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RAPPORTEUR'S REPORT

ON

ENERGY REQUIREMENTS OF DIFFERENT FARM SYSTEMS

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Thirty-five papers have been accepted for discussion on the topic 'Energy Requirements of Different Farm Systems.' Most of the papers have been written on the level and pattern of energy use, one of the four aspects of the problem outlined in the synopsis published in the Journal. Very few papers have attempted to explain the variations in energy use in terms of agro-climatic and economic factors. Attempts have not been made to analyse the issues such as (*i*) divergence between the private costs (to the farmer) and 'economic costs' (to the society) of using different sources of energy, (*ii*) isolating the effect of use of tractors and other machinery on intensity of cropping, level of yields and level of employment, and (*iii*) the extent to which non-availability of suitable sources of energy has been a constraining factor for the growth of output in a particular region. In fact, in some of the papers the authors have not even shown awareness of the results of other studies available on the particular aspect of the problem analysed by them.

Broadly, the papers can be grouped into the following categories: (*i*) nine papers on the level and pattern of energy consumption in different States such as Uttar Pradesh, Punjab, Maharashtra, Tamil Nadu, Rajasthan and Himachal Pradesh; (*ii*) ten papers on the energy requirements of various crops in different regions; (*iii*) six papers on the economics of use of tractors vis-a-vis bullocks; (*iv*) six papers on the use of diesel engines vis-a-vis electric motor as well as the economics of using different sources of irrigation. There are isolated attempts at presenting economic analysis of energy requirements of alternative farming systems for the small farmer, relating trends in energy consumption and agricultural development in Punjab and Haryana and presenting a detailed social benefit-cost analysis of bio-gas plants.

I

SCOPE AND COVERAGE OF ENERGY USE IN AGRICULTURE

In most of the papers, energy requirements of the following agricultural operations have been estimated: land preparation, sowing, fertilization and manuring, irrigation, inter-culture, harvesting, threshing and winnowing and transporting. The coverage is rather comprehensive in terms of crop production activities of the farm enterprise. However, the energy requirements of livestock maintenance, processing of output as well as domestic cooking and

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lighting are not explicitly considered. Since fodder crops compete with other crops for scarce resources such as land and water and the availability of organic manures depends on the number of livestock as well as alternative uses of cow dung as manure and/or domestic fuel, it may be useful to consider the entire farming system rather than looking only at its major component. As would be discussed later, the relative economics of bullocks vis-a-vis tractors or threshers or machinery for processing of produce depends on the 'economic costs' of bullocks which, in turn, is determined by the resource costs of inputs used for maintaining bullocks and other livestock. Also, the availability of organic manure for farm activities would be higher if a bio-gas unit is installed which provides both manure and fuel gas. Thus, it may be useful to extend the scope of energy use studies to cover the entire farming system including the energy requirements for household work. The paper by Ajay K. Sanghi and Melvin G. Blase is an attempt to analyse alternative farming systems for a small farmer, in their entirety for energy intensiveness, resource use and economic returns.

II

AGGREGATION OF ENERGY OBTAINED FROM DIFFERENT SOURCES

For major agricultural operations three sources of energy have been identified : human energy, animal power and mechanical power. Mechanical power is further sub-divided into tractor, electric motor and diesel engine used on the farm. In five papers,[1] the variations in energy use over different categories of farms have been compared in terms of per acre requirements of man-days, bullock-pair days, tractor hours, electricity units or operating hours of electric motor/diesel engine. In these papers, no attempt has been made to aggregate these different sources of energy. In a number of other papers, the authors have tried to aggregate energy supplied through different sources. Four different methods used for aggregating as well as comparing the energy supplied through various sources are:

(*i*) to convert each form of energy into horse power hours (H.P. hours) by multiplying the number of hours of use of each source with the corresponding horse power (H.P.). For mechanical power sources their rated horse power is used while for others it is assumed that one adult man develops 0.10 horse power and one pair of bullocks develops 1.0 H.P.;

(*ii*) to convert the energy used as well as other inputs such as seeds, fertilizers, organic manure, etc., into kilo calories assuming, say, 1 H.P. hours=641.6 kilo calories and 1 kg. of N=18.48 kilo calories;

(*iii*) to aggregate the energy consumption by multiplying price or hiring rate of each source with the number of hours/days used of each source;

1. These papers are by the following authors : S. M. Soham and B. S. Rathore; J. S. Garg, G. N. Singh and K. N. Pandey; S. A. Radhakrishnan and B. Sridharan; Jagannathrao R. Pawar and T. K. T. Acharya; Raj Vir Singh and L. R. Singh.

