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Energy requirement and economic analysis of rice production in western part of Pakistan

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Abstract

This study examines energy use pattern and the relationship between energy inputs and rice production in Dera Ismail Khan, District of Pakistan. The information used in this study were based on cross-sectional data collected from growers by using face-to-face interviews. The sample farms were selected through a stratified sampling technique. The results revealed that energy consumption and rice yield were 5,756 kWh and 3.23 tonnes per hectare on Bullock Operated Farms (BOF) and 11,162 kWh and 4.12 tonnes per hectare on Tractor Operated Farms (TOF). Consumption of animate energy on BOF was more than TOF due to heavy use of animate energy in land preparation operation. Result also showed that energy efficiency i.e. output-input ratio on BOF (6.32) was higher than TOF (4.16). Cost of production remained lower on BOF than TOF, however, the yield and consequently crop values and net return were higher on TOF than BOF. It was concluded that increase in energy consumption at farm level increased yield of rice, hence the farmers with higher cost of production could get better return of their crop.

Key words: Rice, energy requirement, economic analysis

Introduction

Agriculture is a continuos process of energy conversion i.e. the conversion of solar energy into food, feed and fiber through photosynthesis. Old agriculture was just scattering of seed on unprepared land in unplanned manner and accepting too little output that resulted, and that also if nature was kind enough. On the other hand, today's agriculture is well-planned application of energy to achieve desired results (Stout, 1990).

The agriculture sector is one of the large energy-consuming sectors of Pakistan (Pakistan Energy Year book, 2008), as agricultural production has many energy consuming operations such as tillage, interculture, irrigation, application of fertilizers, agro-chemicals for plant protection, harvesting, transportation etc. At this stage, agriculture in Pakistan is in transition from the traditional i.e. low energy input methods of farming to higher level of energy input methods for agricultural production to cope with the food requirements of the country's population, which is growing at a rate of almost 2% (Economic Survey of Pakistan, 2007-08). Mandal *et al.* (2002) reported that increase in mechanized level of operations for higher crop production increases the energy consumption.

Rice is one of the important crops of not only Pakistan but also of the world. Its production remained more than 5.56 million tonnes in Pakistan in 2007 (Economic Survey of Pakistan, 2007-08). The world wide average yield of rice was 3.8 tons per hectare (Agricultural Statistics of Pakistan, 2006-07) whereas, the average yield of rice in Pakistan remained only 2.2 tonnes per hectare (Economic Survey of Pakistan, 2007-08). Therefore, efforts are immediately required to look into the matter of low yield. Furthermore, in order to sustain agricultural production, effective energy use is required, since it provides ultimate financial saving, preservation of fossil resources and reduction of environment distortion (Demircan *et al*., 2006). To formulate a policy to increase the use of commercial energy, it is imperative to examine the pattern of present situation of energy consumption for agricultural production.

Numerous researches have been conducted on energy and economic analysis to determine the energy efficiency of different crop production practices in the developed countries (Canakci *et al*., 2005; Ozkan *et al.*, 2004; Hatirli *et al.*, 2005) as well as in the neighbour country (India) (Mandal *et al*., 2002; Singh and Mittal, 1992). However, very few researches have been published on energy and economic analysis of rice crop with respect to Pakistan. Moreover, one very important factor i.e. water is missing in all the mentioned studies. In some of the studies, water was included but it was not considered like other energetics. This paper analyses the energy, water and economic efficiencies of rice production in Dera Ismail Khan District of Pakistan to identify where cost saving (in long term) can be done without importing the yield or profitability. From this research, priorities of mechanization of certain agricultural operations can be assigned after assessing the effects of various alternatives for increasing agricultural production through minimising energy bottlenecks.

The results of this study can help farmers, resource managers and policy makers to develop alternative technologies/practices, and energy optimal plan to save

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non-renewable energy inputs to sustain production without substantial reduction in the level of output and of course, without imposing a significant economic burden on the farmers.

Materials and Methods

Study area

The study was conducted in 2005-06 in Dera Ismail Khan (D.I. Khan) District of the North West Frontier Province (NWFP), Pakistan. It has a total geographic area of 0.73 million hectares out of which only 0.24 million hectares is cultivated. About one third of the cultivated area is irrigated while the other two third depends on rainfall and hill torrents for its moisture requirements.

The irrigated areas of D.I. Khan can be divided according to the systems of irrigation. The west bank of the River Indus (more than fifty three thousand hectares) is irrigated by Chashma Right Bank Canal. In the southeast part of the district, irrigation is done with tube wells; the farmers have installed centrifugal pumps for irrigation. The water table in this area ranges from 3 meters to 10 meters.

