The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Vol XXXVIII
No. 4

ISSN 0019-5014

OCTOBER-
DECEMBER
1983

INDIAN JOURNAL OF AGRICULTURAL ECONOMICS

INDIAN SOCIETY OF
AGRICULTURAL ECONOMICS,
BOMBAY

ENERGY CONSTRAINTS TO AGRICULTURAL PRODUCTION

B. S. Pathak*

Enhanced inputs of energy and improvements in its quality have played key roles in the development of all technologies including those associated with agricultural production. The muscle energy output of a man is rather small, not exceeding one-tenth, in most cases one-fifteenth of the energy output of a horse. Our ancestors first tried to supplement human energy with energy from other sources. Domestication of animals for draught purposes 8000 years ago was a good example of the success achieved in such an endeavour. Innovations to use energy more effectively came simultaneously. Improvement in the plough and the development of wheel (and the cart) made animal draught more efficient. The fabrication of these innovations itself required additional energy inputs. In agriculture, these developments were followed by efforts to control the soil-crop environment so that the combination of energy and innovated tools could be more effective in helping man to achieve the ever rising goals of food production. The practice of irrigation is an example of this type. In the agriculture of today, the control of soil-crop environment through the use of inputs like water, plant nutrients, chemicals, etc., has become a highly energy intensive practice. Significant and far-reaching changes have taken place in this century in regard to (*i*) supplementary energy sources, (*ii*) equipment and machinery through which the energy is utilized and (*iii*) the control of soil-crop environment. The extent of these changes is a good indicator of the technological status of agriculture in a region.

Before proceeding further, it would be useful to agree on some common classifications of energy and energy resources used in agriculture. Humans, draught animals, engines, motors, power tillers and tractors supply mechanical energy to perform various farm operations. The term direct energy is commonly used to describe this group of energy inputs. Large quantities of energy inputs are made in the form of materials like fertilizers, chemicals, equipment, seed, farmyard manure, etc. The heat content or the amount of energy consumed to produce these materials are considered as indirect energy inputs. Energy inputs like electricity, diesel fuel, equipment, fertilizer and chemicals are obtained through commercial channels, and are grouped under 'commercial energy'. Other energy inputs (farmyard manure, seed produced on one's own farm, animal draught, etc.) are classified as non-commercial energy inputs. The society is presently more concerned about the commercial energy inputs because of their increasing cost and also because most of the commercial energy, both direct and indirect, is obtained from non-renewable energy resources which continue to deplete at an increasing rate.

I would like to approach the subject of energy constraints to agricultural production through a set of hypotheses listed below:

1. There is a positive correlation between energy input and agricultural production.

* Professor of Eminence in Energy Agriculture, Punjab Agricultural University, Ludhiana.

2. Under conditions of limited cultivated area, energy inputs to field operations increase production only if the production (soil-crop) environment is appropriately modified through the use of additional energy inputs.
3. Technological advances force a shift from non-commercial to commercial energy inputs and lead to increased consumption of commercial energy.
4. Not enough energy resources are available to achieve and maintain high levels of agricultural production if advanced but conventional technology is used in the production agriculture of the Northern region.

ENERGY INPUT AND AGRICULTURAL PRODUCTION

Giles carried out an analysis of the data on mechanical energy input and crop yields of 12 countries and suggested that there was a positive correlation between the crop yields of cereals, pulses, oilseeds, sugar crop, etc., and horse power (HP) per hectare.* Giles did not take into account the mechanical energy consumed in lift irrigation. Further, the HP/ha. is not always a reliable indicator of the total energy input. Giles' findings were considered inconclusive by many economists.

