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Changing Energy-use Pattern and the Demand Projection for Indian Agriculture[§]

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Abstract

The structure of energy-use in Indian agriculture has changed substantially, with a significant shift from the animal and human power towards machines, electricity and diesel. The total commercial energy input in Indian agriculture has increased from 425.4×10^9 Mega Joules in 1980-81 to 2592.8×10^9 Mega Joules in 2006-07. This shift, coupled with increasing commercialization and diversification towards high-value crops, will require more commercial energy. In this paper, a direct and robust relationship between energy use and agricultural gross domestic product (GDP) has been established using the cointegration analysis. The demand for direct energy input in agriculture in the year 2016 is projected to be 33.33 million tonnes of oil equivalent (MTOE) if agricultural GDP grows at 3 per cent and 41.49 MTOE if agricultural GDP grows at 4 per cent; this represents an annual average growth rate of 7-9 per cent over the current consumption.

Key words: Agriculture, energy, future demand

JEL Classification: Q41, Q47

Introduction

The global climate change and shift in food consumption towards high-value commodities are putting immense pressure on the Indian agriculture to produce more and efficiently for improving food and nutritional security while reducing the environmental footprints. The growth in Indian agriculture has been moderate (nearly 3 % per annum) in the past one decade. But, there have been some structural shifts in terms of composition of output. There are increasing trends towards commercialization and diversification of agriculture (Joshi *et al*., 2007). Livestock, horticulture, fisheries and poultry sectors are growing rapidly. On the input side, there is increasing inclination towards the use of modern inputs and farm mechanization. These developments have significant implications for energy-use in agriculture. Modern inputs and mechanization require more commercial energy and this holds true for the management of perishable commodities also. This implies a significant change in energy-use pattern in the Indian agriculture. This coupled with rising requirement of commercial energy in the non-agricultural sectors is escalating the demand for more energy. Globally also, there is again a rising trend in oil prices and countries are looking for alternative sources of energy and energy-efficient technologies.

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. The

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§ This paper is drawn from the research work undertaken as a part of an Institute project entitled “Energy use in Indian agriculture in the context of climate change” present paper has analyzed sectoral changes in the sources of energy and the cost of energy-based inputs. This is followed by an analysis of energy-output relationship and its implications for future energy demand. Finally, some options to meet the energy demand whilst reducing environmental footprints are discussed.

Trends in Energy-Use Pattern

With economic growth, the demand for commercial energy is rising. The consumption of commercial energy has increased 3.2-times since 1980-81. While the industrial sector continues to be the largest consumer of commercial energy, its share has declined from 54 per cent in 1980-81 to 45 per cent in 2006-07. On the other hand, the share of agriculture sector has increased from 2 to 7 per cent during this period. Energy-use in the agriculture sector has registered the highest growth rate of 10.4 per cent, while its use in industry and transport sectors has grown at 3.6 per cent and 3.2 per cent, respectively, during the past two and a half decades.

The structure of energy consumption in the Indian agriculture has changed substantially, with a significant shift from animal and human labour towards tractor for different farming operations and electricity and diesel for irrigation. Quantitative assessment has indicated that in 1970-71, agricultural workers and draught animals contributed considerably to the total energy-use in agriculture (15 % and 45 %, respectively), while electricity and fossil energy together provided 40 per cent energy. In a span of three and a half decades, the share of these energy inputs in agriculture has undergone a drastic change —the contribution of electricity and fossil energy together has gone up to 86 per cent and of agricultural workers and draught animals has come down to 6 per cent and 8 per cent, respectively.

