Effects of Energy Input Sources on Crop Production: A Study of Selected Farmers of Northern India Region

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ABSTRACT

The effects of energy inputs from various sources on annual crop production per hectare, cropping intensity and the energy utilization pattern of selected farmers were studied using data from six villages of the Meerut district of Northern India. Farmers were classified according to energy sources available to them and they represented five well-defined mechanization levels ranging from farmers with only animate energy sources to farmers with tractors.

Average annual crop production per hectare exhibited a good response to annual energy use per hectare with production increasing manifold over the five categories. The cropping intensity increased rapidly with available power per hectare and annual energy use per hectare from about 75% to 150% at 0.5 kW/ha and 500 kWh/ha and then increased gradually up to 180% at 1 kW/ha and 1000 kWh/ha.

The energy utilization pattern of farmers representing increasing mechanization levels indicated a rapid initial increase in the utilization of energy from all the sources and then marginal decline in the share of animate energy sources and further increase in the use of electrical and mechanical energy sources. Energy output/input ratios were low for higher mechanization levels as compared to the energy ratio of farmers with minimum mechanization.

INTRODUCTION

Ever growing demand for food in India for its rapidly increasing human population compels the country's agricultural scientists and engineers to constantly search for ways to enhance food production from a nearly inexpandable arable land area. The population will be approaching one billion by the turn of this century needing twice as much food as is being produced today to ensure a standard diet for the whole population. The rational choice in such a situation is to improve substantially the productivity of land and labor and this will require higher input levels and efficient management of crop production systems. Both the application of higher input doses and efficient management need larger energy sources on the country's agricultural farms. The country can not hope to double its food production in the next decade at the present level of energy inputs on the majority of its farms.

Mechanical energy is necessary for all sorts of physical movements like soil manipulation, material input application, transportation, etc. In Indian agriculture it is supplied by human laborers, draft animals, electric motors, diesel engines and tractors, but so far animals have dominated the scene.

Increasing fodder production and in turn feeding a larger animal population is the traditional method of increasing power availability on farms. This method is slow and can not be expected to provide large increases in installed power which are necessary for rapid agricultural growth (Makhijani and Poole, 1975). Furthermore, every year a substantial area is being occupied by fodder crops, which could otherwise be utilized for food crops. Therefore, India with its limited landmass can not afford to have more draft animals which compete for food with human beings and which are inefficient when total energy input to sustain them are taken into account. The expected deficit in farm energy availability can be met from commercial energy-consuming farm machines.

Low oil prices up to 1970 were largely responsible for extensive mechanization of agriculture in developed countries. Prevailing energy consciousness makes us critical about energy intensification in agriculture but at the same time we simply can not compromise the national objective of higher productivity in agriculture to feed the growing human population. Agricultural policies based on facts regarding energy-annual production, -cropping intensity, -labor utilization relationships are needed. This study was carried out to provide some of these facts.

The effects of energy inputs from various sources and their utilization on annual crop production, cropping intensity and energy utilization pattern were evaluated in six villages of a farming district in Northern India. It should also be noted here that the aim of this study was not to provide mathematical relationships for quantitative extrapolation but to understand relationships between energy inputs and crop production within their existing ranges.

METHODOLOGY

For one year, daily energy inputs into various crop production activities on 500 crop plots of 24 farmers of six villages of the Meerut district of Northern India and respective crop yields of these plots were entered on a database program for organization, classification and preliminary analysis of data (Singh, 1987). The energy inputs were classified into two groups: direct and indirect. The direct energy inputs were those which were applied directly on the field while indirect energy inputs were those which were consumed in manufacturing, storage and transportation of fertilizers.

All the direct energy inputs were computed using recorded power ratings of bullocks, electric motors and tractors and time consumed by different operations. Human labor was rated at 0.07 kW (0.1 hp) which is widely used in energy analysis procedures. All the fertilizers were first converted into their nitrogen contents and then fertilizer energy input (indirect energy) was calculated by using the equivalent energy value of nitrogen as 15180 kcal/kg as recommended by Pimentel (1980).

Power available to each farmer was calculated separately on the basis of power sources available to him. Power available per household was used in place of power available per hectare because the power available to the farmer usually varies in proportion to the farm holding size. In such a situation a farmer using only animal power may rank higher on a power-per-hectare-scale due to very small holding size and his mechanization level on the basis of power available per hectare will be misleading. The farmers were grouped into five categories representing increasing levels of mechanization as suggested by Singh and Chancellor (1974).