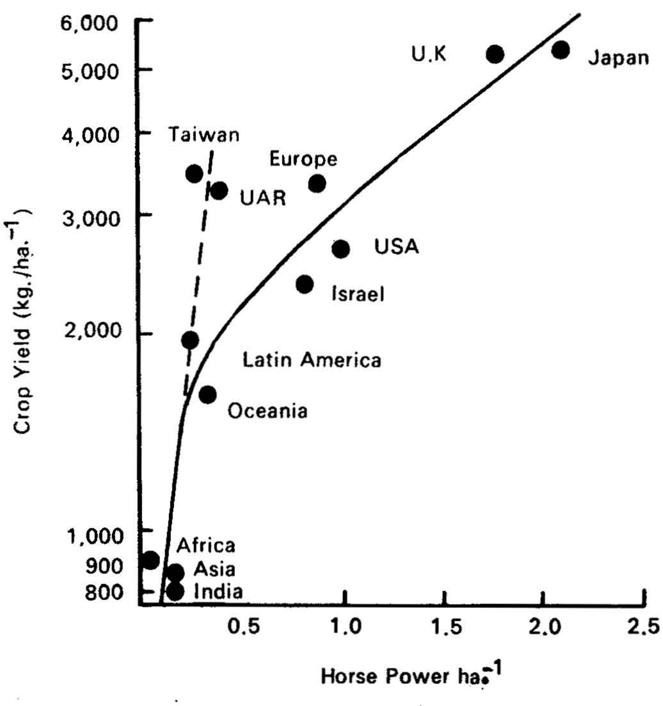

Figure 1—Relationship between Crop Yields Per Hectare and HP/ha. Reported by Giles (*Source:* Blaxter, *op. cit.*)

* K. Blaxter, "What Happens to Farming When the Fossil Fuels Run Out", *Farmer's Weekly*. January 20, 1978.

Detailed information has been generated during the last ten years to support the contention that there is a positive relationship between energy input and agricultural production. A case study of the production agriculture of Punjab for a 14-year period (1965-66 to 1979-80) has yielded results as shown in Table I.

TABLE I—PRODUCTIVITY, PRODUCTION AND ENERGY INPUT (MAJOR CROPS)

Year	Productivity (tonne/ha./year)	Production (tonne/year)	Commercial energy input (MJ*/tonne)
1965-66	1·64	4,964·82	985·1
1966-67	1·78	5,672·00	1,016·2
1967-68	2·13	7,049·41	1,222·8
1968-69	2·34	7,795·68	1,660·7
1969-70	2·52	8,582·77	1,791·9
1970-71	2·63	8,922·39	2,138·5
1971-72	2·79	9,611·09	2,476·2
1972-73	2·76	9,471·04	3,257·3
1973-74	2·77	9,684·59	3,122·6
1974-75	2·87	10,054·65	3,568·8
1975-76	3·06	10,908·67	3,512·7
1976-77	3·15	11,283·29	3,773·4
1977-78	3·45	12,448·87	4,215·3
1978-79	3·76	13,816·08	4,352·2
1979-80	3·73	13,639·46	4,758·9

Source: B. S. Pathak: Energetics of a Developing Agriculture, ICAR Project on "Energy Agriculture", Punjab Agricultural University, Ludhiana, 1982.
* M.J.=Mega joules.

The regression to commercial energy input against productivity yields the equation

$$y = -2452 + 1932.2x$$

where y is the commercial energy input in MJ/tonne of main product and x the productivity in tonne/ha./year of the main product. The correlation coefficient of the equation is 0.96. Although this equation is not applicable if the value of y lies outside the range of 1.6 to 4.0 tonne/year, the positive correlation between the energy, particularly the commercial energy, and productivity is maintained over a very wide range of productivity. During the 14-year period, the commercial energy input/tonne of production increased to 4.83 times and the production increased to 2.74 times. The total commercial energy, which is a multiple of energy input/tonne and total production, increased by 13.25 times. A wide range of information from different agricultural situations confirms the positive correlation between energy input and agricultural production.

ENERGY INPUTS TO FIELD OPERATIONS AND ENERGY FOR MODIFYING PRODUCTION ENVIRONMENT

As in the case of Giles, till 1970, the scope of research on energy inputs to production agriculture was limited to direct energy used for performing various operations like seed-bed preparation, planting, interculture, harvesting, etc. The data obtained from these studies did not show a consistent trend because of the variations created by different levels of other energy inputs used to modify the soil-crop environment. However, case studies on increase in energy input to field operations only showed that the productivity in such a case did not change.

TABLE II—ENERGY INPUTS TO MAIZE PRODUCTION IN GAUTEMALA

(*kcal./ha.*)

Inputs	A. Using manpower only	B. Using manpower and oxen
Labour	728,725	360,500
Oxen	Nil	777,500
Tools	16,570	41,400
Seed	36,608	36,608
Total	781,903	1,216,008

Source: R. Stadelman: Maize Cultivation in Northwestern Gautemala, Compiled by the Carnegie Institution of Washington, Contributions to American Anthropology and History, No. 33 Carnegie Institute of Washington, Publication 523, 1940, pp. 83-263.

