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indicated that output was significantly affected by farm size, seed-fertilizer-insecticides and tractor hours in the overall analysis. The analysis also revealed that the marginal productivity of land was the highest followed by human labour, seed-fertilizer-insecticides and tractor energy, whereas the marginal value productivity of bullock energy was found to be negative but non-significant. The ranking of the explanatory variables for their contribution to output indicated that human energy ranked first followed by seed-fertilizer-insecticides, land and tractor energy in order. The comparison of marginal rates of substitution of tractor energy for bullock energy with price ratio indicated the need for substituting tractor power for bullock power. This type of substitution is already taking place. On the other hand, the comparison of marginal rate of substitution of machine energy for human energy with the corresponding price ratio pointed to the need for substituting human energy for mechanical energy on purely economic considerations. However, a number of other considerations were responsible for increasing substitution of machine power for human power. These were the desire of the farmers to perform the important agricultural operations more effectively and on time, their preference for greater convenience and leisure and lastly, their urge to enhance their social prestige.

ENERGY CONSUMPTION AND AGRICULTURAL DEVELOPMENT IN PUNJAB AND HARYANA

R. N. Senapati*

The use of energy in agriculture has received a great deal of emphasis in recent years with increasing modernization and mechanization of traditional agriculture in developing countries like India. The objectives of this paper are : (a) to present some estimates of the consumption of energy in its various forms in the agricultural sector in the States of Punjab and Haryana for the years 1961-62, 1966-67 and 1972-73; (b) to analyse the changes in the pattern of energy consumption during the above period; (c) to study the relationship between changes in energy consumption and changes in cropping intensity, yield and production in these two States for the above years; and (d) to investigate into the social cost of such energy consumption in relation to the value of the total output for the same years.

Energy as input into agriculture can be applied in the form of draft power, irrigation and fertilizers. In the category of draft power we have included the number of bullocks, the number of tractors operating in those years. As regards irrigation, we have considered the number of oil engines and the

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consumption of electricity to lift water. We have taken into account the consumption of fertilizers and calculated the quantum of energy used in the production of fertilizers.

The principal sources of energy used in agriculture are bullock labour, diesel oil used both in tractors and in oil engines, electricity used to energise pumpsets for lifting water and used as feedstock to produce fertilizer and fuel oil, naphtha, coal used as feedstock to produce fertilizer.

The present study analyses the trends in the consumption of commercial energy such as electricity, diesel, naphtha in Punjab and Haryana and the analysis is confined only to three points of time, namely, 1961-62, 1966-67 and 1972-73 because of non-availability of annual data in respect of tractors, oil engines and bullocks.

I

In Table I we have presented the estimates of actual consumption of electricity and fertilizer in the years 1961-62, 1966-67 and 1972-73 measured in their original units. In 1961-62, the consumption of electricity was 100 million kwh, while it has increased upto 257 million kwh in 1966-67 but in 1972-73 we find a tremendous increase in its consumption *i.e.*, 1123 million kwh. So far as fertilizer consumption is concerned, it amounts to 15,000 tonnes N while in 1966-67, it is 82,000 tonnes N. But in 1972-73 the increase is appreciable reaching a figure of 3,18,000 tonnes N. Similarly, the number of tractors in 1961-62 was 7,866 and it has increased upto 15,486 in 1966-67. But in 1972-73, it has gone upto 67,000 which represents more than four-fold increase over 1966-67.

TABLE I—ELECTRICITY CONSUMPTION, FERTILIZER CONSUMPTION, NUMBER OF TRACTORS, BULLOCKS AND OIL ENGINES IN THE AGRICULTURAL SECTOR IN THE STATES OF PUNJAB AND HARYANA

Energy input	1961-62	1966-67	1972-73
1. Electricity (million kwh)	100.00	257.00	1123.00
2. Fertilizer (N) (metric tonnes)	15,000	82,000	3,18,000*
Electricity consumption in fertilizer production (million kwh)	197.1	1077.48	709.56
Naphtha for fertilizer (thousand tonnes)	—	—	330
3. Number of oil engines	8,158	29,326	2,80,061
Diesel consumption (tonnes)	12,237	43,989	4,20,092
4. Bullocks	21,32,400	21,99,200	23,51,300
Diesel equivalent of animal power (tonnes)	6,35,242	6,55,142	7,00,451
5. Number of tractors	7,866	15,486	67,000
Diesel consumption of tractors (tonnes)	18,746	36,906	1,59,674

* Out of 318,000 tonnes of N, 54,000 tonnes were produced by Nangal using electricity as feedstock.