Data collection

The study made use of systematic sampling procedure of probability sampling where random sampling procedure was followed in three stages (Steel *et al*., 1997). At the outset, after travelling extensively in the District and consulting authorities in the Departments of Agriculture, Irrigation, Revenue and NGO's, seven villages were selected to represent the district. In the second phase, farms were selected based on their main power source.

1. Bullock operated farms (BOF)
2. Tractor operated farms (TOF)

After the selection of 15 farms, data were collected from each of the farms about the number of family members engaged in farming operations, the number of permanent hired labourers, the number of plots and their size and number of draft animals and/or other power sources etc. For whole crop period survey, a schedule of meeting with the farmers once every two weeks was followed. Data from the farmers were collected on inputs to crop plots on a daily basis in the 2005-06 production year. For each crop-plot, information was collected about the energy inputs from various direct energy sources like human labour, bullocks and tractors used to perform the agricultural operations, as well as indirect energy sources like seed, water and fertilizers. Family, labour and permanently hired labour were counted as permanent labour. The draft animals used for ploughing the fields were bullocks. An approximate power rating was assigned to each animal depending on its size, physical condition, and the performance during the study period.

During the interviews, the information recorded in forms was entered and processed using MS Excel software package.

Energy requirements of the rice crop

Energy coefficient for various sources of energy

Each agricultural input has its own energy values. Energy is invested to produce individual component. These individual energy inputs may be in the form of food/ feed, machinery etc. Energy coefficient thus may be defined as the energy equivalent of such sources of energy taking into account all forms of energy in their production (Thakur and Makan, 1997).

Analysis of energy coefficients (of rice) were based on energy equivalents available in the literature (Canakci *et al*., 2005; Ozkan *et al*., 2004; Hatirli *et al*., 2005; Singh and Mittal, 1992; Khan and Singh, 1996; Khan and Singh, 1997). The energy values used in this paper are the dietary energy value of agricultural output to the fossil energy expended to obtain it (Bonny, 1993).

Energy Conversion

For this study, the following procedures of energy conversion were adopted:

Human labour

The human power (man-hours) was converted into energy inputs by multiplying the number of man-hours and estimated power rating of human labour (Khan and Singh, 1996).

Tractors

The output of tractor was calculated by the product of fuel consumed by tractor, time consumed in operation, caloric value of the fuel and load factor (Khan and Singh, 1996). The Load factor was equal to actual fuel consumption over fuel consumed at rated power.

$$\left[E_c = F_c * T_c * C_v * Load\ factor\right] \tag{3}$$

Where E_c = Energy output of the Machine (kWh)

F_c = Fuel consumption of the Machine (L/h)

T_c = Time consumed in operation (h)

C_v = Caloric value of the fuel (kWh/L)

$$Load\ \ factor = \frac{Actual\ \ fuel\ consumed}{Fuel\ consumed\ at\ rated\ \ power} \tag{4}$$

Seed and fertilizer

The materials like seed and fertilizers used in crop production were transformed to energy equivalent by multiplying the quantity of the material used in the plots with the energy value of each material (Khan and Singh, 1996; 1997).

Energetics of the rice production

The input energy is also classified into direct, indirect, renewable, non-renewable and commercial, non-commercial forms. The indirect energy consists of seed, water and fertilizer while direct energy includes human power, animal power tractor and/or other machinery and fuel for machinery used in the production process. Renewable energy includes human power, animal power, water and seed and non-renewable energy consists of fertilizer, machinery and fuel for machinery. Commercial energy consisted of tractor, seed, water and fertilizer while non-commercial energy consisted of labour and bullock.

Input-output relationship of rice crop

In this study, energy efficiency, specific energy, energy productivity, water productivity and combined water and energy productivity for rice crop production were also calculated on per hectare basis using the following equations as suggested in literature (Canakci *et al.*, 2005; Ozkan *et al.*, 2004; Hatirli *et al.*, 2005; Singh and Mittal, 1992; Khan *et al.*, 2004).

$$Energy\ efficiency = \frac{Total\ energy\ output\ (kWh)}{Total\ energy\ input\ (kWh)} \quad (5)$$

$$Specific\ energy = \frac{Amount\ of\ energy\ applied\ (kWh)}{Grain\ yield\ (kg)} \quad (6)$$

$$Energy\ productivity = \frac{Grain\ yield\ (kg)}{Energy\ input\ (kWh)} \quad (7)$$

$$Water\ productivity = \frac{Grain\ yield\ (kg)}{Amount\ of\ water\ applied\ (m^3)} \quad (8)$$

$$Energy-water\ productivity = \frac{Grain\ yield\ (kg)}{Amount\ of\ water\ (m^3)\ and\ energy\ (kWh)\ applied} \quad (9)$$

Economics of rice crop production

Net economic returns from rice production were calculated to estimate the economic efficiency of rice production. Net return of the crop was calculated as gross returns minus the cost of all variables, which include the cost of labour, machinery, irrigation, seed and fertilizers. The cost of family labour was counted equal to the cost of permanently hired labour.

