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ENERGY USE ANALYSIS OF WHEAT PRODUCTION IN INDIA

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ABSTRACT

The energy use pattern in wheat production showed an intensive use of energy with total energy input for wheat production being 44.31 Giga Joules per hectare(GJha^{-1}) .About 29.58% of total energy is contributed by diesel fuel, 20.31% from chemical fertilizers and 16.13% by machinery. About 69.74% of the total energy inputs used in wheat production was indirect (seeds, fertilizers, manure, chemicals, machinery, water) and 30.26% was direct (human labor, diesel). Mean grain wheat yield was about 3442.6 kgha^{-1} obtained under normal conditions on irrigated farming, and taking into account the energy value of the seed, the net energy and energy productivity value was estimated to be 50.12 GJha^{-1} and 0.077 kg MJ^{-1}, respectively. The ratio of energy outputs to energy inputs was found to be 2.13. The energy values reveal that there is further scope of improving energy use efficiency of wheat production by judicious use of various input energy options.

KEY WORDS
Energy Productivity
Energy Ratio
Net Energy

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INTRODUCTION

Wheat production is a direct function of high yielding varieties, chemicals, fertilizers, mechanization and other energy inputs. Wheat is produced using energy sources ranging from human and animal power to power of heavy machinery. Energy input and yield vary with each system, influencing the ultimate output-input ratio. The production of wheat in the country has increased significantly from 75.81 million tons in 2006-07 to all-time historic production of 95.91 million tons in 2013-14. The productivity of wheat which was 2602 kg/ hectare in 2004-05 has increased to 3075 kg/hectare in 2013-14 (DES-GOI, 2014). The major increase in the productivity of wheat has been observed in the states of Haryana, Punjab and Uttar Pradesh. Utttar Pradesh alone contributes around 31.53% of total wheat production of country. The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy (Alam *et al*., 2005). Sustainable development focuses on three vital dimensions of sustainability viz., Economic, Environmental and Social. Sustainable economic development is closely linked with the energy availability (Rajakumar and Nagesh, 2011). Energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labor-intensive practices, or both (Esengun *et al*., 2007a). The increased use of inputs such as fertilizer, irrigation water, diesel, plant protection chemicals, electricity etc. demands more energy in the form of human, animal and machinery. The rising price of energy, particularly of crude oil, has significant implications for profitability of agriculture. Increasing use of energy-based inputs and rising oil prices are likely to enhance the cost of production in agriculture. Therefore, there is a need to assess energy trends in the Indian agriculture. (Jha *et al*., 2012). Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution Reduction (Uhlin ,1998). shahan *et al*. (2008) studied the energy use and economic analysis of wheat production in Iran and reported total energy input 47.08 GJha^{-1}. Aghaalkhani *et al*. (2013) reported that averagely diesel fuel had the highest share within the total energy inputs, followed by chemical fertilizer in rice production in Iran. However in India ,no study related to energy use pattern of wheat and/or rice has been made.

The aim of this study was to determine the energy input and output used in wheat production in Aligarh division of Uttar Pradesh, India. It also identifies operations where energy savings could be realized by changing applied practices in order to increase the energy ratio and propose improvements to reduce energy consumption for wheat production.

MATERIALS AND METHODS

The study was carried out in 270 wheat producers in Aligarh division of Uttar

Pradesh, India. Fourty eight villages were chosen to represent the whole study area. The province is located in the northern part of India, within 27º30' and 37º36' north latitude and 78º 06' and 79º40' east longitude. The total area of the study division is 795484 ha, and the net sown area is 638364 ha, with a share of 80.24%. Data were collected from the growers by using a face-to-face questionnaire performed in October-December, 2014. The collected data belonged to the production period of 2013-2014. The Secondary data for the present study was also obtained from project documents and line departments. Farmers were randomly chosen from the villages in the area of study. The size of each sample was determined using Eq. (1) derived from Neyman technique (Yamane, 1967).

$$n = \frac{\sum N_h \sigma_h}{N^2 D^2 + N_h \sigma_h^2} \quad \text{.........(1)}$$

where n is the required sample size; N is the number of holdings in target population; N_h is the number of the population in the h stratification; σ_h is the standard deviation in the h stratification, σ^2_h is the variance of h stratification; $D^2 = d^2/z^2$; d is the precision ($\bar{x} - \bar{X}$); z is the reliability coefficient (1.96 which represents the 95% reliability); The permissible error in the sample size was defined to be 5% for 95% confidence, and sample size was calculated as 270 farms.