Temporal Behaviour of Energy Use

Energy use in agriculture can be divided into two categories, viz. direct use of energy for pumping and mechanization (tractors, power tiller, etc.) and indirect use of energy in the form of fertilizers and pesticides. The consumption pattern of both direct and indirect sources of commercial energy[1] was analysed using time series data from 1980-81 to 2006-07 to explain the direction and the extent of energy-use in Indian agriculture. A standard procedure was used to convert each energy input into common energy unit, that is, mega joules following Singh and Mittal (1992). The consumption pattern of different sources of energy is depicted in Table 1. It can be seen from Table 1 that the consumption of electricity witnessed a sharp increase between 1980-81 and 1995-96 owing to rapid expansion of tube-well irrigation in the Indo-Gangetic Plains (IGP) but thereafter, it became stagnant. It has started increasing again in recent years. The consumption of diesel had a sudden spurt during 1995-2000. The consumption of fertilizer increased consistently during the period 1981 to 2007. The total commercial energy input to Indian agriculture has increased from 425.4×10^9 Mega Joules (MJ) in 1980-81 to 2592.8×10^9 MJ in 2006-07. The consumption of energy per hectare of net sown area has increased from 3 thousand MJ to 18.5 thousand MJ during this period. The consumption of energy per hectare of gross cropped area has also increased from 2.5 thousand MJ to 13.4 thousand MJ during this period. This clearly indicates that energy intensity per unit of area for various crops has increased manifold during 1981 to 2007. Increase in cropping intensity and shift of area towards energy-intensive crops were mainly responsible for this shift.

Changes in the supply and demand for energy can have significant implications for the composition of output, management practices and profitability in agriculture. Therefore, an attempt was made to examine the relationship between the gross value of output and energy consumption in agriculture over time. Figure 1 depicts this relationship between commercial energy-use and the gross value of agricultural output. The gross value of agricultural output in real terms (1999-00 prices) increased from ₹ 286.5 thousand crores in 1980-81 to ₹ 609 thousand crores in 2006-07. The gross value of agricultural output per thousand MJ of energy declined from ₹ 6734 in 1980-81 to ₹ 2557 in 1995-96 and thereafter remained almost stagnant with small fluctuations, perhaps due to weather-induced yield variability. The value per unit of direct as well as indirect energy-use has also declined over time. This

[1] The electricity and diesel have been classified as direct sources of commercial energy while fertilizers and pesticides have been classified as indirect sources of commercial energy.

Table 1. Temporal behaviour of commercial energy-use in Indian agriculture

Year	Electricity (GWh)	Diesel ('000 tonnes)	Nitrogen ('000 tonnes)	Phosphorus & potassium ('000 tonnes)	Pesticides ('000 tonnes)	Total energy (10^9 MJ)	Energy input (10^3 MJ/ha)	
							Net sown area	Gross cropped area
1980-81	14,489 (1,72,854)	101 (6,579)	3,678 (2,22,893)	1,838 (17,651)	45 (5,400)	425.38	3.04	2.46
1985-86	23,422 (2,79,424)	149 (9,756)	5,660 (3,43,045)	2,813 (27,672)	52 (6,240)	666.14	4.73	3.73
1990-91	50,321 (6,00,330)	318 (20,822)	7,997 (4,84,630)	4,549 (44,650)	75 (9,000)	1,159.43	8.11	6.24
1995-96	85,732 (10,22,783)	789 (51,661)	9,822 (5,95,262)	4,053 (39,906)	61 (7,351)	1,716.96	12.07	9.16
2000-01	84,729 (10,10,817)	7,497 (4,90,879)	10,920 (6,61,764)	5,782 (57,284)	44 (5,230)	2,225.97	15.74	12.01
2006-07	97,089 (11,58,272)	7,914 (5,18,183)	13,773 (8,34,638)	7,878 (77,174)	38 (4,554)	2,592.82	18.48	13.38

Note: Figures within the parentheses denote the inputs in energy term, i.e., 10^6 MJ
Source: Based on data in TERI and DES, New Delhi.

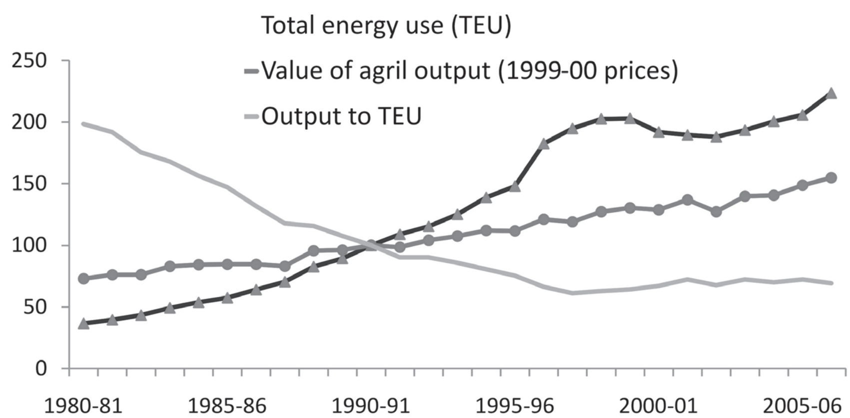

Figure1. Trends in energy use and value of agricultural output

further underscores that the Indian agriculture has become more energy-intensive. Keeping in view the declining groundwater table and increasing nutrient deficiencies in soil, the direct and indirect energy requirements for sustaining the current yield levels will further increase. Therefore, there is an urgent need for developing energy savings technologies for agricultural production.