(*iv*) to consider the quantum of energy actually consumed in the form of litres of high speed diesel oil used in tractors, litres of light diesel oil in diesel engines used for irrigation and kilo-watt hours of electricity consumed in operating the electric motor and then aggregating these into a common unit of tonnes of coal replacement (tcr).

In nine papers energy use has been aggregated in terms of horse power hours (H.P. hours) and in one paper it has been aggregated in terms of kilo calories. L. R. Singh and Brijendra Singh in their paper on the pattern of energy use in five purposively selected villages of Nainital district find that per hectare of operated area, the bullock farms use 1,391 H.P. hours as compared with the tractor farms which use 3,233 H.P. hours. On the basis of this data, it is concluded that energy use per hectare on the tractor farmss is more than double of that used on the bullock farms. Land preparation accounts for 37 per cent of the total energy use on the bullock farms and 53 per cent on the tractor farms. It is found that per hectare energy requirements for land preparation on the tractor farms are more than three times that on the bullock farms. However, it may be noted that this high level of energy use is mainly due to their method of comparison of bullock labour with tractor power. For example, in bullock farms, 153 bullock-pair hours of work has been converted into 153 H.P. hours while about 48 hours of work with a tractor (35 H.P.) is converted into 1,642 H.P. hours. If energy use on land preparation is excluded, irrigation accounts for a major share of energy input. A. J. Singh and K. C. Dhawan, using standard conversion ratios, for Ludhiana, find that the total energy requirement per acre on the bullock farms is 541 H.P. hours as compared with 1,720 H.P. hours on the tractor farms. From this, they conclude that even on the bullock operated farms in the existing situation, 59.34 per cent of the energy was provided through mechanical sources and only 27.5 per cent was provided through animal sources. The share of mechanical energy on the tractor farms was found to be 94.8 per cent. It may be noted that the above conclusion of higher share of mechanical sources in energy use on the bullock farms is mainly on account of the assumption of 1 pair of bullocks =1 H.P.

A. J. Singh and S. S. Miglani have analysed the marginal productivities and marginal rates of substitution between different sources of energy for Ferozepur district. They conclude that energy use per hectare varied significantly as between different types of soil-crop-climate complexes, between levels of technology and also according to size categories of farms. They find that "the comparison of marginal rates of substitution of tractor energy for bullocks with price ratios indicated the need for substituting tractor power for bullock power." In the production function analysis, the marginal value productivity of bullock energy was found to be negative but non-significant. Energy use per hectare in Bareilly (Uttar Pradesh) studied by D. S. Shukla, P. K. Sharma, Shri Ram Yadav and Y. S. Chauhan shows that the cost of energy is relatively lower on the larger farms (4 hectares and more) as compared to the smaller farms (0-2 hectares). The paper by R. I. Singh, V. Prasad and R. K. Singh presents the energy requirements (in horse power terms) for various farm operations on different size of farms for selected villages in Barhpur block of Farrukhabad district in Uttar Pradesh. They found that the use of energy per hectare for all operations was highest on farms of medium size-group (1-3 hectares), followed by large (3 hectares and above) and small size-group (less than 1 hectare). They find that land preparation accounts for around 40-50 per cent of the total energy consumed, followed by 10-15 per cent for sowing operations.