Category I: Farmers with most or all of their land unirrigated and having animate energy sources only for farm operations.

Category II: Farmers with most or all of their land irrigated by persian wheel or canal and having animate energy sources only.

Category III: Farmers using electric motors for irrigation and having animate energy sources for all other operations.

Category IV: Farmers using electric motor for irrigation and to power stationary machines like wheat thresher, cane crusher and corn sheller.

Category V: Farmers owning a tractor mainly for tillage and transportation and using an electric motor to run irrigation pump and stationary machines.

Annual production for each farmer was calculated in terms of kilocalories per hectare to facilitate summation of different crops using their equivalent energy values as given in Table 1 compiled from Mittal et al. (1985). Then the average annual crop production for farmers in different categories was calculated. Energy output/input ratios were also computed for different levels of mechanization.

Table 1. Energy values used for different crops in the calculation of annual production.

Crops	Energy Value (kcal/kg)
Wheat, Maize, Rice, Barley, Chick-pea, Pigeon-pea, Millet, Oat, Peas	3510
Sugarcane	500
Cotton, Green Fodder, Oil Seed	2810
Onions	380
Potato	1340
Green Manure	72

Source: Mittal et al. (1985).

EFFECTS OF ENERGY INPUT SOURCES ON ANNUAL CROP PRODUCTION

Figure 1 summarizes the production features of farmers in each category. It shows that as the mechanization level increased from category I to category V the average annual production per hectare also increased substantially. The farmers in category I had minimum production of 15.15 Million kcal/ha, it doubled for the farmers in category II who managed to get their lands irrigated. It shows a further increase for farmers in category III and this trend continues up to the most mechanized category, i.e. the farmers in category V who obtained 60.27 Million kcal/ha, or four times that of the farmers in category I. Average energy use per hectare also increased with increased mechanization level. Regression analysis of annual production per hectare on total energy use per hectare showed a positive correlation as shown in Fig. 2. This curve represents a typical input-output relationship, i.e. the annual production increasing at a decreasing rate with total energy input. A qualitative evaluation of the effects of direct and indirect components of total

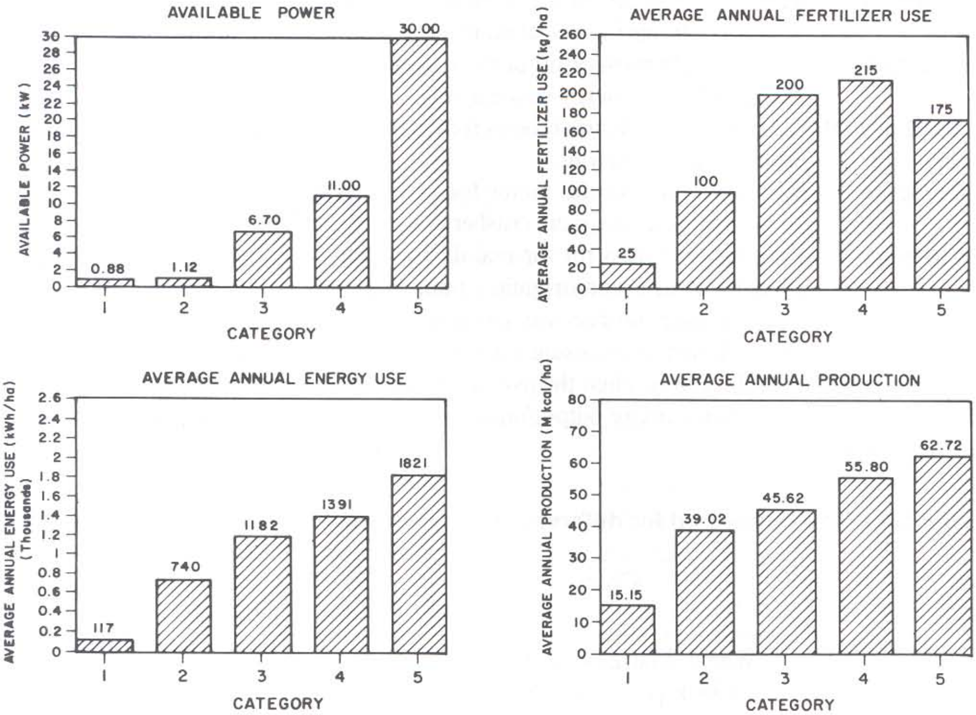

Fig. 1. Production features of farmers of different categories.

energy use on annual crop production as shown in Figs. 3 and 4, respectively, further reveals that the pattern of increase in annual production was the same with both types of energy inputs. Annual direct energy use includes the post-harvest energy also which of course does not affect production directly but it ensures timely harvesting and threshing of crops to clear the field for new cultivation and thereby enhancing cropping intensity.

