ANALYSIS OF ENERGY INPUTS AND OUTPUTS IN PAKISTAN AGRICULTURE-PART I

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ABSTRACT

This study investigates the pattern of energy consumption and its relationship with crop production in Pakistan from 1981-82 to 2005-06. The study period was divided into five phases of five years each. The inputs of energy included human and animal labour, machinery, electricity, fuels, fertilizers, and seeds of 13 commonly grown crops in Pakistan. Energy values were calculated by multiplying the amount of input and output by their energy equivalent. The results indicated the output/input ratio in phase I was higher than other phases after wards due to higher use of energy inputs compared to energy outputs. Total energy input raised from 226×10^{15} J in phase I to 387×10^{15} J in phase V. On the other hand total output raised from 758×10^{15} J in phase I to 1191×10^{15} J in phase V. As a consequence output-input ratio was 3.35 in phase I and 3.08 in phase V. This result indicates that the demand for commercial energy will increase with the passage of time in Pakistan. Availability and use of fossil fuels (a key input in commercial energy) has been and will continue to be an important factor in improving the productivity of agricultural system in Pakistan.

INTRODUCTION

Agriculture in Pakistan is going through remarkable changes for the last three decades with the introduction of various energy inputs such as chemical fertilizers, high yielding varieties, etc. Crop production technologies and agro processing has emerged as one of the major consumer of commercial energy in the form of petroleum and electricity. Overall consumption of commercial energy increased from 23,162,121 Tonnes of Oil Equivalent (TOE) in 1995 to 33,94,5689 TOE in 2005-06 in all sectors of the country (Pakistan Energy Yearbook, 2001, Pakistan Energy Yearbook, 2003, Pakistan Energy Yearbook, 2006). The energy consumption trend remained uneven in Agriculture. For example, the consumption of oil/petroleum decreased from 124,200 tonnes in 1981-82 to 81,900 tonnes in 2005-06. However, electricity consumption in agriculture sector increased from 2,369 GWh in 1981-82 to 7,949 GWh in 2005-06 (Economic Survey of Pakistan 1995-96, Economic Survey of Pakistan 2002-03, Economic Survey of Pakistan 2005-06).

Although, Pakistan has well-developed surface irrigation system, but the rain-fed area accounted for approximately 17% of the total cultivated area in 2005. This increased from 9.25 million hectare in 1950-51 to 19.02 million hectare in 2005-06 (Agricultural Statistics of Pakistan, 2005-06). The cultivated areas (irrigated and rainfed) are diverse in soil, climate, resource base, and production system and rich in physical and human resources. This diversity can be utilized beneficially through integrated planning. The development of a sound irrigation system and improved agricultural mechanization system in an integrated approach will be helpful in improving the economic condition of farmers. This will ultimately play a vital role in reducing poverty and the development of the country. Much could be achieved if a system approach is adopted for planning. This approach involves a comprehensive assessment of the local situation; available energy sources, skills, and needs. The objective of this study is to analyse various sources of energy inputs in agriculture from 1981-82 to 2005-06. The analysis is necessary for better planning for future. This will lead to better understanding of the present food production system and assist in improving the efficiency and output of the system that is environmental friendly and sustainable in the longer term.

METHODOLOGY

Study Period

The study is conducted from the fiscal year 1981-82 to 2005-06. The span of 25 years is divided into five phases of 5 years each. The data of each phase represents the average annual data of the five years in any given phase.

Energy coefficient for various sources of energy

Each agricultural input has its own energy values. Energy is invested to produce individual component. The energy inputs may be in the form of food/feed, machinery and fuel, etc. Energy coefficient thus may be defined as the energy equivalent of such sources of energy taking into account all form of energy in their production (Thakur and Makan, 1997). Analysis of energy coefficients of direct and indirect energy sources including crops are based on energy equivalents available in the literature (Panecar and Bhatnagar, 1987; Khan and Singh, 1996; Croke, 1979; Ozkan *et al*, 2004; Canakci *et al*, 2005; Hatirli *et al*, 2005; Demircan *et al*, 2006; Gundogmus 2006). The energy values used in this study are the dietary energy value of agricultural output obtained by spending the fossil energy (Bonny 1993).
Direct energy sources of energy inputs on farms include human and animal power, machinery, and other implement used for various production operations, diesel and electricity., Indirect energy sources include seeds of various crops, fertilizers and chemicals used in production process.