Cropwise analysis of energy use by B. K. Sikka, R. P. S. Malik, D. S. Dogra and Rajeev Kaushal for Solan district (Himachal Pradesh) shows that the energy requirements (in H.P. hours) of cauliflower seed and tomato are about four times those of wheat and maize. Also, the energy requirement in the case of wheat was almost the same for all sizes of farms while in the case of maize, it was more for the small farms followed by the large and medium. In the paper by L. R. Singh and Brijendra Singh, the estimates for energy consumption for different crops for bullock farms are: wheat (HYV) 955 H.P. hours, paddy (HYV) 987 H.P. hours, and 910 H.P. hours for sugarcane. For tractor operated farms the figures in H.P. hours for the three crops are 1,981 1,183 and 1,218 respectively. The differentials in the cropwise energy use in the two types of farms seem to be on account of use of H.P. hours as a method of aggregation. Ashok Chamotra, T. V. Moorti and Bhim Singh find that in Sirmur district of Himachal Pradesh per quintal of crop output, the bullock energy consumption decreased with the increase in farm size. Bullock energy requirements for medium farms (2-3 hectares) in horse power days per hectare for different crops was as follows: 25 for maize, 30 for wheat (local), 24 for wheat (HYV) and 72 for sugarcane. Analysing the energy requirements of commercial crops in Himachal Pradesh, D. R. Thakur, R. P. Yadava and A. L. Nadda find that the total energy (human + bullock) was maximum in tomato (850 H.P. hours) and lowest in potato (412 H.P. hours). Ginger and green peas consumed around 586 and 551 H.P. hours respectively. The bullock energy applied per unit of area of seed decreased with the increase in the size of farm except in the case of tomato.

The paper by R. P. Singh, Lakshman Singh and Himmat Singh presents the results for Gurgaon and Rohtak districts of Haryana and concludes that "the cultivation of high-yielding varieties of wheat consumed energy more than three times than the growing of hybrid bajra." They estimate that if the levels of mechanization and irrigation are raised to the extent as observed on the sample farms, HYV wheat and hybrid bajra together would absorb about 11 per cent of the total tractors available in Haryana and would require 107 per cent of the total electric power presently consumed for agricultural purposes in Haryana.

K. D. Rajmane and V. C. Kale present the analysis of energy requirements of participants and non-participants of the wheat pilot project scheme in Parbhani district of Maharashtra. They find that for the participants energy consumed was 160 H.P. hours/acre while in the case of non-participants it was 120 H.P. hours/acre. However, since the yield per acre obtained by the participants was 12 quintals/acre as against 5.6 quintals/acre for the non-participants, energy use per quintal of output was less for the participants. However, it may be noted that the substantial difference in yield was on account of other inputs, mainly fertilizers and manures, and could not be attributed to higher energy input alone. This indicates the need for isolating the effect of higher energy input on yield.

As mentioned earlier, all the above papers have used the concept of 'Engineering Equivalence' in comparing animal power and mechanical energy. For example, it has been assumed that a pair of bullocks develops 1.0 horse power while an adult man develops 0.1 horse power (H.P.). According to this 'Engineering Equivalence' a tractor of 35 H.P. would be equivalent to 35 pairs of bullocks. However, if we consider 'Economic Equivalence' in terms of work performance or replacement ratios, the equivalent number of bullocks would be much less. Although, the precise estimate of the bullock-pair equivalent of tractor in terms of acreage farmed would depend on the type of implements used by the bullock, the type of soil and the cropping pattern, it may be reasonable to assume that the peak demand for draft power of a 30-acre farm can be met either by a 35 H.P. tractor or by 5 to 6 pairs of bullocks.[2] The available estimates show that on account of various factors, a tractor replaces, on an average, not more than 2 to 3 pairs of bullocks on the farm.[3] In view of these considerations, treating a pair of bullocks as equivalent of 1 H.P. (or 1/35th of a tractor) results in under-estimation of the contribution of bullocks to the farm economy and over-estimates the share of mechanical energy in the total energy consumption. This is responsible for conclusions such as "even on the bullock operated farms in the existing situation, 59.34 per cent of the energy was provided through mechanical sources, whereas 13.2 per cent and 27.46 per cent was contributed by human and animal sources" (Singh and Dhawan) and "the mechanical energy content is 92.81 per cent of the total energy use on the tractor operated farms as against 75.40 per cent on the bullock operated farms" (L. R. Singh and Brijendra Singh). Hence, one of the issues to be discussed in the Conference is: What conversion factors should be used to compare and aggregate energy provided by different sources of energy such as animal power and mechanical power?

Four papers have used prices of different forms of energy for aggregating the energy consumption. M. S. Rathore, J. P. Bhati and Bhim Singh in their paper have made a comparative study of energy utilization on various sizes

2. For a detailed discussion on this point, see Ramesh Bhatia, "Energy and Rural Development in India: Some Issues," in William Lockeretz (Ed.): Proceedings of the Conference on Energy and Agriculture, Academic Press, New York (forthcoming).