EFFECTS OF ENERGY INPUT SOURCES ON CROPPING INTENSITY

In conditions of limited arable land and large human population multiple cropping is highly desirable as it increases annual food output and creates employment almost throughout the year.

A graph was plotted between power available per hectare (kW/ha) and cropping intensity (%) for all 24 farmers and is shown in Fig. 5. It shows that cropping intensity increased rapidly from about 60% to 150% when the power available increased from a negligible value to 0.5 kW/ha at point B. After point B it increased gradually along line BC up to 180% at 1 kW/ha at point C. Then it stabilized as indicated by line CD which explains the agronomic limitations of current cultural practices for increasing cropping intensity. A similar plot (Fig. 6) between annual direct energy use per hectare also shows a rapid initial increase (line AB) in cropping intensity from about 90% up to 150% at 500 kWh/ha of direct energy use, then a gradual increase (line BC) up to 180% at 1000 kWh/ha and finally no increase.

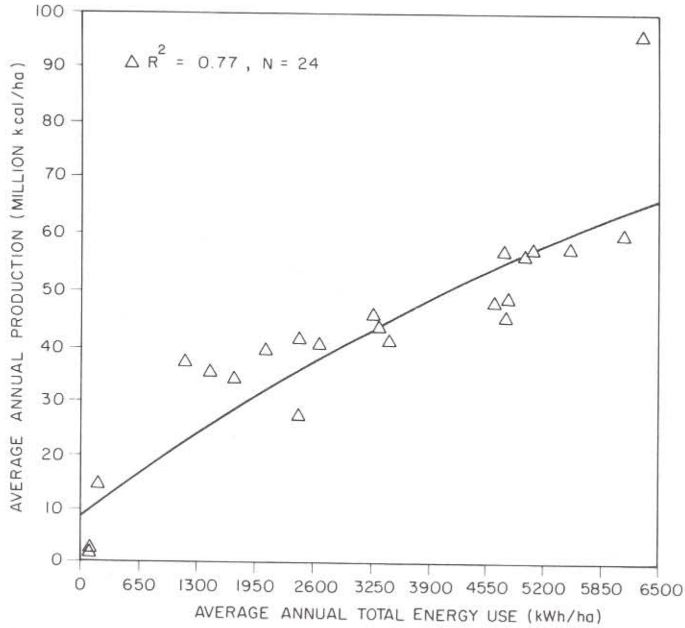

Fig. 2. Annual production vs total energy use.

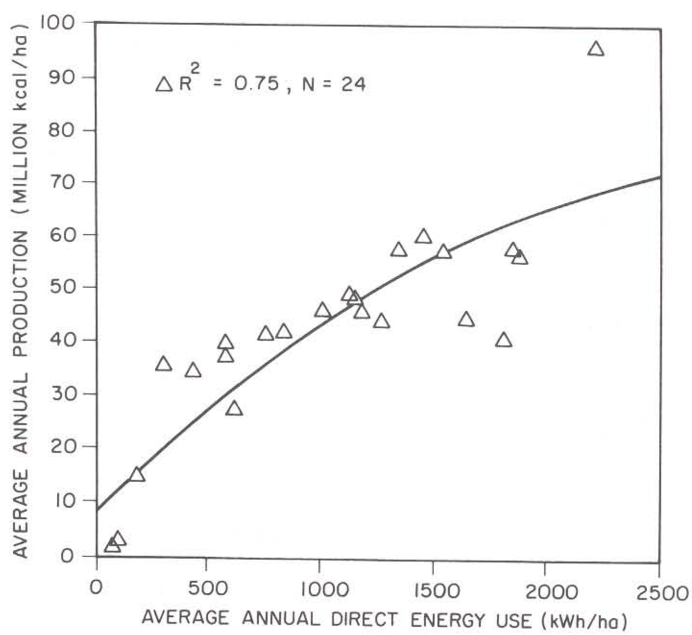

Fig. 3. Effect of direct energy use on annual production.