Energy conversion

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

Human and animal energy

The data of human labour and animal engaged in agriculture were collected from various sources (Economic Survey of Pakistan, 1995-96, Economic Survey of Pakistan, 2002-03, Economic Survey of Pakistan, 2005-06; Agricultural Statistics of Pakistan, 1990-91; Agricultural Statistics of Pakistan, 1998-99; Agricultural Statistics of Pakistan,2005-06). For the estimation of grass energy inputs in agriculture, approximate working days of agricultural labour were assumed as 210 days at an average of 8 hours of working day; the numbers of working hours of animal power in agriculture production are taken 360 hours annually. The average field capacity of a pair of bullock commonly used in Pakistan was 1.5 ha per day (Khan and Singh, 1997).

Tractors and diesel engines

The input for repair of tractors, self propelled machines and diesel engines in agricultural production were calculated by the following formula suggested by Ozkan (2004).

$M_e = (G \times E) / (T \times C_a)$

Where M_e = Machinery energy (MJ/ha)

G = Weight of tractor (kg)

E = Constant (158.3 MJ/kg) for tractor

T = Economic life of tractor (h)

C_a = Effective field capacity (ha/h)

Five makes and models of tractors (Massey Ferguson, Fiat, IMT, Belarus and Ford) are assembled/ manufactured in Pakistan; the average hp of tractor was assumed to 50.

On an average diesel consumption was 0.092 litter per hour for each rated horsepower (0.746 kW) and an effective field capacity of one tractor as 4 ha (Khan, 1994).

Electricity and Petroleum products

Data of electricity and petroleum products used in agriculture in Pakistan was taken from Pakistan Energy Yearbooks (2001, 2003, 2006) and Economic Survey of Pakistan (1995-96, 2002-03, 2005-06).

Seed, Agro-Chemical (fertilizer and plant protection)

The materials like seed and agro-chemicals used for crop production were transformed to energy equivalent by multiplying the quantity of the material used with the energy value of each material available in the literature (Panecar and Bhatnagar, 1987; Khan and Singh, 1996; Croke, 1979; Ozkan *et al*, 2004; Canakci *et al*, 2005; Hatirli *et al*, 2005; Demircan *et al*, 2006; Gundogmus 2006). The quantity of seed and fertilizer was taken from the Agricultural Statistics of Pakistan (1990-91; 1998-99; 2005-06). Energy consumption of plant protection chemical was negligible as compared to other energy inputs and was ignored as result while estimating energy inputs.

Output of Crops.

Energy output comprises of the product itself and its by-products. Energy outputs of main product is calculated by multiplying product obtained with their energy equivalent available in the literature (Panecar and Bhatnagar, 1987; Khan and Singh, 1996; Croke, 1979; Ozkan *et al*, 2004; Canakci *et al*, 2005; Hatirli *et al*, 2005; Demircan *et al*, 2006; Gundogmus 2006). The production of crops was taken from the Agricultural Statistics of Pakistan (1990-91; 1998-99; 2005-06).

By-products of only cereal crops were considered for energy calculation. The quantity of by-product was taken as 125 % of the main crops (Khan, 1994); however, the energy values of by-product were taken from the mentioned literature.

RESULT AND DISCUSSION

Average available power sources and their estimated energy consumption for crop production are presented in Tables 1 and 2. It is clear from Table 1 that human labour and consequently human energy increased from phase I to V, i.e. from 1981-82 to 2005-06. This was primarily due to increase in cropping area and cropping intensity. However, increase in human energy in phase IV to V was small mainly because of higher machinery use in many of the labour intensive operations. The non-availability of agricultural labour because of other job opportunities in feactories with better working conditions during the last two phases.

Animal power consumption was highest in phase I and has been declining throughout the period under consideration. The cropping areas and cropping intensities have been increasing with time. Therefore, the number of animal dependent farms also increased. However, transition of low energy consuming farms (i.e. farms having animal as main power source) to high energy consuming farms (i.e. mechanized farms) continued with time. With the transformation low energy dependent farms to partially mechanized farms, there was no significant increase in animal power as a result.

Table 1 **Average annual available physical energy sources in Pakistan agriculture**

Phase	Year	Human Labour No. (million)	Animal No. (000 Heads)	Electricity(GWH)	(Tonnes)	Tractor No.
I	1981-82 to85-86	13.76	6259	2659.80	184060	24335
II	1986-87 to90-91	14.81	4924	4582.40	283318	20296
III	1991-92 to 95-96	15.29	4468	6040.20	279035	16384
IV	1996-97 to2000-01	17.47	3675	5822.80	262188	25550
V	2001-02 to 05 to 06	17.89	3924	6646.00	185998	37144

Growth in electricity consumption was very prominent through out the five phases. This was due to increase in irrigated area of the country. The area under pump irrigation was 2.99 million hectare (Mha) in 1981-82 and 3.48 Mha in 2005-06. However, consumption of diesel (petroleum products) fluctuated from year to year. Its consumption reduced mainly with significant increase in cost its cost. Moreover, with the supply of electricity to new areas, made it easy for the farmers to switch over to electric motor driven pumps which was comparatively cheaper than diesel pumps used for irrigation purposes.