As can be seen from Table II, the maize yield in the two cases having different energy inputs was the same, *i.e.*, about one tonne/ha. The introduction of oxen and the resulting increase in direct energy for field operation reduced the labour energy to about half and it became possible for one person to increase the area under maize by 100 per cent, which under conditions of adequate land availability would lead to higher production. But under conditions of limited land availability, additional energy input to field operations would not raise production. Fortunately in most situations of developing agriculture, the increase in energy inputs to field operations has been accompanied by matching increases in the use of energy for controlling soil-crop environment through application of water, use of fertilizers and chemicals, etc. Table III gives an example of a balanced growth of the two types of energy inputs and of the resulting change in productivity.

COMMERCIAL AND NON-COMMERCIAL ENERGY

The substitution of non-commercial energy input from labour and draught animals and in the form of farm produced seeds and organic manures by com-

TABLE III—CONSUMPTION OF DIFFERENT TYPES OF ENERGY IN PUNJAB AGRICULTURE

Commercial energy input	Quantity (TJ)*		
	1965-66	1972-73	1979-80
Field operations (from land levelling to threshing) ..	924	3,960	13,200
Soil-crop environment (lift irrigation, fertilizer and chemicals)	3,868	28,660	55,400
Productivity (tonne/ha./year)	1·64	2·76	3·73

* TJ=Tera joules=10^6 MJ.

mercial energy input from internal combustion and electrical prime movers and in the form of commercial seeds, fertilizers and chemicals has been an accepted trend during this century in the developed agriculture of the West. The analysis of the energy data for the agriculture of Punjab, however, shows a different trend (Figure 2).

