Mysore J. Agric. Sci., 51 (4) : 888-895, 2017

Trends and Pattern of Energy Consumption in Indian Agriculture

P. S. Prasanna Kumar, B. V. Chinnappa Reddy and K. B. Umesh
Department of Agricultural Economics, College of Agriculture, UAS, GKVK, Bengaluru-560 065
E-mail : shiprasannamk415@gmail.com

Abstract

The data on important variables like sector wise energy consumption, population, energy production, gross domestic product, farm power availability and average productivity of food grains in India were compiled for the period 1960-61 to 2012-13 from various published sources. The analysis of data reveals that the energy use pattern in Indian agriculture has undergone significant changes over time. The farm power availability from agricultural workers, tractors, power tillers, diesel engines and electric pumps had shown positive growth. The intensive cultivation as a result of introduction of high yielding varieties in the mid 1960s resulted in higher demand for higher energy inputs in agriculture. However, the contribution of farm energy from agricultural workers and draught animals had declined from 13.32 and 68.83 per cent to 5.08 and 8.46 per cent from phase I to phase IV, respectively. For enhancing cropping intensity with timely in field operations, animate energy sources alone were no longer adequate. Farmers opted for mechanical power sources to supplement the animate power. The trends in fertilizer consumption in terms of nutrients in Indian agriculture showed that the per hectare consumption of N, K, P nutrients had increased from 4.61 to 108.08 kg per ha from phase I to phase IV (from 1960 to 2013). The consumption of nitrogen, phosphorus and potash had increased at a compound annual growth rate of 8.97, 9.93 and 8.72 per cent. Further, per hectare electricity consumption has increased from 26.96 to 758.59 Kwh / ha from phase I to phase IV with compound annual growth rate of 8.47 per cent, respectively. The use of modern fertilizer responsive varieties and increased area under irrigation were the important factors that demand higher energy consumption in Indian agriculture.

Keywords: Energy consumption, energy use pattern**,** energy productivity, energy intensity

Energy has been termed as the fuel of economic progress. It is the prime mover of economic growth and development. The positive correlation between energy use and economic development has been well noted by economists and policy-makers in both developed and developing countries (Sahu, 2008). The ever-growing world population is expected to get doubled by the middle of this century and almost every country across the globe is aiming for positive economic growth. This intensifying economic development across the globe is coupled with increased demand for energy. Demand for energy in a growing economy stems from diverse sectors such as agriculture, industry, commerce, transport and residential. The growth of world population and economic standard is increasing the consumption of energy. As the amount of available fossil energy resources becomes scarce with time, development of new and renewable energy technologies and improvement of conventional technologies are imminent to fulfil the energy demand in future.

The relationship between energy consumption and economic growth has been a subject of greater inquiry as energy is one of the important driving forces for economic growth. Energy dependency is evident in every sector of the economy justifies the association between energy consumption and the overall growth rate in an economy.

Per capita energy consumption and energy intensity was used to analyze the relationship between energy consumption and economic growth. Per-capita Energy Consumption (PEC) during a year is computed as the ratio of the estimate of total energy consumption during the year to the estimated mid-year population of that year. Energy intensity is defined as the amount of energy consumed for generating one unit of Gross Domestic Product (At constant prices). It is an

indicator that shows how efficiently energy is used in the economy. PEC and energy intensity are the most widely used policy indicators, both at national and international levels.

Agriculture in India occupies a significant position in the country, as it provides livelihood and employment to over 54 per cent of the population and contributes around 14 per cent to the GDP. The agriculture sector has major implications for the overall demand and supply of energy in India. There has been an increase in the consumption of high-speed diesel (HSD) in the agriculture sector in India since the sale of tractors and agricultural machinery and implements has increased with the joint effort of the government and the private sector. The sector is a major consumer of diesel in India; it accounted for 13 per cent of the total consumption in 2012-13. Energy is a fundamental resource in the economy and there is a very strong link between energy use and both the level of economic activity and economic growth. Hence, economic growth is directly related to energy consumption and is affected by energy availability. For instance, the industrial sector has the greatest proportion of economic activity and consumes about one third of total energy use worldwide (UNIDO, 2010).

The past and current patterns of energy generation and consumption are bound to determine the economic future and wellbeing of the country. The final commercial energy consumption in India which has increased from 124.9 to 353.01 million tonne of oil equivalent in 1990-91 to 2011-12. Among different sectors of the economy, the industrial sector accounted for the highest share (45.35 %), whereas, agricultural sector accounted for 21.79 per cent in 2011-12 (TEDDY, 2015). The objectives of the present study are :

1) To analyse the trends and pattern of different energy sources in Indian agriculture, and
2) To examine the relationship between energy consumption and agricultural productivity.