Source-wise Commercial Energy Input

The source-wise direct as well as indirect energy-use in Indian agriculture is depicted in Table 2. In a span of two and a half decades, the share of diesel has increased from 1.5 per cent to 20 per cent of the total energy-use. During the 1980s, indirect use of energy in the form of fertilizers contributed to the tune of 56.55 per cent, which however reduced to 35.17 per cent in 2006-07. At present, electricity, fertilizer and diesel are the main sources of commercial energy for agriculture. The indirect use of energy in the form of pesticides has reduced to 0.18 per cent in 2006-07 from 1.27 per cent in 1980-81, giving an indication of better awareness of the farmers about appropriate use of chemicals and environmental pollution.

Table 2. Shift in different sources of commercial energy consumption in Indian agriculture

(in per cent)

Source	1980-81	2006-07
Diesel	1.55	19.99
Electricity	40.64	44.67
Fertilizers	56.55	35.17
Pesticides	1.27	0.18
Total	100.00	100.00

Source: Based on data in TERI and DES, New Delhi.

Share of Energy in Cost of Agricultural Production

The cost of production and the share of energy costs vary widely by crops and regions. The productivity of crops depends upon the energy inputs consumed during various farm operations. The sources of energy that go into the production of crops include material inputs such as seeds, fertilizers, manures, insecticides and mechanical energy along with human and bullock labour hours used in the crop production process. Considerable variations in the form and extent of energy use and its efficiency exist in the production of major crops.

To study temporal and spatial variations in energy utilization in major crops of India, secondary data on their cost of cultivation were analyzed. Table 3 presents the percentage shares of direct and indirect energy costs in the total cost of crop production. The share of energy cost ranges from 45.0 per cent in rapeseed & mustard to 68.4 per cent in potato. It can be observed that the share of energy cost is more in rice than wheat in spite of more mechanization in wheat.

Rice produces lower dietary energy-output per unit of external energy-input as compared to wheat as rice uses more energy to generate the same calorie energy than of wheat. This implies that the environmental footprint of rice production may be higher than of wheat. In other words, wheat is a more energy-efficient crop. Energy-share in the total production cost is higher for coarse cereals as these are mainly grown by the resource-poor farmers using traditional forms of energy, namely human and animal power. The energy-shares in total production cost of rice and wheat across different states in India are presented in Table 4. In the case of rice, the share of commercial energy ranges from 20.43 per cent to 34.60 per cent in the states of West Bengal and Bihar, respectively. For rice crop, the state of Punjab has the highest mechanization

Table 3. Share of energy in production cost of major crops in India: TE 2007-08

Crop	Production cost (₹/ha)	Energy cost (₹/ha)	Share of direct energy costs (%)		Share of indirect energy cost (%)	Share of commercial energy costs (%) (1979-80)
			Human & animal	Machine		
Rice	23,080	13,529	38.00	7.00	14.00	16.85
Wheat	24,193	11,565	18.00	14.00	16.00	25.55
Maize	16,351	10,031	37.84	7.85	15.65	NA
Bajra	10,538	6,678	40.00	14.00	9.00	NA
Jowar	10,965	7,220	47.73	7.78	10.34	11.79
Rapeseed & mustard	15,704	6,913	22.00	14.00	9.00	10.18
Groundnut	20,794	13,876	36.89	4.78	25.07	27.37
Soybean	14,473	9,527	35.22	12.11	18.49	20.57
Gram	14,555	7,465	23.00	9.00	19.00	30.82
Arhar	14,473	7,241	40.05	5.39	10.25	11.79
Cotton	26,960	16,681	36.15	5.46	19.41	NA
Potato	55,185	37,743	18.72	4.13	45.55	37.85
Sugarcane	56,256	29,723	33.00	4.00	16.00	8.51

NA=Data not available

Source: Based on data in DES, New Delhi.