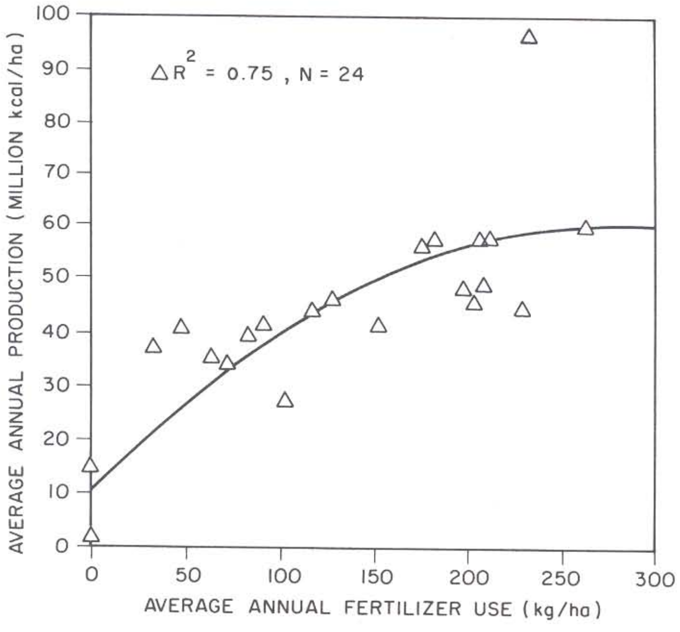

Fig. 4. Effect of fertilizers on annual production.

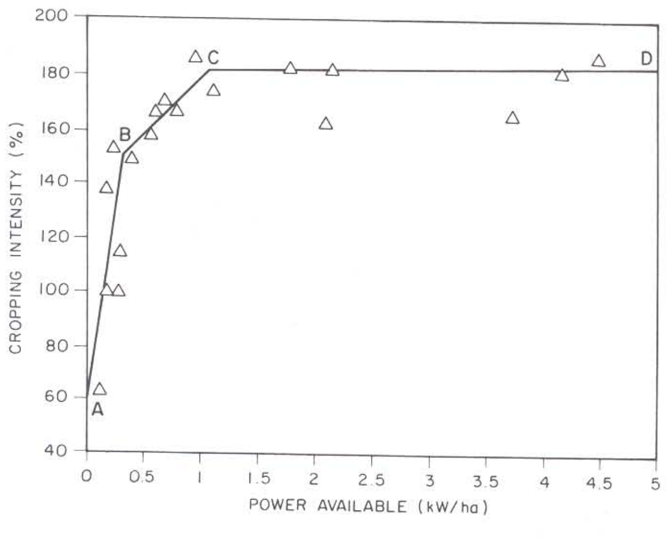

Fig. 5. Cropping intensity vs power available.

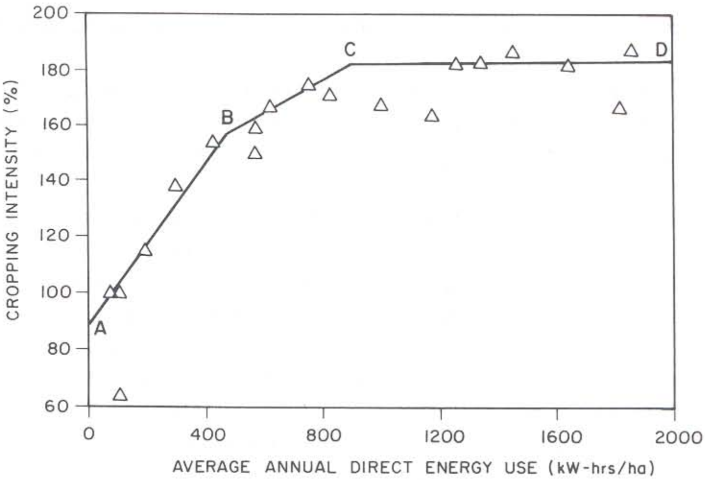

Fig. 6. Cropping intensity vs direct energy use.