METHODOLOGY

Nature and Source of Data

The data pertaining to various energy sources, energy equivalents of inputs and outputs in agricultural production, sector wise energy consumption, population, energy production, gross domestic product, farm power availability and average productivity of food grains in India were collected from the different Government of India published documents and websites such as Directorate of Economics and Statistics, Department of Agriculture, Government of India and Karnataka.

The secondary data pertaining to different energy sources were also collected from various issues of Energy Statistics reports of National Statistical Organization, NATCOM India and indiastat.com, various issues of Tata Energy Data Directory and Yearbook (TEDDY), The Energy and Resource Institute (TERI), New Delhi and Energy Information Administration (EIA) website, which is the official website of US Government.

Analytical Tools and Techniques Used

In order to analyze growth of different energy sources over 53 years (1960-2013), growth functions were considered. Several functional forms were tried to estimate the growth rates of the selected economic variables. Finally, exponential growth model was selected based on statistical significance, expected signs of parameters and R2. The model was of the following form.

$$Y_t = a\ b^t e^u \quad \text{——————} \quad (1)$$

Where,

Y_t = Dependent variable for which the growth rate is estimated (different energy sources)

a = Intercept

b = Regression coefficient

t = Time variable (1960 to 2013)

u = Error term

The compound growth rate was obtained from the logarithmic form of the equation (1) as below :

$$\ln Y = \ln a + t \ln b + u$$

The per cent compound growth rate (g) was derived using the expression.

$$g = (\text{Anti} \ln b - 1) \times 100 \ldots\ldots\ldots\ldots (2)$$

Where,

g = growth rate in terms of percentage

Results and Discussion

Trends of energy consumption in agriculture is analyzed and presented under the following headings.

Trends and pattern of physical energy sources in Indian agriculture

The trends in the possession of farm machinery and equipment at macro level was examined in terms of compound annual growth rate over the reference period 1960-2013 (Table I). The study period was divided into six phases each consisting a decade for facilitating better comprehension of trends in physical sources of energy. The results of the study indicated that that the average physical energy from agricultural workers, tractor, power tiller, diesel engines and electric pumps had shown increasing trend from phase I to phase VI (from the 1960 to 2013). However, the increasing trend was highly conspicuous in the case of power tiller, tractor, electric pumps and diesel engines, respectively, as they reported increased growth rate over the reference period. The increasing use of tractors and irrigation pumps operated by electric motors and diesel engines are the indicators of the fact that use of mechanical power in India has increased many fold during the reference period. This increased trend in physical energy sources was mainly attributed to the increased area under high yielding varieties, area under irrigation, crop diversification, cropping intensity and dwindling animal power in Indian agriculture.

During the reference period, the growth in power tillers was highest at 12.46 per cent followed by tractors (9.48 %), electric pumps (8.97 %) and diesel engines (7.04 %) and the lowest and negative growth was recorded in the case of agricultural workers at 1.50 and -0.98 per cent, respectively. The negative growth rate of draught animals was due to higher machinery use in many intensive operations in crop production, besides declining interest among farmers in maintaining bullocks for various reasons including high cost of maintaining bullocks due to non-availability of fodder.

Trends in Farm Power availability in Indian Agriculture

The trends and pattern of farm power availability in Indian agriculture (Table II) indicated that the total farm power availability in Indian agriculture has increased from 44.91 to 236.14 m Kw with a compound annual growth rate of 3.64 per cent from phase I to phase IV (1960 to 2013). The intensive cultivation as a result of introduction of high yielding varieties in the mid 1960s resulted in higher demand for higher energy inputs in agriculture. However, the contribution of farm energy from agricultural workers and draught animals had declined from 13.32 and 68.83 per cent to 5.08 and 8.46 per cent from phase I to phase IV, respectively. For enhancing cropping intensity with timely in field operations, animate energy sources alone were no longer adequate. Farmers opted

Table I

Trends and pattern of physical energy sources in Indian agriculture

(Millions)