Table 4. Share of energy in the production cost in major rice and wheat growing states: TE-2007-08

State	Rice				Wheat			
	Production cost (₹/ha)	Share of direct energy cost (%)		Share of indirect energy cost (%)	Production cost (₹/ha)	Share of direct energy cost (%)		Share of indirect energy cost (%)
		Human & animal	Machine			Human & animal	Machine	
Andhra Pradesh	32,566	34.32	8.21	15.62	NA	NA	NA	NA
Bihar	15,885	38.53	9.16	12.70	16,260	19.72	15.49	19.11
Gujarat	18,702	33.53	8.54	21.23	19,928	21.07	12.07	20.51
Haryana	32,787	25.19	9.07	14.39	29,948	17.56	14.85	14.84
Madhya Pradesh	13,025	42.35	5.90	16.10	19,346	18.99	11.00	14.20
Odisha	20,424	39.36	6.72	12.95	NA	NA	NA	NA
Punjab	31,724	16.62	10.12	14.34	30,233	10.47	15.37	16.46
Rajasthan	NA	NA	NA	NA	24,361	21.74	11.34	15.48
Uttar Pradesh	21,167	34.59	6.78	15.98	24,695	19.93	14.46	15.57
West Bengal	26,713	49.72	2.68	11.84	23,940	38.56	1.93	18.50
India	23,384	38.00	7.00	14.00	24,101	18.00	14.00	16.00

NA=Data not available
Source: Based on data in DES, New Delhi.

(10.12 %) and the minimum is observed in the state of West Bengal (2.68 %). For wheat crop, about 15 per cent mechanization was observed in the states of Bihar, Haryana and Punjab and it was lowest in West Bengal. Table 3 also shows the temporal shift in the share of commercial energy for major crops between 1979-80 and 2007-08. The share of commercial energy in the total production cost has increased across all the crops, except gram in a span of two and a half decades. A wide variation in the increase of commercial energy share ranging from 9.03 per cent to 138.75 per cent in groundnut and sugarcane, respectively, has been noticed during these periods.

Energy Prices and Farm Profitability

In view of a significant share of energy in the cultivation cost of different crops, agriculture is vulnerable to energy price increase. Table 5 presents the changes in price index of foodgrains and commercial energy sources between 2001 and 2006. During this period, the diesel price index increased by 86 per cent, while foodgrain price index increased only by 12 per cent. As the majority of Indian farmers are price-takers and lack the capacity to quickly pass on the higher cost through the marketing chain, any rise in production cost will reduce farm profitability, at least in the short-run. The higher fuel costs would also increase marketing cost which will further reduce agriculture sector's net returns. In the long-run, a sustained rise in energy prices may affect input-use and production practices. On the output side, it will raise the output prices which will have far more serious implications for food security, poverty status and cost of industrial production.

Table 5. Wholesale price index of foodgrains and commercial energy (base year: 1993-94)

Item	2001	2006	Change (%)
Foodgrains	174.00	195.00	12.07
Diesel	239.80	446.80	86.32
Electricity	206.30	300.80	45.81
Fertilizers	159.10	175.10	10.06

Energy Use and Agricultural Output

In this section, an effort is made to establish a relationship between direct energy-use and agricultural gross domestic product (AgGDP). As regression involving two non-stationary time series variables may produce spurious regression, we resorted to the use of cointegating vector approach. Two series, namely energy use and agricultural output in value-terms are said to be co-integrated if they move together in the

Table 6. Augmented Dickey Fuller stationarity test

Null hypothesis	Original series		Transformed series		1st difference series	
	t-statistic	Probability	t-statistic	Probability	t-statistic	Probability
Direct energy has a unit root	0.4009	0.9791	-1.2398	0.6412	-5.611	0.0001
AgGDP has a unit root	0.8729	0.9933	-0.6340	0.8435	-4.235	0.0036

long-run. As discussed by Engle and Granger (1987), a linear combination of two or more non-stationary series which share the same order of integration, may be stationary. If such a stationary linear combination exists, the series are said to be co-integrated and long-run equilibrium relationship exists.