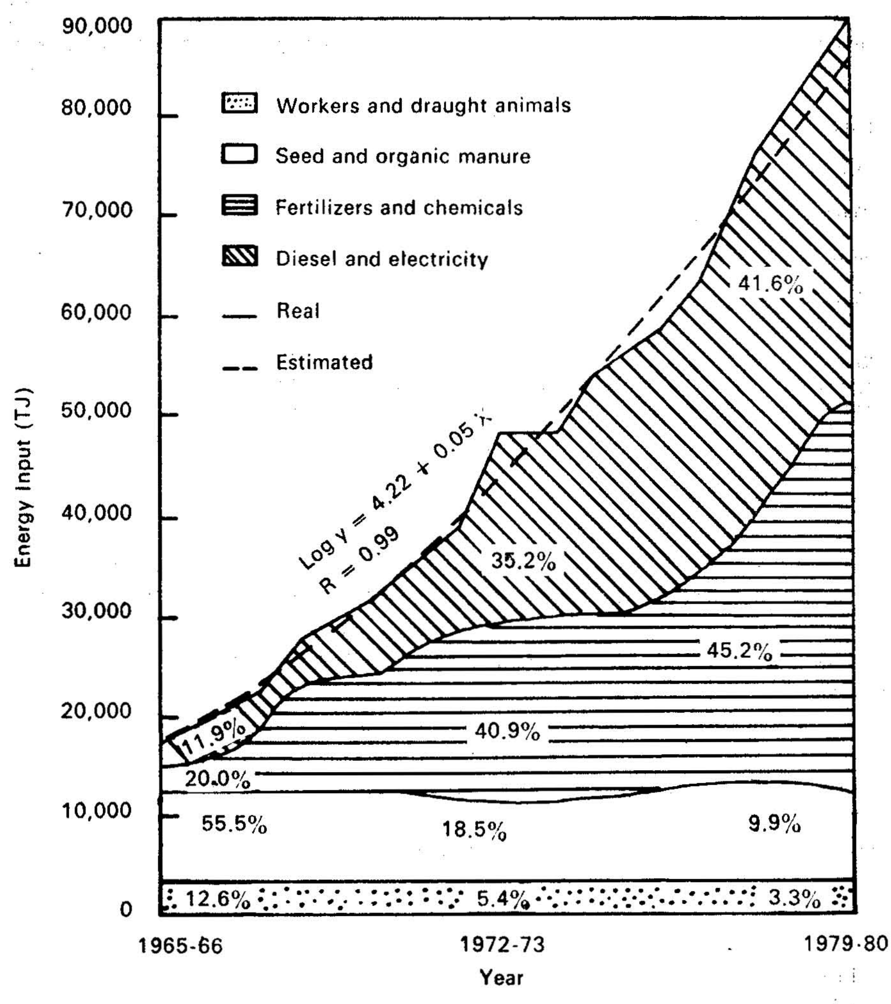

Figure 2—Growth in Energy Consumption in the Agriculture of Punjab

The use of non-commercial inputs has been retained by the farmers. But the additional requirements of energy for field operations, lift irrigation and fertilizers have been met from commercial sources. Preliminary analysis of the data for Haryana and Uttar Pradesh shows a similar trend. In the agriculture of North India, there is no replacement of the existing use of non-commercial energy by commercial energy. However, the incremental requirements of energy are being met primarily from commercial energy sources. Depending on the rate of development, the demand for commercial energy in the agriculture of the States of Punjab, Haryana and Uttar Pradesh has risen steeply during the last 10-15 years. This trend is likely to continue. For example, the yearly growth rate curve of electric energy and diesel oil for Punjab agriculture is described by the equation

$$y = \frac{1}{1+\left(\frac{24}{x}\right)^{3.294}}$$

The demand for diesel and electricity in the agriculture of Punjab will continue to grow for the next 20 years and the direct energy consumption will increase by 100 per cent during that period. The commercial energy consumption in the agriculture of Haryana and Uttar Pradesh is at a relatively lower level and the demand for commercial energy in these two States is likely to grow even faster compared to Punjab.

ENERGY REQUIREMENTS AND CONSTRAINTS

Having discussed the inevitability of steep increase in the demand for commercial energy during the coming years, it would be interesting to quantify these demands and discuss whether these can be met if the present rate of growth of energy resources is maintained.

In the States of Haryana, Punjab and Uttar Pradesh, rise, maize and wheat account for 74 per cent of the gross cropped area under cereals. For simplicity it is proposed to analyse the additional energy needs for these three crops only. The energy needs would be discussed in the context of two field operations, namely, land levelling and threshing, and two measures for the control of soil-crop environment, namely, lift irrigation and use of fertilizers. This is not to minimize the importance of other field operations and environment control measures and their additional energy needs. However, it is feasible to bring out the magnitude of the additional energy demands of the production agriculture of North India quite adequately even if the discussion is limited to the above four items.

Table IV gives the area, production and yields of rice, maize and wheat in the three States for the year 1980-81. Table V gives the estimated consumption of diesel oil (tractor and stationary engines), electricity (motors) and nitrogen (nutrient) of the region for the same year. Table VI gives the potential for expansion of lift irrigation in the three States. While discussing

TABLE IV—AREA, PRODUCTION AND YIELD IN HARYANA, PUNJAB AND UTTAR PRADESH, 1980-81

State		Rice	Maize	Wheat
Haryana	Area ('000 ha.)	472	74	1,476
	Production ('000 tonnes)	1,227	83	3,601
	Yield (tonne/ha.)	2·6	1·12	2·44
Punjab	Area ('000 ha.)	1,178	376	2,827
	Production ('000 tonnes)	3,228	602	7,689
	Yield (tonne/ha.)	2·74	1·6	2·72
Uttar Pradesh	Area ('000 ha.)	5,180	1,283	8,009
	Production ('000 tonnes)	5,698	916	13,135
	Yield (tonne/ha.)	1·1	0·71	1·64

TABLE V—CONSUMPTION OF DIESEL OIL, ELECTRICITY AND NITROGEN (NUTRIENT) IN NORTHERN REGION, 1980-81

	Diesel oil ('000 kl.)	Electricity (10^6 kWh)	Nitrogen ('000 tonnes)
Tractors	420	—	—
Oil engine	1,080	—	—
Motors	—	6,078	—
Chemical nitrogen to:			
(a) All crops	—	—	1,565
(b) Rice, maize and wheat	—	—	991

TABLE VI—POTENTIAL FOR THE EXPANSION OF LIFT IRRIGATION SYSTEM IN NORTHERN REGION, 1981-82*

State	Electrical pumpsets ('000)			Diesel pumpsets ('000)		
	Installed	Total potential	Expansion potential	Installed	Total potential	Expansion potential
Haryana	250	300	50	78·25	516	156·75
Punjab	312	500	188	281·00		
Uttar Pradesh	450	2,400	1,950	991·00	1,532	541·00
Total	1,012	3,200	2,188	1,350·25	2,048	697·75

* Based on the estimates of Central Ground Water Board.

these tables, it has been assumed that the potential for lift irrigation can be fully developed during the next 15 years and that matching inputs of mechanical power for land levelling and threshing and of fertilizers would be available to make full use of the expanded lift and canal irrigation facilities for enhancing the yields of the three crops to 4 tonnes/hectare. The present intensity of cultivation for the area under rice, maize and wheat in the three States has been estimated to be 140 per cent. Again for simplicity it has been assumed that the intensity of cultivation will not change during the next 15 years although in practice it is inevitable that with the expansion of irrigation facilities and increased inputs of mechanical power and fertilizer, the intensity of cultivation would increase. In other words, the estimated energy demands for the next 15 years discussed here are likely to be exceeded because of the changes in the intensity of cultivation.