Phase	Year	Agricultural workers	Draught animals	Tractors	Power tillers	Diesel engines	Electric pumps
I	1960-1969	119.63	81.34	0.08	0.00	0.66	0.63
II	1970-1979	135.22	81.16	0.30	0.02	2.25	2.29
III	1980-1989	164.44	72.50	0.80	0.02	4.50	4.78
IV	1990-1999	197.35	65.61	1.73	0.05	5.49	10.64
V	2000-2009	228.33	56.20	3.12	0.15	7.38	14.88
VI	2010-2013	248.91	49.95	4.15	0.27	8.25	18.05
CAGR (%)		1.50 **	-0.98 **	9.48 **	12.46 *	7.04 *	8.97 **

Source : TEDDY (2016), Directorate of Economics and Statistics, Government of India; Indiastat.com

Note : * Significant at 1 per cent ; ** Significant at 5 per cent

TABLE II

Trends and pattern of different sources of farm power in Indian agriculture

(Millions)

Phase	Year	Agril. workers	%	Draught animals	%	Tractors	%	Power tillers	%	Diesel engines	%	Electric pumps	%	Total
I	1960-1969	5.98	13.32	30.91	68.83	1.98	4.42	0.01	0.03	3.69	8.22	2.33	5.19	44.91
II	1970-1979	6.76	10.15	30.84	46.29	7.89	11.84	0.08	0.13	12.58	18.88	8.47	12.72	66.63
III	1980-1989	8.22	8.24	27.55	27.62	20.94	20.99	0.12	0.12	25.21	25.28	17.70	17.75	99.74
IV	1990-1999	9.87	6.56	24.93	16.57	45.25	30.08	0.30	0.20	30.74	20.43	39.38	26.17	150.47
V	2000-2009	11.42	5.40	21.36	10.10	81.46	38.52	0.84	0.40	41.33	19.55	55.06	26.04	211.46
VI	2010-2013	12.00	5.08	19.99	8.46	96.65	40.93	1.23	0.52	44.67	18.92	61.60	26.09	236.14
CGAR (%)		1.48 **		-0.95 **		9.42 **		12.31 *		7.02 *		8.93 **		3.64 **

Source : TEDDY (2016); Directorate of Economics and Statistics, Government of India; Indiastat.com

Note : * Significant at 1 per cent; ** Significant at 5 per cent

for mechanical power sources to supplement the animate power.

The contribution of tractor to farm power was highest to agriculture which increased from 4.42 per cent in phase I to 40.93 per cent in phase IV followed by electric pumps (5.19 to 26.09 %) diesel engines (8.22 to 18.92 %), and power tiller (0.03 to 0.52 %). The results of the study clearly revealed that the structure of the energy consumption in Indian agriculture has changed with a marked shift from renewable to non-renewable energy sources [(animal and human power (renewable) to tractor, electricity and diesel power (non-renewable)]. Due to modernization of agriculture production systems, increase in cropping intensity and shift towards high yielding commercial crops resulted in increased use of mechanical power sources and draught animal use was drastically reduced coupled with the dwindling energy supply from livestock enhanced greater dependency on mechanical sources of power. A study by Pandey (2009) also reported that both draught animal population and power availability from draught animals was decreasing over a period of time in Indian agriculture.

Growth in Fertilizer Consumption in terms of Nutrients and Energy in Indian Agriculture

The trends in fertilizer consumption in terms of nutrients in Indian agriculture showed that consumption pattern of nitrogen, phosphorus and potash (NPK) had increased many folds from phase I (1960-69) to phase IV (2010-13). Total energy consumption from NPK nutrients had increased from 44.12 GJ to 1281.63 GJ from phase I to phase IV (Table III). The per hectare consumption of NKP nutrients increased from 4.61 to 108.08 kg/ha from phase I to phase IV. The consumption of nitrogen, phosphorus and potash has increased at a compound annual growth rate of 8.97, 9.93 and 8.72 per cent during the reference period. The introduction of fertilizer-responsive high yielding varities (HYVs), expansion in the gross irrigated area and subsidies on fertilizers led to a sharp increase in fertilizer consumption in agriculture. Similar results of increased trend of fertilizer usuage in Indian agriculture was reported by Jaga and Patel (2012). The results of Hatirli, *et al.* (2006) indicated that the development of technology in farming and the level of production were the main factors which are directly related to energy consumption per unit area in agriculture. Green Revolution has led to the increasing use of fertilizers, chemicals, high yielding variety, diesel and electricity. A study by Houshyar *et al.* (2010) revealed that because of increase in mechanization level in agricultural production, the use of substitutes for land such as chemical fertilizers had increased which implied greater energy use in agriculture.