3. See R. K. Sharma: Economics of Tractor Versus Bullock Cultivation, Agro-Economic Research Centre, Delhi, 1972, and Government of Punjab: Economics of Tractor Cultivation and Economics of Production and Cultivation Practices of HYV of Wheat, Maize and Paddy in Punjab.

of farms in four agro-climatic zones of Himachal Pradesh. They feel that the problem of aggregation has been avoided by converting energy hours from various sources into monetary value by multiplying respective energy hours, by prices/hiring rates. By and large, they find, there was more intensive use of bullock energy on small size of holdings. An examination of the total value of energy (from all sources) on different sizes of farms in various zones reveals that per hectare energy use was inversely related to farm size. They have studied the economics of energy input through output-energy ratio obtained by dividing the gross value of the total farm produce by the value of total energy. The output-energy ratio revealed that, by and large, farm output per rupee invested in energy increases with the size of farm in all the four zones under study. However, it may be noted that the differences in the gross value of output between farms cannot be attributed to differences in energy use alone and hence this measure of the average productivity of energy has to be used with caution. Shukla, Sharma, Yadav and Chauhan have concluded that (*a*) the cost of energy per hectare is higher in the developed areas of Bareilly district than in the less developed regions, (*b*) the utilization of tractor and electricity is higher in the developed areas and (*c*) the proportion of tractor and electricity cost in the total is higher for farms of 4 hectares and above. For Kolhapur district in Maharashtra, the paper by T. K. T. Acharya, R. E. Waghmare and S. K. Gore found that the cost of preparatory tillage, lay-out and earthing up together for sugarcane cultivation was less (Rs. 185.25 per hectare) on owned tractor farms and was high (Rs. 308.99 per hectare) on non-tractor use farms, indicating thereby that the tractor energy use for some of the operations in sugarcane cultivation was economical in addition to the saving of time. P. K. Chatterjee and S. Banerjee's paper shows that (*a*) there appears no significant relationship between farm size and requirement of human and animal energy per unit of output, (*b*) the cost of animal energy per rupee of output is definitely higher, on an average, for the traditional than for HYV paddy and (*c*) the cost of electricity may be only marginally higher than the cost of diesel for the purpose of irrigation.

In all these papers, the details of the assumptions regarding prices used for human labour, bullock labour and tractor power have not been presented. In the absence of this information, it is difficult to comment on the prices/hiring rates used in the analyses. It would be necessary to ensure that while comparing the relative economics of different sources of energy the prices used reflect the relative scarcity of these individual sources during the peak period of their requirement. A comparison of average cost of bullock-pair day with the average cost of using a tractor would not be correct since the true scarcities at the peak period of land preparation and sowing might indicate a different ratio of prices. As discussed later, it may be mentioned that a correct comparison of these costs is possible only when the farm system is considered as a whole rather than when various agricultural operations are considered individually. Besides, the relevant costs may be the costs to the society rather than costs to the individual farmer. In view of these points, the method of using prices of each of the energy sources for comparison and aggregation has to be used with caution in order to avoid wrong judgments regarding the relative economies of different forms of energy.

A third method for aggregation has been used by R. N. Senapati in his paper relating energy consumption with agricultural development in Punjab and Haryana. His approach[4] in estimating energy use consists of (*a*) estimating direct consumption[5] of oil products and electricity actually used in running tractors, oil engines, electric motors and other machinery; (*b*) estimating indirect energy use in terms of oil products and electricity consumed in the manufacture of chemical fertilizers, tractors, diesel engines, electric motors, agricultural implements, and other inputs and assets; (*c*) estimating the diesel oil equivalent of animal power, (*i.e.*, the quantity of diesel oil that would have to be consumed if all these bullocks were replaced by tractors; and (*d*) converting the sum of diesel oils, naphtha, furnace oil and electricity consumed (directly and indirectly) into a common unit of measurement, *i.e.*, tonnes of coal replacement.[6]