In calculating energy consumption of agricultural machinery only tractors were considered in the study. Number of tractor increased with every phase, showing the increase in mechanization in the country. Total physical energy consumption increased from 115×10^{15} J in phase I to 166×10^{15} J in phase V (Table 2). The overall 31% increase in total physical energy was primarily due to electricity consumption. There was approximately 60% increase in physical energy consumption during phase V compared to phase I. The energy consumption due to human labour also increased. This increase was 23% in the phase V than phase I.The commonly used fertilizers in agriculture were N, P_2O_5 and K_2O and their estimated values are summarised in Table 3. Nitrogen and P_2O_5 consumptions were 63% higher and 60% respectively higher in phase V than phase I. The K_2O consumption fluctuated during different phases. Overall, fertilizer energy consumption was 63% higher in phase V than phase I.

Table 2 Average annual physical energy inputs in Pakistan agriculture

Phase	Year	Human	Animal	Tractor*	Electricity	Petroleum	Total Physical
		(10^{15} J)	(10^{15} J)	(10^{15} J)	(10^{15} J)	(10^{15} J)	(10^{15} J)
I	1981-82 To1985-86	45.322	27.829	0.016	31.731	10.364	115.264
II	1986-87 To1990-91	48.753	21.890	0.014	54.668	15.954	141.279
III	1991-92 To1995-96	50.360	19.864	0.011	72.060	15.712	158.007
IV	1996-97 to 2000-01	57.538	16.337	0.017	69.466	14.764	158.123
V	2001-02 to 2005-06	58.895	17.446	0.025	79.287	10.474	166.126

*Tractor manufacturing and repair energy input

Consumption of seed energy of commonly grown crop in Pakistan was examined from phase I to V (Table 4). Almost 11% increase in seed energy was noted in phase V than phase I. Cash crops were grown on relatively smaller areas than cereal crops mainly, because of higher energy inputs of cash crops.

Table 3 Annual average fertilizer energy inputs in Pakistani agriculture

Year	N	Energy	P_2O_5	Energy	K_2O	Energy	Total energy
	(000 tonnes)	(10^{12} J)	(000 tones)	(10^{12} J)	(000 tonnes)	(10^{12} J)	(10^{15} J)
1981-82 to1985-86	952.10	57697.26	278.79	3094.55	26.75	179.24	60.97
1986-87 to1990-91	1375.70	83367.30	392.78	4359.81	37.00	247.89	87.97
1991-92 to1995-96	1697.26	102853.71	454.67	5046.79	23.35	156.45	108.06
1996-97 to 2000-01	2127.88	128949.77	541.86	6014.60	18.20	121.93	135.09
2001-02 to 2005-06	2576.83	156156.14	696.76	7734.06	24.12	161.58	164.05

Table 4 Annual average seed energy in Pakistan agriculture

Year	Cereals*	Cash Crops**	Pulses***	Oil seeds****	Total energy
-	(10^{15} J)	(10^{15} J)	(10^{15} J)	(10^{15} J)	(10^{15} J)
1981-82 to1985-86	12.549	36.711	0.770	0.005	50.035
1986-87 to1990-91	13.137	35.157	0.810	0.004	49.108
1991-92 to1995-96	13.854	39.255	0.846	0.005	53.960
1996-97 to 2000-01	14.126	42.782	0.834	0.005	57.746
2001-02 to 2005-06	13.998	42.025	0.813	0.004	56.840

**Cereal includes Wheat, Rice, Millet, Sorghum, Maize and Barley.*
***Cash Crops include Sugarcane, Cotton and Tobacco.*
****Pulses includes Gram*
*****Oil seed crops include Rapeseed, Mustered and Sesamum.*

Table 5 shows the energy output of selected (commonly grown) crops of Pakistan. Consistent increase in production of cereal crops was observed throughout the study period i.e. from 1981-82 to 2005-06. Energy output in phase V was 36 % higher than phase I. Production of cereal and cash crops were 38% and 34% respectively higher in phase V than phase I. Production of pulses increased from 7.11×10^{15} J in phase I to 8.96×10^{15} J in phase V. However, no significant increase in oilseed production was observed during this period.