The visual inspection of time series plot (Figure 1) suggested non-stationarity for both the series, which is obvious in the case of trended series. Further, we subjected the time series data of both the variables to unit root analysis using the conventional statistical test namely, Augmented Dickey Fuller (ADF) test and results are presented in Table 6. The values of both the variables, given in Table 6, indicate that the null hypothesis of unit root was not rejected even at 10 per cent level. Table 6 also shows ADF test statistics and probability value for the logarithmic transformed series and first difference series for both the variables. Both the series exhibit non-stationarity even after logarithmic transformation. Hence, level series and transformed series of the two variables are non-stationary and are integrated of the order one that is I(1). First difference series of both the variables are stationary, that is I(0).

A natural step in the analysis of cointegration is to establish that it is indeed a characteristic of the data. Two broad approaches for testing the cointegration exist in the literature. The Engle and Granger (1987) method is based on assessing whether single equation estimates of the equilibrium errors appear to be stationery. The second approach (Johansen, 1988;1990) is based on the vector autoregression (VAR) method. In this paper, the Johansen test was performed for the presence of cointegration between the energy input and AgGDP.

The first step of Johansen test involves the determination of cointegrating rank, that is, the number of cointegrating relations. Two statistics, namely trace statistic and max statistic are used for testing the hypothesis that the cointegrating rank is at most r ($<$ k), k is the number of variables. In trace statistic, the alternative hypothesis is that the rank is k, while in case of max statistic, the alternative hypothesis is that the rank is r + 1. Table 7 presents both trace and max statistics for the time series data on energy input and AgGDP. The value in Table 7 clearly shows that both statistics failed to reject the null hypothesis of no cointegration between the energy input and AgGDP. Johansen has developed maximum likelihood estimators for cointegrating vectors. Empirical findings supported the presence of one cointegrating vector for the pair of analyzed time series data.

The cointegration relationship ('t' statistics within the parentheses) representing the equilibrium relationship between logarithm of AgGDP and logarithm of direct energy input is given by Equation (1):

$$\underset{(-14.72)}{\ln (\text{AgGDP})} - 0.422^{*}\underset{(431.33)}{\ln (\text{direct energy})} - 12.239 = 0$$

$R^2 = 0.95$ D-W statistic = 1.53

...(1)

Table 7. Cointegration rank test

Hypothesized number of cointegration	Eigen value	Trace statistic	Probability	Maximum-Eigen statistic	Probability
None*	0.5371	25.3091	0.0092	19.2588	0.0142
At most 1	0.2149	6.0503	0.1869	6.0503	0.1869

*Denotes rejection of the hypothesis at the 0.05 per cent level

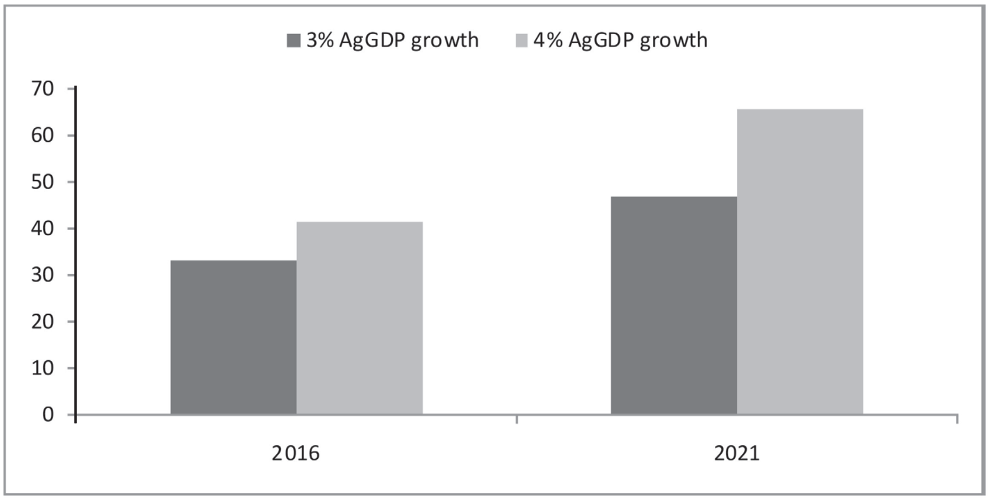

Figure 2. Energy requirement scenarios for the years 2016 and 2021

Applying the unit root test to the residuals obtained from the preceding cointegrating regression, it was found that the residuals were stationary, suggesting the existence of a long-run relationship between the two variables. Since relationship (1) was established between the logarithmic transformations of two variables, it provided some kind of long-run energy elasticity of 0.4215 for the agricultural growth. This indicates that for any target growth of AgGDP, growth in energy-use should be more than two-times the AgGDP growth.