For the growth and development, energy demand in agriculture can be divided into direct and indirect, renewable, and non-renewable energies (Alam *et al.*, 2005). The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input. Human labor, machinery, diesel oil, fertilizer, pesticides and seed amounts and output yield values of wheat crops have been used to estimate the energy ratio. Energy equivalents shown in Table 1 were used for estimation. The sources of mechanical energy used on the selected farms included tractors, machinery and diesel oil. The mechanical energy was computed on the basis of total fuel consumption (L ha^{-1}) in different operations. Therefore, the energy consumed was calculated using conversion factors (1L diesel = 56.31 MJ) and expressed in MJ ha^{-1} (Tsatsarelis, 1991). Basic information on energy inputs and wheat yields were entered into Excel spreadsheets. Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity and the specific energy were calculated (Sartori *et al.*, 2005; Demircan *et al.*, 2006; Shahan *et al.*,2008)

$$\text{Energy use efficiency} = \frac{\text{Energy Output (MJ ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \quad \text{.........(2)}$$

$$\text{Energy productivity(kg/MJ)} = \frac{\text{Grain output (kg ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \quad \text{.........(3)}$$

$$\text{Specific energy(MJ/kg)} = \frac{\text{Energy Input (MJ ha}^{-1})}{\text{Grain output (kg ha}^{-1})} \quad \text{.........(4)}$$

$$\text{Net energy(MJ ha}^{-1}) = \text{Energy Output (MJ ha}^{-1}) - \text{Energy Input (MJ ha}^{-1}) \quad \text{.........(5)}$$

Indirect energy included energy embodied in seeds, fertilizers, manure, chemicals, machinery while direct energy covered human labor and diesel used in the wheat production. Non-renewable energy includes diesel, chemical, fertilizers and machinery, and renewable energy consists of human labor, seeds and manure.

RESULTS AND DISCUSSION

Socio-economic structures of farms

Average farm size was 1.8 ha and wheat production occupied 68.53% of total farm lands. The other crops grown besides wheat were paddy, potato, sugar etc.100% of total land in each farm was irrigated. The agronomic practices during the growing process of wheat along with the periods relevant to these preparations are shown in Table 2.

Land preparation and soil tillage were mostly accomplished by 35-45 hp tractor along with using disc harrows, cultivator and rotavator. Land preparation was followed by sowing with machine having a capacity of 0.4 ha/h. Fertilizer is mainly applied through broadcasting with an initial dose applied along with seed using seed cum fertilizer drill. Irrigation water is applied five times during the whole crop growing period and 5 hp diesel pumps are used for this purpose. Spraying is done with the use of hand operated knap sack sprayer. Harvesting

Table 1: Energy equivalent of inputs and outputs in agricultural production

Inputs	Unit	Energy equivalent(MJ/Unit)	Reference
1.Labour	h	1.96	(Yilmaz *et al.*, 2005 ; Singh and Mittal,1992)
2.Machinery	h	62.7	(Erdal *et al.*, 2007a; Singh *et al.*, 2002; Singh,2002)
3.Tractor	h	68.40	(Singh and Mittal,1992)
4.Diesel	L	56.31	(Erdal *et al.*, 2007b; Singh *et al.*, 2002)
5.Fertilizers			
(a)Nitrogen	kg	60.6	(Shahan *et al.*,2008; Esengun *et al.*, 2007)
(b)Phosphorus	kg	11.1	(Shahan *et al.*,2008; Esengun *et al.*, 2007)
(c)Potassium	kg	6.7	(Shahan *et al.*,2008; Esengun *et al.*, 2007)
(d)Zinc	kg	8.40	(Pimentel, 1980; Argiro *et al.*, 2006)
6.Manure	kg	0.3	(Shahan *et al.*,2008; Demircan *et al.*, 2006)
7.chemicals	kg	20.9	(Canakci *et al.*, 2005; Mandal *et al.*, 2002; Singh, 2002)
8.water	m^3	1.02	(Shahan *et al.*,2008; Acaroglu and Aksoy,2005)
9.seeds	kg	14.7	(Singh and Mittal,1992; Ozkan *et al.*, 2004)
B.Outputs			
1.Grain	kg	14.7	(Singh and Mittal,1992; Ozkan *et al.*, 2004)
2.straw	Kg	12.5	(Singh and Mittal,1992; Ozkan *et al.*, 2004)