It is estimated that only one-third of the net cropped area of 15 million hectares under these three crops has been properly levelled and developed. The remaining ten million hectares of land requires proper levelling. Since the benefits from land levelling in terms of higher yields are obtained only after a few years of completion of the operation, it would be reasonable to plan for the levelling of ten million hectares of land within the first five years. The initial levelling of land which has been under traditional cultivation and water management requires about 75 litres of diesel oil for completing the operation in one hectare. This would mean an additional consumption of 0.15 million kilo-litres of diesel oil per year for the next five years. In addition to the initial land levelling operation, the entire cropped area is to be levelled to remove minor surface irregularities during each crop season at the time of seed-bed preparation. It is estimated that 14 litres of diesel oil is needed for this purpose for each crop. The recurring requirement of diesel oil for the minor land levelling operations would, therefore, be about 0.29 million kilo-litres. To improve the land surface of the rice, maize and wheat area of the Northern region and to maintain it properly, an annual expenditure of 0.44 million kilo-litres of diesel oil will have to be incurred.

As can be seen from Table VI, there is a potential for the installation of an additional 0.698 million diesel pumpsets in the region. At the rate of 0.8 kilo-litre of fuel consumption per pumpset per year, the annual requirement for diesel fuel would increase by 0.56 million kilo-litres. According to the estimates of Central Ground Water Board, there is a potential for the installation of an additional 2.2 million electric pumpsets in the region. At an average annual consumption rate of 6,000 kWh per motor, the additional requirement of electric energy would be of the order of 13,130 million kWh per year.

Assuming that 50 per cent of the nitrogen in Uttar Pradesh and 80 per cent of the nitrogen in Punjab and Haryana is used for rice, maize and wheat, the total nitrogen consumption of these three crops in the region comes to about one million tonnes per year (Table V). The total requirement for nitrogen at the rate of 120 kg. per crop hectare per year (compatible with the yield level of 4 tonnes/ha.) comes to a little over 2.5 million tonnes of this nutrient per year, an increase of about 150 per cent.

For working out the additional energy requirement for threshing operation, a stationary task most efficiently performed by using electric power, the maize crop has been ignored because of its relatively lower tonnage and the small requirement of energy for its shelling. In 1980-81, 19.142 million hectares of area were put under rice and wheat in the region and the total production of these two cereals was 32.263 million tonnes. At a yield level of 4 tonnes/ha., 76.568 million tonnes of rice and wheat are expected to be produced. The annual energy requirement to thresh the additional tonnage of rice and wheat would be of the order of 2,178 million kWh.

Aggregating the additional consumption of each type of energy input, we come to the following figures:

1. Diesel oil—one million tonnes. This is about 70 per cent of the present consumption of diesel oil (including consumption in tractors) in the agricultural sector of Northern India and is about 33 per cent of the diesel oil consumption in the agricultural sector of the nation.

2. Electricity—15,308 million kWh. This represents an increase of 252 per cent over the present consumption of electricity in the agricultural sector of the region and exceeds the total consumption of this energy in the agricultural sector of the nation in the year 1978-79 by a substantial amount.

3. Nitrogen—1.5 million tonnes, which represents an increase of 150 per cent over the nitrogen consumption level in 1980-81.

The above analysis brings out the wide gap between the required and the presently used quantities of different types of energy inputs in the context of a yield of 4 tonnes/ha. of major cereals. The results of the analysis and discussion contained in this paper are obviously influenced by certain assumptions made in the beginning as well as by the limited number of crops included in the discussion. While the quantitative refinement of the data would be useful, following broad conclusions could be legitimately drawn from this discussion:

1. The requirement of production agriculture of Northern region for commercial energy would increase very rapidly in the next 15 years if the production potential of the region is to be adequately utilized.

2. Electric energy is likely to be the major constraint to agricultural production followed by fertilizer and diesel oil.