It can safely be inferred from these two plots that within the existing agronomic practices a cropping intensity of about 180%, i.e. almost two crops a year could be achieved with 1 kW/ha of farm power. Any further increase in power availability would not affect cropping intensity. Similarly, 1000 kWh/ha of direct energy use in various crop production activities may ensure two crops a year.

ENERGY UTILIZATION PATTERN

Table 2 shows the average annual energy expenditure from various sources for farmers in the different categories on a per hectare basis. It is clear from this table that the total energy use increased uniformly for farmers in category I to category V and the components of total energy showed a varying but definite pattern of degree of utilization of different energy input sources. The farmers in category II made maximum use of human labor. The change from category I to category II by the mere introduction of irrigation generated six times more employment of human labor and five times more utilization of animal power with double annual production on a per hectare basis. The farmers in higher categories showed a decline in human labor and bullock power use.

Table 2. Utilization of different sources of energy per hectare by various categories of farmers.

Category	Human Labour (hrs)	Bullock Labour (hrs)	Electric Motor (kWh)	Tractor Energy (kWh)	Total (kWh)
I	290	95	0	0	117
II	1665	490	103	23	740
III	1370	334	738	7	1182
IV	1228	118	1077	30	1391
V	1100	70	1050	655	1821

Figure 7 illustrates the evolution of mechanization along with the changing pattern of energy use both in terms of quality and quantity.

Stage one represents the energy use by traditional farmers having only animate energy sources and using them for their rain-fed farming operations. The bullock energy contributed 82.6% of total energy use per hectare per year (117 kWh), the remaining part was provided by human labor.

In the next stage, i.e. in category II, the farmers used bullock pairs for operating Persian wheels for irrigation, hired electric motors for irrigation on some plots and tractors for tillage operations on hard plots especially plots with sugarcane or cotton roots. The total energy use increased to 740 kWh/ha/year and some bullock energy was replaced but it still had a share of 66.8% of the total. Human energy input was marginally lower in terms of percentage of the total (16%) than the previous stage but highest in absolute terms, 1665 man-hrs/ha/year.

In the third stage the farmers owned electric motors for irrigation purposes and contribution of bullock energy was considerably reduced to 28.4% of total energy use of 1182 kWh/ha/year. In this stage electrical energy contributed the most (62.8%) and the share of human energy was reduced to 8.2%.

In the subsequent stage the farmers acquired stationary machines for post-harvest operations which enabled them to increase utilization of electric motor. The contribution of electrical energy reached its highest level, i.e. 78% of the total energy use of 1391 kWh/ha/year and bullock and human energies were further reduced to 13.6% and 6.2%, respectively.

In the fifth stage the farmers purchased tractors which they used for tillage and transportation operations. In this stage bullock energy contributed only 3.8% and human energy 4.2% of the total energy use of 1821 kWh/ha/year. The electric motor (56.7%) and tractor (35.4%) provided the majority of the energy requirement of farm operations. This was the last stage of mechanization in the region.

ENERGY RATIOS

Table 3 shows the energy output/input ratios for five different mechanization levels. Category I had highest ratio (31.55) because of minimum inputs used by the farmers in this category. For the farmers in category II the energy ratio was 18.11. The farmers in the remaining three categories had significantly lower energy ratios (11.31, 12.51, and 14.85 for Category III, IV, and V, respectively) due to greater use of mechanical and fertilizer energy. The energy ratio analysis shows that the energy output did not increase in proportion to the increased energy input with the increase in mechanization level.

Table 3. Energy ratios for farmers of different categories.

Category	Direct Energy	Fertilizer Energy	Total Input	Total Output	Output/Input
	(Million kcal/ha)				Ratio
I	0.101	0.380	0.481	15.15	31.55
II	0.636	1.518	2.154	39.02	18.11
III	1.017	3.036	4.053	45.82	11.31
IV	1.196	3.264	4.460	55.80	12.51
V	1.566	2.657	4.223	62.72	14.85