Table 5. Annual average production energy in Pakistan agriculture

Year	Cereals*	Cash Crops**	Pulses***	Oil seeds****	Total energy
	(10^{15} J)	(10^{15} J)	(10^{15} J)	(10^{15} J)	(10^{15} J)
to1985-86	249.36	262.17	7.11	6.26	524.90
1986-87 to1990-91	275.91	279.34	7.36	6.28	568.89
1991-92 to1995-96	317.51	347.22	7.38	6.40	678.51
1996-97 to 2000-01	374.16	388.62	8.88	7.86	779.51
2001-02 to 2005-06	401.51	399.02	8.96	6.27	815.76

* *Cereal includes Wheat, Rice, Millet, Sorghum, Maize and Barley.*
** *Cash Crops include Sugarcane, Cotton and Tobacco.*
*** *Pulses includes Gram*
**** *Oil seed crops include Rapeseed, Mustered and Sesamum.*

Table 6 shows the overall results of energy inputs and outputs of Pakistan agriculture. Size of cropping area of the selected crops increased from 15.76 Mha in phase I to 17.86 Mha in phase V. The cropping area in phase V was less than phase IV. Sever drought during phase V could be one of the major reasons for this reduction. Irrigated area of the selected crops continued increasing throughout the five phases. Farmers of irrigated area have the flexibility of moving to higher energy consuming operations and growing of high yielding varieties for better results. The constant annual increase in physical and total energy depicts the constant growth of country's agriculture. Energy inputs increased from 14.36 GJ per hectare in phase I to 21.67 GJ/ha per hectare in phase V. The energy inputs increased by 34% and production increased by 28% in phase V as compared to phase I which are and a good growth indicator for the country.

Table 6. Annual average inputs and outputs values in Pakistan agriculture

	Year				
	1981-82 to1985-86	1986-87 to1990-91	1991-92 to1995-96	1996-97 to 2000-01	2001-02 to 2005-06
	Phase				
	I	II	III	IV	V
Area sown (million ha	15.76	16.44	17.35	17.99	17.86
Irrigated area (million ha)	11.23	11.79	12.41	13.21	13.65
Estimated physical energy input (10^{15} J)	115.26	141.28	158.01	158.12	166.13
Fertilizer energy inputs (10^{15} J)	60.97	87.97	108.06	135.09	164.05
Seed energy inputs (10^{15} J)	50.04	49.11	53.96	57.75	56.84
Total Energy (10^{15} J)	226.27	278.36	320.02	350.96	387.02
Energy input per ha (GJ/ha)	14.36	16.93	18.45	19.50	21.67
Production energy (10^{15} J)	524.90	568.89	678.51	779.51	815.76
By-product energy equivalent(10^{15} J)	233.25	258.08	296.99	349.98	375.56
Total product energy equivalent (10^{15} J)	758.15	826.97	975.50	1129.49	1191.32
Total output per ha (GJ/ha)	48.11	50.29	56.24	62.77	66.72
Output/input ratio	3.35	2.97	3.05	3.22	3.08

Output/input ratio was higher in phase I than rest of the phases. This was because of increase in energy inputs outbalancing the increase in energy output in these phases. The output-input ratio can be increased by reducing the energy consumption. The lower energy consumptions results in lower energy outputs wand it cannot be recommended for meeting the food demand of increasing population of the country.

CONCLUSION

The results show that total energy inputs and outputs continue increasing throughout the 25 years study period. Total energy input increased from 226 × 10^{15} J in phase I to 387 × 10^{15} J in phase V. This indicates that average annual energy inputs in phase V was 42% higher than phase I. Similarly total output increased from 758 × 10^{15} J in phase I to 1191.32 × 10^{15} J in phase V, which is 36% higher than phase I.Decreasing consumption of animal energy with increasing cropped area shows a transition from conventional (low energy consuming) farms to mechanized (higher energy consuming) farms; which is a good indication of country’s progress. Decreasing trend of petroleum use can be attributed for two reasons (1) increasing cost of petroleum products, and (2) availability of electricity to rural areas, which replaced the diesel operated irrigation pumps with electric motor powered pumps. During the last 25 years the increase in physical energy inputs, fertilizer and seed energy input values were estimated as 1.44, 2.69 and 1.14 folds respectively. The crop and its by-product energy outputs increased by 1.55 fold and 1.60 fold respectively. These results indicated that the increase in inputs in Pakistan agricultural production systems could not increase the resulting output at the same rate. Therefore, the output/input ratio decreases.. These results show the importance of integrated planning in achieving desired outputs while using all the available technologies for improving agricultural production. Therefore, the planners need to formulate policies which are environmental friendly and sustainable in longer terms.

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