The advantages of the above approach are that it enables the analyst to assess the total (direct and indirect) energy input in a farming system as well as to estimate the 'real resource costs' to the society of providing the required quantum of energy through different sources. For example, the foreign exchange outflow on account of additional import of diesel oil (or crude oil) to meet additional demand for tractors can be estimated only if energy consumption is in terms of diesel oil and not in terms of horse power capacity of additional number of tractors. In Senapati's paper we find that the intensity of energy inputs in the agricultural sector of Punjab and Haryana has increased from 6.3 million tonnes of coal replacement (mtcr) in 1961-62 to about 8.0 mtcr in 1966-67 and to about 16 mtcr in 1972-73. The indices of energy use in irrigation and fertilizers indicate that after 1966-67 the new agricultural strategy was heavily oriented towards a more intensive effort at irrigation and fertilizers. These increases are accompanied by increases in the indices of yield and output during these years. "Since agricultural production is a function of so many variables, it is difficult to single out the effects of energy inputs on the total production and yield" with the data available for three different points of time. He has also estimated the economic costs to the society of energy input used in the agricultural sector and concluded that although "in absolute terms, energy inputs have increased in their use, but the social cost of energy as a proportion of the social value of

4. For detailed discussion of a similar approach and all-India estimates of energy use in Indian Agriculture, see Ramesh Bhatia, *op. cit.*

5. Actual consumption of various sources of commercial energy would depend on the number of hours of use and H.P. rating of the machinery. However, rather than considering H.P. hours as indicator of energy use, this approach considers diesel oil and electricity actually consumed as indicator of energy consumption.

6. This method of aggregating coal, oil and electricity has been suggested in the Report of the Fuel Policy Committee in 1972. The conversion coefficients are : 1·0 tonne of diesel oil=9 tonnes of coal replacement (tcr); 103 kwh of electricity=1.0 tcr; 1.0 ton of naphtha=8.3 tcr.

the total output has undergone a relative decline in 1972-73 as compared to 1966-67."

In view of the points mentioned above, the Group should discuss the advantages and disadvantages of using various methods of aggregating energy obtained from different sources. The relative merits of different methods would depend on the objectives of the energy study under consideration. One can put forward a hypothesis that for a comprehensive economic analysis of energy use and resource endowments the third approach in which the aggregation of actual energy consumed (directly as well as indirectly) is done by using tonnes of coal replacement (tcr) would be a more appropriate method.

III

ECONOMICS OF USE OF TRACTORS VIS-A-VIS BULLOCKS

Six papers have specifically analysed the economics of use of tractors vis-a-vis bullocks in different regions. It would be useful to present the findings of these papers in the context of the following issues:

(*i*) Does tractorisation, *per se*, result in higher intensity of cropping, yield and output?

(*ii*) What are the 'real' savings in human labour and animal labour when a tractor is used in place of bullocks for land preparation, sowing, threshing, etc.?

(*iii*) What are the relative costs to the farmer and to the society of using tractors and bullocks? More specifically, is there a divergence between the private profitability and social profitability of using tractors?

(*iv*) What are the employment and income distribution implications of replacing human and animal labour by tractors?

N.T. Patel and M. S. Patel have studied 100 farmers classified into four categories, *viz.*, farmers with tractor and pumpset (F1); farmers with only tractor (F2); farmers with only pumpset (F3) and farmers with neither pumpset nor tractor (F4). They find that for F1 farmers, who owned tractor and pumpset, the intensity of cropping was highest (133 per cent) followed by F3 farmers who owned only pumpset (127 per cent). If correction is made for the fact that the proportion of area devoted to (longer duration crop) cotton by F3 farmers is twice that devoted by F1 farmers, the differential in the intensity of cropping would be further narrowed. This would mean that the use of tractor by F1 farmers did not result in higher intensity of cropping. A comparison of F2 farmers with F4 farmers shows that the intensity of cropping and the proportion of area under wheat are marginally higher for F2. They conclude that "the profitability of farming, the employment of human labour and cropping intensity were related at the higher extent with the pumpset energy than to that of the tractor energy."