Source: (1) Central Electricity Supply: All-India Statistics Annuals, 1961-62, 1966-67, 1972-73.

(2) Fertilizer Statistics of India, Annual Number.

(3) Statistical Abstracts of Punjab and Haryana.

The bullock population has increased from 21,32,400 in 1961-62 to 21,99,200 in 1966-67. But in 1972-73, the number of bullocks was 23,51,300. Compared to the increased number of tractors the rise in bullock population is not significant. This indicates the trend of increasing mechanization in Punjab and Haryana. The number of oil engines has also registered a sharp rise from 8,158 in 1961-62 to 29,326 in 1966-67, but its increase in 1972-73 is quite substantial amounting to 2,80,061. On the whole, the increase in the use of tractors, oil engines, fertilizer and electricity is quite conspicuous between 1966-67 and 1972-73. This period being the era of Green Revolution the reason is not far to seek.

Table I also describes the total consumption of diesel oil by tractors and oil engines; the amount of electricity and naphtha used in the production of fertilizer N and the consumption of diesel equivalent to the animal power, *i.e.*, the quantity of diesel that would have to be consumed if these bullocks were replaced by tractors. In efficiency terms, we have assumed 4 pairs of bullocks=1 tractor, although there is no unanimity in the studies related to this ratio. The average annual consumption of diesel per tractor is taken as 1,986 litres. In the case of oil engines we have taken 1.25 litre as the average consumption of each oil engine per hour and the average annual working hours have been assumed to be 1000 hours. As regards fertilizer for 1961-62 and 1966-67, electricity has been taken as feedstock in the production of fertilizer N. While for 1972-73, both electricity and naphtha have been taken as feedstock in the production of fertilizer. For fertilizer production in 1961-62, 197.1 million kwh were consumed while the consumption increased upto 1,077.48 million kwh in 1966-67, while in 1972-73, it involved the use of 709.56 million kwh and 330,000 tonnes of naphtha. The consumption of oil in the oil engines has increased from 12,237 tonnes in 1961-62 to 43,989 tonnes in 1966-67. But the increase in the consumption of diesel has shown a sharp rise to 4,20,092 tonnes in 1972-73 due to a substantial increase in the number of oil engines. The consumption of diesel oil in the tractors was 18,746 tonnes in 1961-62, but it has risen upto 36,906 tonnes in 1966-67. In 1972-73, it has increased upto 1,59,674 tonnes. In the case of bullock labour, we get an estimate of 6,35,242 tonnes of diesel equivalent of animal power and its increase is nominal in 1966-67 amounting to 6,55,142 tonnes. In 1972-73, we get an estimate of 7,00,451 tonnes of diesel oil equivalent of animal power.

To ensure comparability in the use of different sources of energy, we have converted each form of energy into a common unit of measurement following the practice laid down by the Fuel Policy Committee (1972) and accordingly we have presented Table II showing the amount of energy in terms of million tonnes of coal replacement (mtrc). In 1961-62, the total consumption of energy in the form of draft power, irrigation and fertilizer is estimated at 6.293125 mtrc, while in 1966-67 it is estimated to rise to 7.958813 mtrc and the rise is of the order of 26 per cent. But in 1972-73, the total energy consumption amounted to 16.093513 mtrc which is more than two times of the 1966-67 level. This shows that agriculture in Punjab and Haryana have be-

TABLE II—TOTAL CONSUMPTION OF ENERGY IN AGRICULTURE IN PUNJAB AND HARYANA
(million tonnes of coal replacement-mtr)

Energy input	1961-62	1966-67	1972-73
1. Electricity	·100 (2)	·257 (3)	1·123 (7)
2. Diesel for oil engines	·110133 (2)	·395901 (5)	3·780828 (23)
3. Energy input for fertilizer production	·1971 (3)	1·07748 (14)	3·448560 (22)
4. Diesel equivalent of animal power	5·717178 (91)	5·896278 (74)	6·304059 (39)
5. Diesel for tractors	·168714 (2)	·332154 (4)	1·437066 (9)
6. Total energy consumption	6·293125 (100)	7·958813 (100)	16·093513 (100)
Indices of total energy consumption	100	126	255·73

Notes:—Figures in brackets indicate the percentage of that particular energy to the total consumption in that year.