Price estimates

In the analysis, all stochastic variables such as yield, price, etc. were used by their actual values as told by the farmers. The price estimates for various input and output were as follows:

Regarding charges on human labour, the prevailing market rate of 8 hours work was Pakistani Rupees (Pk. Rs.). 180 to 200 (1 US$ = 80 Pk. Rs. in December, 2008).

Cost of tractor operation includes labour cost for the operator, which was calculated separately. Operating cost includes fuel, lubrication, and repairs for power units and implements; and overhead costs, which included depreciation, interest on investment in machinery, property taxes, insurance and housing. To estimate the fuel cost of each operation, the fuel usage was multiplied by the fuel price. It was commonly assumed that lubrication costs are 15% of the fuel cost.

A common seed rate of rice nursery was 1 kg for 2.5×10^{-3} hectare, and the prepared nursery was sufficient for 0.051 ha. On an average, the price of seed was Rs. 25 per kg in the study area.

Two types of fertilizers were commonly used on the farms of D.I. Khan District (Urea and Di Ammonium Phosphate). The farmers on BOF used these fertilizers at an average rate of 192 and 88 kg per hectare, respectively, whereas, the farmers on TOF used the above mentioned fertilizers at an average rate of 428 and 169 kg per hectare , respectively. Cost of particular fertilizer varied depending on the type and amount of fertilizer used, on the farm.

Gross value of output was computed using an average market price (farm gate price) that was almost Pk. Rs. 16, 000 per ton of paddy rice.

Certain operations were performed on contractual basis. For these types of operation, the farmers did not apply the energy by themselves, however, paid for the energy applied by the contractor, therefore, for these operations energy consumption was calculated based on data of other farmers of the area and the charges were counted according to the amount, the particular farmer paid for that particular operation to the contractor.

Results and Discussion

The research results cover four main components; namely, energy requirements of rice crop, energy input – output relationship, energetics of producing rice crop, and economic analysis of rice crop.

Energy requirement of the rice crop

Rice is one of the highest labour demanding crops among all field crops produced in Pakistan. The input used in rice production and their energy equivalent on BOF and TOF are presented in Table 1 and 2.

The results revealed that 720 and 634 hours of manpower per hectare were needed to produce rice crop on one hectare on BOF and TOF, respectively. The sowing/ transplanting operation accounts for 34 and 33% of the total manpower in BOF and TOF, respectively (research is in progress for shifting of manual sowing/ transplanting operation to mechanized transplanting operation because of the difficulties of enough labourer availability). It was followed by harvesting and threshing operations. The crop was harvested by the farmers themselves and with the help of neighbouring farmers on exchange basis. Inter-culture operation included weeding and application of fertilizer. Weeding operation was performed with human labour. None of the farmer used agro-chemical for plant protection.

The total energy used in the two categories of farms producing rice crop was 5,756 and 11,163 k Wh per hectare on BOF and TOF, respectively. Out of the entire farm operations in producing rice, fertilizers consumed most of the energy (61% in BOF and 69% of the total energy on TOF) followed by water (31% on BOF and 23% in TOF) (Table 3).

Of this total, seed energy remained very low, none of the farmer sowed the crop by direct broadcast method. All farmers prepared nursery and manually transplanted the crop with the help of neighbouring farmers on reciprocal basis. The contribution of tractor and bullock energy inputs remained at relatively low level.

Input-output relationship of rice crop

Table 3 illustrate the mean yields, energy efficiency, specific energy, energy and water productivities. It is clear from the Table 3 that the mean yield of the rice was significantly higher on TOF than BOF. The farmers on TOF used higher energy in the form of fertilizer and obtained higher output (yield) than BOF. Energy efficiency remained higher on BOF than TOF. This was due to lower use of energy inputs on BOFs. The farmers on BOF were comparatively poorer than TOF, therefore, the use of fertilizer remained low on BOF and consequently yield was lower on BOF than TOF. Specific energy shows the amount of energy spent to produce a unit of marketable product. It was higher on TOF than BOF (Table 3). Energy and water productivity is the term used to estimate the yield of marketable product on per unit of energy or water consumption. Energy and water productivity and consequently energy-water productivity was higher on BOF than TOF (Table 3).