Table 2: Management practices for the wheat

Operation	Period	Method
Land preparation	*1st No-15 Nov*	*Harrow,cultivator,rotavator*
Sowing	*15 Nov-10 Dec*	*Wheat seed drill*
Fertilizer application	*15 Nov-15 Feb*	*Broadcasting & seed cum fertilizer drill(basal)*
Irrigation	*Nov-April*	*Diesel powered pump-set*
Average number of irrigation	*5 times*	
Spraying period	*15 Dec-15 Feb.*	*Knapsack sprayer*
Harvesting	*1st April-30th April*	*Manual Labour /combine Harvester*
Threshing	*1st April-30th April*	*Power operated wheat thresher*

Table 3: Amount of different inputs and outputs in wheat production

Inputs	Quantity per unit area
1.Labour(h/ha)	156.23
Land preparation	18.8
Sowing	5.13
Irrigation	16.29
Fertilizer application	18.4
Spraying	6.66
Harvesting	58
Threshing	18.75
Transporting	14.2
2.Machinery(h/ha)	114.02
Land preparation	4.8
Sowing	2.5
Irrigation	81.49
Fertilizer application	2.52
Spraying	6.66
Harvesting	9.23
Threshing	3.12
Transporting	3.7
3.Tractor(h/ha)	16.64
4.Diesel(L/ha)	232.87
Land preparation	65.5
Sowing	10.2
Irrigation	122.23
Fertilizer application	10.04
Spraying	-
Harvesting	-
Threshing	8.2
Transporting	7.4
5.Fertilizers(kg/ha)	253.89
Nitrogen	128.6
Phosphorus(P_2O_5)	79.43
Potassium(K_2O)	33.86
Zinc	12.0
6.Manure(kg/ha)	25013.2
7.chemicals(kg/ha)	2.37
8.water(m^3/ha)	4116
9.seeds(kg/ha)	127.3
B.Outputs	
1.Grain(kg/ha)	3442.6
2.straw(kg/ha)	3508.39

is done mostly manually with the use of sickle (except few large farms using combine), followed by threshing by using power operated thresher having a capacity of 2 ton/h.

The inputs and output used in wheat production in the area of survey can be seen in Table 3. Their energy equivalents with output energy rates and their equivalents are illustrated in Table 4. The results revealed that 156.23 h of human power and 114.02 h of machine power was required per hectare of wheat production in the study area. The amount of fertilizers used for wheat growing was 253.89 kg ha^{-1} that constitutes nitrogen (N), phosphorus (P_2O_5), potassium (K_2O) and Zinc (Zn) as 50.65%, 31.28%, 13.37% and 4.7%, respectively.

The energy input and output, yield, energy use efficiency, specific energy, energy productivity and net energy of wheat production in the Aligarh Division of Uttar Pradesh are shown in Table 5. Energy use efficiency (energy ratio) was calculated as 2.13. In Turkey, Canakci *et al.*(2005) reported wheat output/input ratio as 2.8; while for Iran, Shahan *et al.*(2008) reported a ratio of 1.97. In this study, the average energy productivity of farms was 0.077. This means that 0.077 grain output was obtained per unit of energy input. Calculation of energy productivity rate is well documented in the literatures such as for tomato (1.0) (Esengun *et al.*, 2007), cotton (0.06) (Yilmaz *et al.*, 2005), sugar beet (1.53) (Erdal *et al.*, 2007). The specific energy and net energy of wheat production were 12.87 MJ kg^{-1} and 50129.4 MJ ha^{-1}, respectively. Canakci *et al.* (2005) reported specific energy for field crops and vegetable production in Turkey, as 5.24 for wheat, 11.24 for cotton, 3.88 for maize, 16.21 for sesame, 1.14 for tomato, 0.98 for melon and 0.97 for water- melon.