One million tonnes of high speed diesel oil and light diesel oil = 9 mtr; 10⁹ kwh electricity = 1 mtr; 1 million tons of naphtha = 8·3 mtr; 1·25 tons of naphtha is used as feedstock to produce one ton of nitrogen.

come more and more energy intensive during the years between 1966-67 and 1972-73.

As regards the relative share of different sources of energy in the total energy consumption, we observe that in 1961-62, draft power in the form of bullock labour accounted for 91 per cent of the total energy consumption and it has declined over the years. In 1966-67 it is 74 per cent of the total consumption, while in 1972-73 it has been reduced to only 39 per cent of the total consumption. This significant trend of decline in relative terms indicates the growing level of mechanization in Punjab and Haryana. But an important fact to be borne in mind is that the energy available from bullock labour has increased in absolute terms over the years, though not substantially. Then the additional requirements of draft power have been met by tractorisation. The diesel oil consumption by tractors constituted only 2 per cent of the total consumption of energy in 1961-62 while it has increased to 4 per cent in 1966-67 and in 1972-73 it has reached 9 per cent.

As regards the consumption of electricity in 1961-62 its percentage to total consumption was 2. In 1966-67 it came to 3 per cent but in 1972-73 it has increased upto 7 per cent of the total consumption. This shows the increasing use of electric pumpsets for irrigation purposes.

The consumption of diesel oil by oil engines has been marked by a sharp increase over the years. In 1961-62, its share in total consumption was only 2 per cent, while its share increased upto 5 per cent in 1966-67 and in 1972-73 it jumped upto 23 per cent. This fact is also supported by the substantial rise in the number of oil engines, *i.e.*, 45·66 per cent rate of growth (average annual compound) from 1966-67 to 1972-73. The phenomenal rise in the use of electricity and diesel oil demonstrates that mechanized pumping has

been adopted on a massive scale in Punjab and Haryana between 1966-67 and 1972-73.

Fertilizer consumption has also registered an increase over the years. Its relative share in 1961-62 in the total consumption of energy was 3 per cent and it went up to 14 per cent in 1966-67. In 1972-73 its share in the total consumption of energy is 22 per cent.

II

In order to study the relationship between the changes in different forms of energy consumption and changes that have occurred in cropping intensity, yield and production, we have computed indices for the above items and Table III indicates different indices taking base year 1961-62 as 100. We can note from the table that the index for cropping intensity went up to 106 in 1966-67, while it increased again to 115.9 in 1972-73. Similarly in the case of yield, the index went upto 111.6 and in 1972-73 it reached 159.8. As regards production, it is 125.8 in 1966-67 while it went upto 186.5. As regards different forms of energy, draft power increased upto 105.8 in 1966-67 and again it increased upto 131.5. In the case of irrigation, the increase is really tremendous. Compared to 1961-62, it is 311 in 1966-67 and in 1972-73 it is 2333. As regards fertilizer it is 547 in 1966-67 and 1749 in 1972-73. These indices indicate strongly that after 1966-67 the new agricultural strategy was heavily oriented towards more intensive efforts at irrigation and fertilizers.

TABLE III—INDEX NUMBERS OF YIELD, CROPPING INTENSITY AND AGRICULTURAL PRODUCTION, TOTAL ENERGY CONSUMPTION IN PUNJAB AND HARYANA
(Base 1961-62=100)

Item	1961-62	1966-67	1972-73
Cropping intensity	100	106.0	115.9
Yield	100	111.6	159.8
Production	100	125.8	186.5
Total energy consumption ..	100	126.0	255.73
—Draft power	100	105.8	131.5
—Irrigation	100	310.7	2333.67
—Fertilizer	100	546.66	1749.64

Source : Statistical Abstracts of Punjab and Haryana.

When we compare the indices of total energy consumption and indices of cropping intensity, yield and production in different years, we find that compared to 1961-62, 26 per cent increase in total consumption of energy in 1966-67 is associated with an increase of 26 per cent in production, 12 per cent increase in yield and 6 per cent increase in cropping intensity. But when we compare 1966-67 and 1972-73, we notice that the total energy consumption has increased by more than 100 per cent while cropping intensity has increased by 9.34 per cent, yield has increased by 43 per cent and production has increased by 48 per cent. However, this shows that between the years 1966-67 and 1972-73, more and more energy inputs have been applied to increase yield and production. Since agricultural production is a function of so many

variables, it is difficult to single out the effects of energy inputs on total production and yield. But one fact becomes eminently clear that the intensity of energy inputs has increased over the years.