Energetics of producing rice

The total mean energy inputs as direct and indirect, renewable and non-renewable form is also presented in Table 3 for rice crop on BOF and TOF.

Most of the total energy input (94 % and 93 %) were applied in the indirect form whereas, 6 % and 7 % of the total energy in rice crop were applied in the form of direct energy on BOF and TOF, respectively. The mean indirect input was fertilizer use especially nitrogen. The results showed that most of the energy was consumed in the form of non-renewable energy (65 % on BOF and 75 % on TOF), such as fertilizer, machinery and its fuel.

Economics of rice crop production

The total cost of production per ton of rice for both categories of farms (BOF & TOF) is expressed in Pakistani Rupees (Rs.), which was equal to 0.012 US dollars (US$) in 2008. The cost of production for rice included the costs of all operations performed with various power sources, and the costs of material inputs like seed, fertilizers etc. needed to grow the crop on one hectare. The calculation revealed that the cost of production for rice remained Pk. Rs. 29,113 on BOF and Pk. Rs. 37,564 on TOF in the region (Table 4-5). Gross return and net return were calculated and found higher on TOF than BOF (Table 6). Based on these results, it can be inferred that the net return from rice production in the surveyed farms was at somewhat satisfying level on TOF only. The net return is the only tool, which compel the farmers to decide what to grow and what not to grow. It is apparent from the study that to boost the net return of crop, farmers will have to think for higher energy consumption and better water management.

Conclusions

Relationship between energy inputs and the yield was ascertained for rice production in Dera Ismail Khan District of Pakistan. The results revealed that fertilizer energy was the major component of the total energy use in rice production. Average yield of rice was 3.2 tonnes per hectare on BOF and 4.1 tonnes per hectare on farms having tractor as their main power source. Due of better arrangement of irrigation, water energy remained lower on BOF than TOF. Therefore, total direct energy consumption was lower on BOF than TOF. However, because of higher dose of fertilizer, total energy consumption and consequently yield remained higher on TOF than BOF. The share of labour cost (family as well as casual) was quite

Table 1. Energy inputs per ha for various operations for the production of rice on BOF

Operation	Labour				Bullock energy	Machinery	Machinery Fuel	Total physical energy	Water	Seed	Fertilizer + chemicals	Total energy
	Permanent	Casual	Total									
	(hrs)	(hrs)	(hrs)	(%)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)
Seedbed	65	1	67	09.29	71	24	205	306	0	0	0	306
Sowing	242	0	242	33.60	0	0	0	18	0	137	0	155
Interculture + Fertilizer etc	4	0	4	00.49	0	0	0	0	0	0	3506	3506
Irrigation	96	0	96	13.28	0	0	0	7	1758	0	0	1765
Harvesting	157	0	157	21.75	0	0	0	12	0	0	0	12
Threshing	155	0	155	21.58	0	0	0	12	0	0	0	12
Total	718	1	720		71	24	205	355	1758	137	3506	5756

Table 2. Energy inputs per ha for various operations for the production of rice on TOF

Operation	Labour				Bullock energy	Machinery	Machinery fuel energy	Total physical energy	Water	Seed	Fertilizer + chemicals	Total energy
	Permanent	Casual	Total									
	(hrs)	(hrs)	(hrs)	(%)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)	(kWh)
Seedbed	4	4	9	1.35	0	75	627	703	0	0	0	703
Sowing	208	0	208	32.84	0	0	0	16	0	137	0	153
Interculture + Fertilizer etc	8	0	8	1.21	0	0	0	1	0	0	7722	7723
Irrigation	45	0	45	7.18	0	0	0	3	2554	0	0	2557
Harvesting	157	0	157	24.73	0	0	0	12	0	0	0	12
Threshing	207	0	207	32.69	0	0	0	15	0	0	0	15
Total	630	4	634		0	75	627	749	2554	137	7722	11163