After estimating the model, attempts were made to bring out the broad contours of energy demand by 2016 and 2021, which mark the end of the 12th and 13th Plans, respectively and hence are relevant for India's policy planning. For the direct energy demand projection, two scenarios were considered, viz. business as usual (BAU) scenario, i.e. AgGDP to grow at a rate of 3 per cent per annum, as observed in the previous decade, and an optimistic scenario (OS) of AgGDP growth of 4 per cent per annum, as envisaged in the Plan paper. The log linear specification of econometric models was used for computing the growth rates of energy input and projecting the demand for energy under both the scenarios. Figure 2 presents the energy requirement under the BAU and optimistic scenarios. The demand of direct energy for the year 2016 is projected to be 33.33 MTOE in the BAU scenario and 41.49 MTOE[2] in the optimistic scenario. The corresponding demand for direct energy for the year 2021 has been projected to be 47.0 MTOE and 65.30 MTOE under the two scenarios. These represent an annual average growth rate of 7–9 per cent over the current consumption in the year 2006-07.

Conclusions

The structure of energy consumption in Indian agriculture has changed with a marked shift from animal and human power to tractors, electricity and diesel power. The consumption pattern of both direct and indirect energy inputs has revealed that the energy consumption per hectare of net as well as gross cropped area has increased over time and therefore, the output per unit of energy-use has declined. This underscores that Indian agriculture has become more energy-intensive. The current trends in Indian agriculture reveal that its energy requirement will increase further. Therefore, there is a need of introducing technological change involving energy-efficient farm machinery and irrigation system. Also, in view of the significant contribution of energy-share in the production cost of different crops, agricultural system is vulnerable to increase in energy price through petroleum as well as fertilizer prices. In the short-run, energy-price related disruptions will reduce farm income of farmers. The main concerns of our decision makers relate to managing growing demand for energy in agriculture

[2] MTOE, the million tonnes of oil equivalent is a unit of energy. It is the amount of energy released by burning one million tonnes of crude oil.

to achieve the target growth and to match the domestic supplies with the demand. Actions will be needed on two fronts. First, on utilization of the available energy resources more efficiently to partially address the supply constraints and obviously, technological solutions have an advantage in this task. The second approach should be on promoting alternative renewable sources of energy involving technologies, institutions and policy measures.

References

DES (Directorate of Economics and Statistics) *Cost of Cultivation of Principal Crops in India* (various issues), Government of India, New Delhi.

Dickey, D. and Fuller, W. (1981) Likelihood ratio test for autoregressive time series with a unit root. *Econometrica*, **49**: 1057-1072.

Engel, R. and Granger, C. (1987) Co-integration and error correction: Representation, estimation and testing. *Econometrica*, **35**: 251-276.

Johansen, S. (1988) Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, **12**: 231-254.

Johansen, S. and Juselius, K. (1990) Maximum likelihood estimation and inference on cointegration with application for the demand for money. *Oxford Bulletin of Economics and Statistics*, **52**:169-210.

Joshi, P.K, Gulati, A. and Cummings (Jr), R. (2007) *Agricultural Diversification and Smallholders in South Asia,* Academic Foundation, New Delhi.

Pachauri, R.K. (1998) Economics of energy use in agriculture. *Indian Journal of Agricultural Economics*, **53**: 213-222.

Singh, A. and Singh, A.J. (1998) Economic analysis of energy use in Punjab agriculture. *Indian Journal of Agricultural Economics*, **53**(3): 241-255.

Singh, S. and Mittal, J.P. (1992) *Energy in Production Agriculture*. Mittal Publications, New Delhi.

TERI (Tata Energy Research Institute), *TERI Energy Data Directory & Yearbook* (various issues), New Delhi.

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