III

An attempt has also been made to calculate the social costs of these different forms of energy along with an evaluation of the value of the total output. While taking into account the value of output, we have included total foodgrains, sugarcane and cotton. Various energy inputs and various outputs have been multiplied by their respective shadow or accounting prices. In the case of sugarcane and cotton, we have taken the market prices of *gur* and cotton assuming that market prices do reflect the social prices also. Then the total cost of energy consumption as a proportion of the value of the total output has been calculated for different years.

In absolute terms, the social cost of energy inputs excluding fertilizer has gone up from Rs. 1065.6 million in 1961-62 to Rs. 1186.2 million in 1966-67; it has further increased to Rs. 1836.9 million in 1972-73. But the social cost of energy inputs including fertilizer has moved up to Rs. 5388.40 million in 1966-67 from Rs. 1834.32 million in 1961-62. In 1972-73 it has come down to Rs. 4855.04 million (Table IV).

TABLE IV—TOTAL VALUE OF ENERGY INPUTS AND TOTAL VALUE OF OUTPUT OF PRINCIPAL CROPS IN PUNJAB AND HARYANA

Output of principal crops	(million Rs.)					
	1961-62		1966-67		1972-73	
	Quantity	Value	Quantity	Value	Quantity	Value
Total foodgrains (thousand tons)	6,448	14475.76	6,776	15212.12	11765	26412.42
Sugarcane (thousand tons of <i>gur</i>)	823	1851.75	945	2126.25	1029	2315.25
Cotton (hundred bales*)	954	902.44	1023	967.71	1439	1316.23
Total		17229.95		18306.08		30043.9
Inputs						
Electricity		39.00		100.23		437.97
Light diesel oil for engine		6.32		22.72		217.04
High speed diesel oil for tractors		11.71		23.06		99.79
Energy input in fertilizer production		768.69		4202.17		3018.08
Maintenance cost of bullocks		1008.60		1040.22		1082.16
Total		1834.32		5388.40		4855.04

* 1 *candy* = 1.98 bales of 180 kg.

- Notes:—(1) Shadow price of electricity = 0.39 (Rs./kwh).
 (2) Shadow price of L.D.O. = 620.00 (Rs./kilo litre).
 (3) Shadow price of H.S.D.O. = 750.00 (Rs./kilo litre).
 (4) Shadow price of naphtha = 760.00 (Rs./kilo litre).
 (5) Social cost of maintenance = Rs. 473.00 per bullock.
 (6) Shadow price of foodgrains (per ton) = Rs. 2,245.00.
 (7) *Gur* (price per ton) = Rs. 2,250.00.
 (8) Cotton (price per *candy*) = Rs. 1,873.00.
 (9) Premium on foreign exchange = 1.5.

The social cost of energy inputs as a proportion of the value of the total output turns out to be 10.64 per cent in 1961-62, while it has increased upto 29.42 per cent in 1966-67 and it has declined upto 16.15 per cent in 1972-73. This decline can be attributed to the fact that in 1972-73, a large part of fertilizer consumption was met by naphtha-based fertilizer plants. Since naphtha is a cheaper feedstock than electricity, we see a relative decline in the total cost of energy inputs. However, the social cost of energy inputs excluding fertilizer as a proportion of the value of the total output turns out to be 6.1 per cent in 1961-62, 6.4 per cent in 1966-67 and 6.1 per cent in 1972-73. This shows that the social cost of energy inputs excluding fertilizer as a proportion of the value of the total output has not changed significantly.

On the whole, it can be said that the intensity of energy inputs in the agricultural sector of Punjab and Haryana has increased over the years, particularly between 1966-67 and 1972-73. In absolute terms, energy inputs have increased in their use, but the social cost of energy as a proportion of the value of the total output has undergone a relative decline in 1972-73 as compared to 1966-67.

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AN ECONOMIC ANALYSIS OF ENERGY REQUIREMENTS OF ALTERNATIVE FARMING SYSTEMS FOR SMALL FARMER: SOME PUBLIC POLICY ISSUES

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INTRODUCTION

In recent years the World Food Problem has mandated a search for alternative methods of food production. Special importance has been attached to the general problem of resource-rooted scarcity of agricultural inputs. For example, fossil fuels have been the life line of "modern agriculture" in

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