Table 3. Energetic of rice production

Energy Variables	Units	BOF	(%)	TOF	(%)
Labour	kWh	53a	0.93	47a	0.42
Bullock	kWh	71	1.23	0	0.00
Tractor	kWh	24b	0.42	75a	0.67
Machinery fuel	kWh	205b	3.57	627a	5.62
Total direct energy	kWh	354	6.15	749	6.71
Seed	kWh	137	2.38	137	1.23
Fertilizer & other chemical	kWh	3506b	60.91	7722a	69.18
Water used	m^3/ha	9768	-	14188	-
Water energy	kWh	1758b	30.55	2554a	22.88
Total indirect energy	kWh	5401	93.85	10413	93.29
Total energy inputs	kWh	5756	100.00	11162	100.00
Renewable energy	kWh	2020	35.09	2738	24.53
Non-renewable energy	kWh	3736	64.91	8424	75.47
Commercial Energy	kWh	5494	95.46	10978	98.35
Non-Commercial Energy	kWh	261	4.54	184.0	1.65
Yield	kg	3225b		4122a	
Output energy of the crop	kWh	22378		28604	
By product (stalk)	kWh	13986		17878	
Total energy output	kWh	36365b		46482a	
	MJ	130912		167334	
Energy efficiency	kWh k^{-1}-Wh	6.32		4.16	
Specific energy	kWh kg^{-1}	1.78		2.71	
Energy productivity	Kg kWh^{-1}	0.56		0.37	
Water productivity	Kg m^{-3}	0.33		0.29	
Energy-water productivity	G m^{-3}-kWh	0.06		0.03	

Means followed by the same letters in a row are not significantly different from each other at 5% level of significance.

high. However, most of the farmers do not consider it a part of production cost.

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Table 4. Per ha economic analysis for various operations for the production of rice on BOF

Operation	Labour cost (Rs)	Bullock cost (Rs)	Machinery cost (Rs)	Fuel cost (Rs)	Total physical energy cost (Rs)	Water cost (Rs)	Seed cost (Rs)	Fertilizer + chemical cost (Rs)	Total energy cost (Rs)
Seedbed	1,505	4,168	560	0	6,234	0	0	0	6,234
Sowing	5,442	0	0	0	5,442	0	681	0	6,122
Interculture + Fertilizer etc	79	0	0	0	79	0	0	7,506	7,585
Irrigation	2,151	0	0	0	2,151	2	0	0	2,154
Harvesting	3,523	0	0	0	3,523	0	0	0	3,523
Threshing	3,495	0	0	0	3,495	0	0	0	3,495
Total	16,195	4,168	560	0	20,924	2	681	7,506	29,113

Table 5. Per ha economic analysis for various operations for the production of rice on TOF

Operation	Labour cost (Rs)	Bullock cost (Rs)	Machinery cost (Rs)	Fuel cost (Rs)	Total physical energy cost (Rs)	Water cost (Rs)	Seed cost (Rs)	Fertilizer + chemical cost (Rs)	Total Energy cost (Rs)
Seedbed	193	0	270	6757	7220	0	0	0	7220
Sowing	4682	0	0	0	4682	0	711	0	5394
Interculture + Fertilizer etc.	172	0	0	0	172	0	0	15563	15735
Irrigation	1024	0	0	0	1024	2	0	0	1026
Harvesting	3527	0	0	0	3527	0	0	0	3527
Threshing	4662	0	0	0	4662	0	0	0	4662
Total	14260	0	270	6757	21287	2	711	15563	37564

Table 6. Economics of rice production

S. No.	Energy Variables	Units	BOF	(%)	TOF	(%)
1.	Labour	(Rs)	16195	55.63	14260	37.96
2.	Bullock	(Rs)	4168	14.32	0	0.00
3.	Tractor	(Rs)	560	1.92	270	0.72
4.	Machinery fuel	(Rs)	0	0.00	6757	17.99
5.	Cost of direct energy (1+2+3+4)	(Rs)	20924	71.87	21287	56.67
6.	Seed	(Rs)	681	2.34	711	1.89
7.	Fertilizer & other chemical	(Rs)	7506	25.78	15563	41.43
8.	Water	(Rs)	2	0.01	2	0.01
9.	Cost of indirect energy (6+7+8)	(Rs)	8189	28.13	16276	43.33
10.	Cost of production (5+9)	(Rs)	29113	100.00	37564	100.00
11.	Cost of the renewable energy (1+2+8)	(Rs)	20365	69.95	14262.2	37.97
12.	Cost of the non-renewable energy (3+4+6+7)	(Rs)	8747	30.05	23301	62.03
13.	Cost of the commercial energy (3+4+7+8)	(Rs)	8069	27.72	22592	60.14
14.	Cost of the non-commercial Energy (1+2+6)	(Rs)	21044	72.28	14971	39.86
15.	Yield	kg	3225		4122	
16.	Return of the main crop	(Rs)	70939		90676	
17.	Return of by product (stalk)	(Rs)	8061		10304	
18.	Total gross return of output (16+17)	(Rs)	79001		100980	
19.	Net return of output (18-10)	(Rs)	49888		63416	
20.	Benefit-cost ratio (18/10)		2.71		2.69	

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