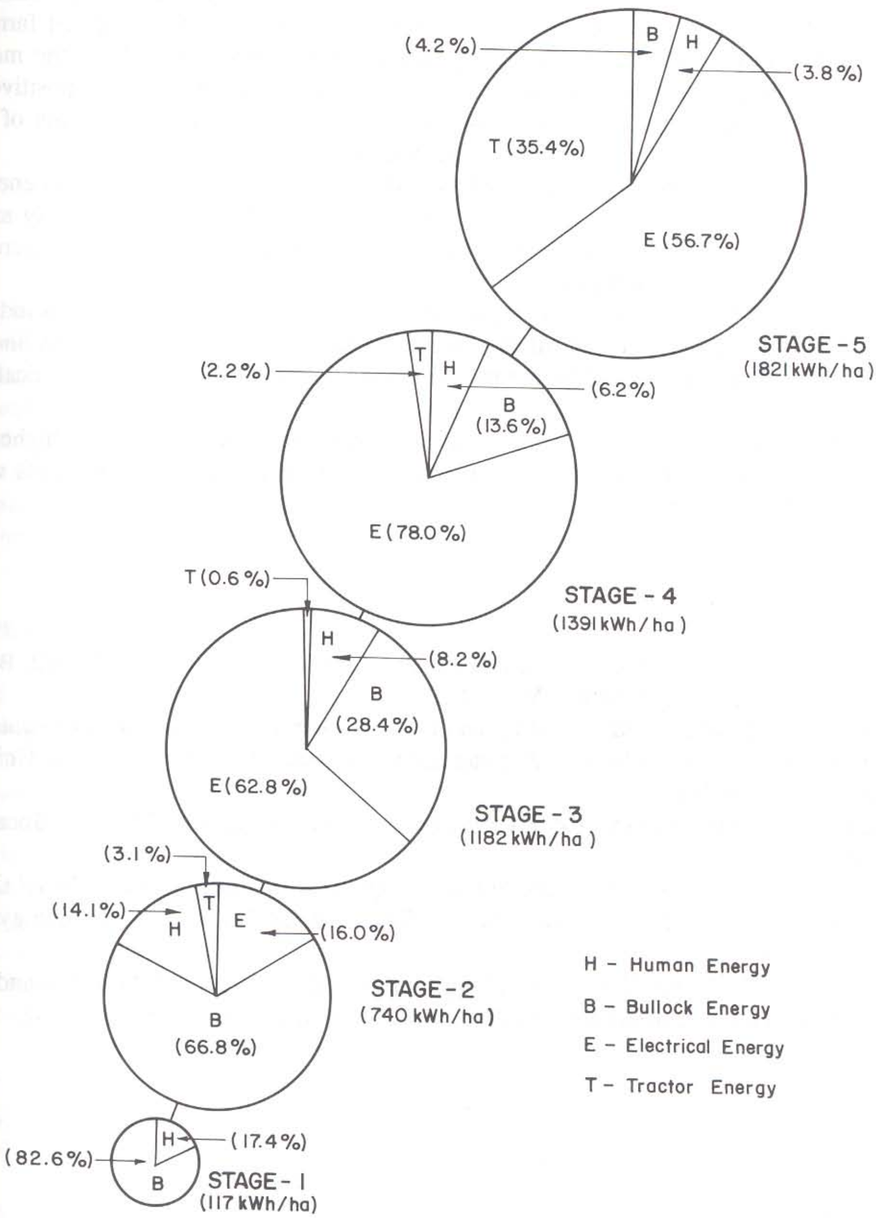

Fig. 7. Evolution of mechanization.

CONCLUSIONS

Annual crop production per hectare increased with the increasing level of mechanization of farmers and the difference was four times between two extremes, i.e. from rainfed farms with animate power to farms with tractors for tillage and transport operations and electric motors to power irrigation pumps and stationary machines. Annual crop production showed a positive correlation with annual energy use per hectare and both direct and indirect components of annual energy use affected the crop production in the same manner.

Cropping intensity increased rapidly with available power per hectare and direct energy use per hectare from about 75% up to 150% at 0.5 kW/ha and 500 kWh/ha, respectively and then gradually up to 180% at 1 kW/ha and 1000 kWh/ha. It showed no response to further increases in power availability and direct energy use.

Energy utilization pattern of farmers representing increasing mechanization levels indicated a rapid initial increase in utilization of all the energy sources and then a marginal decline in the share of animate energy sources and further increase in the use of electrical and mechanical energy sources.

The energy output/input ratio for higher mechanization levels was low due to higher inputs indicating that the energy output did not increase in proportion to the increased inputs with the increase in mechanization level.

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