The growing use of chemical fertilizers, pesticides and water from underground sources drawn through

TABLE III

Trends in fertilizer consumption in terms of nutrients and energy in Indian agriculture

(Millions)

Phase	Year	Nitrogen (N)		Phosphorous (P_2O_5)		Potash (K_2O)		Total NPK		Total NPK Kg/ha	Growth Rate (%)
		Quanity (000 tonnes)	Energy Giga Joule (FJ)	Quanity (000 tonnes)	Energy Giga Joule (FJ)	Quanity (000 tonnes)	Energy Giga Joule (FJ)	Quanity (000 tonnes)	Energy Giga Joule (FJ)		
I	1960-1969	508.91	30.84	147.19	8.92	71.80	4.35	727.90	44.12	4.61	23.71
II	1970-1979	2483.73	150.53	740.95	44.91	418.14	25.34	3642.81	220.78	21.65	10.29
III	1980-1989	5830.68	353.37	2132.46	129.24	889.48	53.91	8852.61	536.52	50.07	8.58
IV	1990-1999	10086.89	611.33	3392.90	205.63	1185.64	71.86	14665.41	888.81	78.20	4.14
V	2000-2009	13106.35	794.32	5351.48	324.33	2448.66	148.40	20906.10	1267.04	110.46	5.26
VI	2010-2013	13282.38	804.99	5534.10	335.40	2330.55	141.25	21146.87	1281.63	108.08	-4.71
CGAR (%)		8.97 **		9.93 **		8.72 **		9.16 **		-	

Source: Indiastat.com; Note: * Significant at 1 per cent level; ** Significant at 5 per cent level

growing use of commercial energy needed to be considered carefully particularly if future strategies were to be developed to create conditions of sustainable development.

Consumption of Electricity in Agriculture

Electricity used for agricultural purpose (Table IV) had increased from 4,470 Gwh to 1, 47,462 Gwh from phase I to phase IV with a compound annual growth rate of 8.90 per cent. Further, per hectare electricity consumption has increased from 26.96 to 758.59 Kwh/ha from phase I to phase IV with compound annual growth rate of 8.47 per cent, respectively. Many factors explain this extraordinarily rapid growth in electricity : consumption in agriculture-increased area under irrigation, low cost of pumps and drilling equipment, institutional finance, high population pressure on farm lands, stimulus provided by public tube well programs, arrival of green revolution technologies; lack of canal irrigation in most places and massive investment in rural electrification. Shah *et al.* (2012) reported that in India, farmers use electricity mainly for energizing irrigation pump sets to extract groundwater. The number of electric tube wells had increased tremendously over time with the availability of free electricity. As a result of free power connections the financial condition of the state electricity boards worsened over the years.

The rural electrification programme launched by the Government of India in the mid sixties undertaken through the Rural Electrification Corporation has helped supply of electricity to new areas and preferential supply to rural sector at subsidized price and this has led to rapid increase in use of electric motors in agricultural sector. Swain (2012) supported these view points that subsidized electricity encouraged farmers for excessive use of water and electricity leading to excess electricity consumption over the years. The results of a study by Shah *et al.* (2012) indicated that substantial increase in the use of energized pump sets resulted in increase in ground water irrigation. One-third of the power consumed in the electricity sector is used to achieve roughly 50 per cent of irrigation needs from groundwater resources of the country.

Energy Use in Agriculture and Agricultural GDP

An effort has been made to analyze the association between farm power availability and the agricultural productivity (Table V). The agricultural productivity was considered as synonymous with food grain productivity. The total energy consumption had increased from 0.28 to 1.19 Kw per ha from phase I to phase IV with an annual compound growth rate of 3.42 per cent. In relation to increased energy input the agricultural productivity has also increased from

TABLE IV

Use of electricity for agricultural purposes

(Millions)

Year	Consumption for agricultural purposes		Total consumption (Gwh)	% Share of agricultural consumption to total consumption
	Total Consumption in Gwh	Kwh / ha		
1970-71	4470	26.96	43724	10.22
1980-81	14489	83.93	82367	17.59
1990-91	23422	126.10	123099	19.03
2000-01	85732	462.57	277029	30.95
2010-11	120209	609.21	612645	19.62
2011-12	131967	675.89	694392	19.00
2012-13	147462	758.59	824,301	17.89
CAGR (%)	8.90**	8.47**	7.42**	1.36**

