop rotation and level of mechanization in the region. Thus, the same crop being grown under different agro-climatic conditions would require different energy for crop production. The large and medium category farmers have high horse power tractors and they generally perform more (5-6 or even more) operations than other category of farmers and therefore energy consumption of large and medium category farmers was found to be greater than farmers of other categories. Farmers of small and marginal category generally hire tractors and implements from other category of farmers and perform lesser number of operations (2-3) to reduce their cost of cultivation therefore the energy consumption of small and marginal category farmer was found lesser than farmers of other categories.

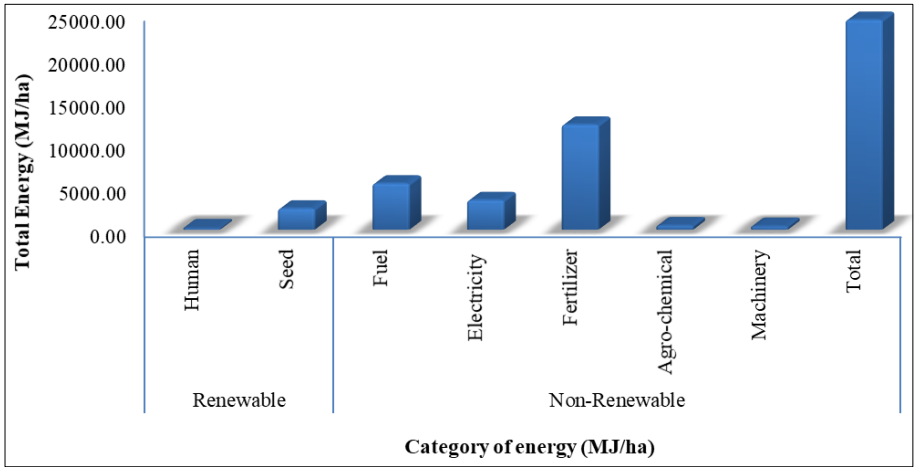

Fig 1: Renewable and non-renewable energy sources

It is illustrated from the Figure 1 that, among all the input energy, the human and seed energy is a renewable energy sources and the fuel, electricity, fertilizer, agro-chemical, machinery comes under the non-renewable energy sources. Maximum energy consumption was found in the fertilizer application than the other operations. Plant protection requires the minimum amount of energy than the other operations**.** Diesel engine or electric motor operated tube well, artisan wells and canals are the main source of irrigation in the area. It was observed that large and small farmers generally use canal water, artisan well and other natural water sources in which no fuel energy is required. Since the large farmers also use canal water for irrigation therefore the energy consumption is comparatively low. Generally farmers apply fertilizer by the broadcasting method in this region. Large and medium category farmers apply more fertilizer than the others so, the energy consumption was high. Result shows the highest amount of energy consumption in fertilizer application. Large and medium farmer generally use tractor operated power sprayer for pesticide application and therefore, the energy consumption was high. It was also observed that all categories of farmers generally use same dose of weedicides for plant protection. Generally, it was found that all farmers of large and medium categories harvest their field with the combine harvesters. However about 50% farmers of semi-medium and small categories harvest their field and thresh by power wheat thresher and so, it requires higher energy than the combine harvester.

4. Conclusions

Direct and the indirect energy both was found highest in the fertilizer application because the fertilizer used by all categories of farmers was higher than the recommended dose. The energy ratio of 6.77 was found for the wheat crop production with the energy productivity of 0.22.

5. Reference

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