Total energy used in various farm operations during wheat production was 44331.7 $MJha^{-1}$. Diesel energy consumes 29.58% of total energy inputs followed by Chemical fertilizer 20.31% during production period. Diesel energy was mainly consumed for land preparation, sowing, irrigation and transportation. The solar powered groundwater pumping coupled with pressurised irrigation systems could be an appropriate alternative approach for minimizing diesel consumption.(Rehman & Bhatt,2014).

Average annual grain yield of farms investigated was 3442.6 kg ha^{-1} and calculated total energy output was 94461.1MJ ha^{-1}. It was observed that chemicals were the least demanding energy input for wheat production with 49.27 MJ ha^{-1} (only 0.11% of the total sequestered energy), followed by human labor by 306.21 MJ ha^{-1}(0.69%) as shown in Table 4. As comparison to Iran, Shahan *et al.(*2008) reported that yield, total energy input and output, in wheat farming were 4514.8 kg ha^{-1}, 47078.5 and 92785.56 MJ ha^{-1}, respectively. In another study in Europe**,** Kuesters & Lammel (1999) found that total energy input in wheat production were between 7.5 and 17.5 GJ ha^{-1}.

The distribution of total energy input as direct, indirect, renewable and non-renewable forms are shown in Table 6. The total energy input could be classified as direct energy (30.26%), indirect energy (69.74%) and renewable energy (31.30%) and non- renewable energy (68.70%).

Table 4: Amount and percentage of different inputs and output energy equivalent in wheat production

Inputs	Quantity per unit area	Total energy Equivalent(MJ/ha)	%age of total energy input
1.Labour(h/ha)	156.23	306.21	0.69
2.Machinery(h/ha)	114.02	7149.05	16.13
3.Tractor	16.64	1138.18	2.57
4.Diesel(L/ha)	232.87	13112.91	29.58
5.Fertilizers(kg/ha)			
Nitrogen	128.6	7793.16	17.58
Phosphorus(P_20_5)	79.43	881.67	1.99
Potassium(K_20)	33.86	226.86	0.51
Zinc	12.0	100.8	0.23
6.Manure(kg/ha)	25013.2	7503.96	16.93
7.chemicals(kg/ha)	2.37	49.27	0.11
8.water(m^3/ha)	4116	4198.32	9.47
9.seeds(kg/ha)	127.3	1871.31	4.22
Total Input Energy(MJ/ha)		44331.7	
B.Outputs			
1.Grain(kg/ha)	3442.6	50606.22	
2.straw(kg/ha)	3508.39	43854.88	
Total Output Energy(MJ/ha)		94461.1	

Table 5: Various Energy performance parameters in wheat production

Parameter	Amount
Total Input Energy(MJ/ha)	44331.7
Total Output Energy(MJ/ha)	94461.1
Energy ratio	2.13
Grain(kg/ha)	3442.6
Specific energy(MJ/kg)	12.87
Energy Productivity(kg/MJ)	0.077
Net energy(MJ/ha)	50129.4

Table 6: Total energy input in the form of direct, indirect, renewable and nonrenewable for wheat production (MJ ha^{-1})

Form of Energy	Amount(MJ/ha)	%[a]
Direct Energy[b]	13419.12	30.26
Indirect Energy[c]	30912.58	69.74
Renewable Energy[d]	13879.8	31.30
Non-Renewable[e]	30451.9	68.70
Total Energy Input	44331.7	

[a]Indicates percentage of total energy input; [b]Includes human labor, diesel; [c]Includes seeds, fertilizers, manure, water, chemicals, machinery; [d]Includes human labor, seeds, manure, water; [e]Includes diesel, chemical, fertilizers, machinery

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