Source : Central Electricity Authority (2012), New Delhi

Note : * Significant at 1 per cent level; ** Significant at 5 per cent level

TABLE V

Energy consumption in relation to agricultural productivity and agricultural GDP

Phase	Year	Energy consumption		Fertilizer consumption in nutrient terms		Agricultural productivity			Agricultural GDP	
		Magnitude (Kw /ha)	percentage change	Magnitude (kg / ha)	percentage change	Magnitude (Tonne/ha)	percentage change	Energy productivity (Kg/MJ)	Magnitude (Tonne/ha)	percentage change
I	1960-1969	0.28	-	4.61	-	0.54	-	1.89	165981	-
II	1970-1979	0.40	39.39	21.65	4.61	0.66	23.19	1.67	209411	26.17
III	1980-1989	0.56	42.43	50.07	21.65	0.83	25.04	1.47	285894	36.52
IV	1990-1999	0.80	42.24	78.20	50.07	1.01	21.46	1.25	393063	37.49
V	2000-2009	1.12	39.32	46.77	78.2	1.11	10.51	0.99	515423	31.13
VI	2010-2013	1.19	6.88	108.08	46.77	1.18	6.10	0.99	574045	11.37
Overall percentage change			320.52		119.37		245.85			2244.47
CAGR (%)			3.42		7.61		1.83			2.93

Source: Indiastat.com

*Note: * Significant at 1 per cent level ** Significant at 5 per cent level*

0.54 to 1.18 tonne per ha from phase I to phase IV with a compound annual growth rate of 1.83 per cent. Further, the agricultural GDP had also reported positively to energy consumption with a tremendous increase from ₹ 1, 65,981 crores in phase I to ₹ 5,74,045 crores in phase IV with an annual compound growth rate of 2.93 per cent. It is clear from the results that there was a strong positive correlation between energy consumption, agricultural productivity and agricultural GDP. This implies that increased energy consumption in agriculture, would stimulate agricultural productivity and agricultural GDP. Hence, it is suggested that farm power input has to be increased further to achieve higher food grains productivity and agricultural GDP. Those states where availability of farm power is more, have in general higher productivity. Singh (2014) pointed that the productivity of farms depends greatly on the availability and judicious use of farm power by the farmers. Thus, availability of adequate farm power is very crucial for timely farm operations for increasing production and productivity and handling the crop produce to reduce losses.

The results of the study indicated that the farm power availability from agricultural workers, tractors, power tillers, diesel engines and electric pumps has shown positive growth and the structure of the energy consumption in Indian agriculture has changed with a marked shift from renewable to non-renewable energy sources. Further, it was observed that a positive relationship exhist between farm power availability and increased agricultural productivity.

References

Hatirli, S. A., Ozkan, B. and Fert, C., 2006, Energy inputs and crop yield relationship in green house tomato production. *Renewable Energy,* **31** : 427 - 438.

Houshyar, E., Sheikh Davoodi, M. J. and Nassiri, S. M., 2010, Energy efficiency for wheat production using data envelopment analysis (DEA) technique. *J. Agril. Technology*, **6** (4) : 663 - 672.

Jaga, P. K. and Yogesh Patel, 2012, An overview of fertilizers consumption in India : Determinants and outlook for 2020 - A review. *Internal. J. Scientific Engineering and Tech.,* **1** (6) : 285 - 291.

Pandey, 2009, Indian Agriculture- An Introduction. *Fourth Session of the Technical Committee of APCAEMkl*, Chiang Rai, Thailand.

Sahu, S. K., 2008, Trends and Patterns of Energy Consumption in India. Indian Institute of Technology, Bombay, pp : 1 - 31.

Shah, T., Giordano, M. and Mukherji, A., 2012, Political economy of energy-groundwater nexus in India: Exploring issues and assessing policy options. *Hydrogeology J.*, **20** (5) : 995 - 1006.

Singh S., 2014, Agricultural Mechanization in India. Conference paper presented in *Regional Roundtable of National Agricultural Machinery Associations in Asia and the Pacific - Connection for Co-operation and Development*, Wuhan, China, pp : 1 - 17.

Swain, A., 2012, In pursuit of energy efficiency in India's agriculture : Fighting free power or working with it ?. *Discussion paper 126, Agence Francaise de Developement, Paris, France*, pp : 1- 80.

Teddy, 2016, The energy data directory and year book. *TERI Publishers*, New Delhi.

Unido, 2010, Global industrial efficiency benchmarking : An energy policy tool. *United Nations Industrial Development Organization*.

(*Received :* Oct., 2017 *Accepted :* Dec., 2017)