The paper by D. K. Mishra, R. N. Pandey and V. K. Pandey has presented a detailed analysis of bullock and tractor power at the farm level using the data obtained from a farm survey of 309 farmers in different parts of Uttar Pradesh. The total cost per pair of bullocks (net of Rs. 69 as the value of dung) has been estimated as Rs. 1,360 per annum. If one excludes the costs of feed and fodder and costs of labour, the out of pocket expenses consisting of interest and depreciation on bullocks and shed, etc., are only Rs. 408 per pair. Further, if interest and depreciation on bullocks are also ignored for farmers raising their own bullocks, the out of pocket expenses are only Rs. 151 per pair per year. Using 96 working days as the average for bullocks, the net total cost per working day is Rs. 14.23 and the out of pocket expenses are Rs. 4.27. At the existing use pattern of 551 working hours per tractor per year and the total annual costs of Rs. 14,373, the average cost works out at Rs.26 per hour. In the case of tractors, the farmers' out of pocket expenses are Rs. 11,373 per annum (or Rs. 20.6 per hour) on the assumption that the tractor is operated by the farmer himself. If the average net cultivated area covered by each tractor is taken as 27 hectares, the average cost incurred on the tractor power per hectare of the net cultivated area will come to be Rs. 528 at the existing use pattern on the sample farms. The corresponding costs for bullock power are Rs. 593 assuming that the average net cultivated area per pair of bullocks is 2.236 hectares.[7] Comparing these costs they maintain that "although the total cost (Rs. 593.72) incurred per hectare of the net cultivated area on the bullock power is higher than the same incurred on the tractor power (Rs.528.34) the actual out of pocket expense incurred per hectare of the net cultivated area in the case of the bullock power (Rs. 182.5) are much lower than the same incurred on the tractor power (Rs. 418.02)." They argue that "the out of pocket expense is a better criterion for economic cost comparison . . . since most of the feeds and fodder and labour used in maintaining bullocks are farm/family owned and have very low opportunity cost on the farms." Using this argument, they compute that for the Uttar Pradesh State as a whole (excluding Hills), this out of pocket expenditure comes to be Rs. 303.95 crores in the case of the bullock power (even if all bullocks are purchased by the farmers), and Rs. 696.3 crores in the case of the tractor power at the existing use pattern

7. It may be interesting to compare the costs per hectare using the norms adopted in the paper entitled "Bullocks—The Mainstay of Farm Power in India" presented by A. R. Rao and I. J. Singh at the Conference on Energy and Agriculture, Washington University, St. Louis, U. S. A. in June, 1976. The cost of tractor power for ploughing one hectare in 8 hours would be Rs. 208 (26 × 8) and the corresponding cost for 2·5 bullock-pair days would be Rs. 35. The corresponding costs as estimated by Rao and Singh in their paper are Rs. 86 per hectare for ploughing with tractor and Rs. 100 for ploughing with bullocks. These figures show the limitations of using cost per hour for tractor and cost per pair-day by bullocks in comparing the economics of tractors versus bullocks. Also, see the paper by Tarvinder Singh Chahal and J. S. Chawla.

of both. From this, they conclude that "the existing farming conditions in the State are more favourable for the bullock power than the tractor power."

The above paper by Mishra, Pandey and Pandey is one of the few papers where an attempt to estimate the 'economic cost' of bullock and tractor power at the farm level has been made. However, rather than using out of pocket expenses as indicators of these costs, it would have been useful to extend the analysis further by a systematic estimation of 'economic costs' by using appropriate accounting prices (or shadow prices) for inputs and resources used in the two cases. For example, using their own data, adjustments in costs could be easily made by (*i*) using shadow wage rate for unskilled labour used in the maintenance of bullocks or for semi-skilled labour for operating the tractor and (*ii*) by using shadow price of foreign exchange for the diesel fuel and lubricating oil used as well as for the indirect foreign exhange outflow involved in the capital cost of a tractor. To illustrate, if shadow wage for unskilled labour is taken as zero and the shadow price of foreign exchange is taken as Rs. 12 per U.S. dollar as compared to the official price of Rs. 8 per U.S. dollar, the resulting cost estimates per pair of bullocks would be Rs. 1,011 (instead of Rs. 1,360) and per tractor would be Rs. 15,738 (instead of Rs. 14,373.) Further, it would not be correct to assume that since feed and fodder are farm-owned they have low opportunity cost on the farms. This fodder could always be sold in the market or diverted for the use of milch cattle resulting in higher yield of milk. In the case of green fodder, one of the methods of estimating 'economic cost' would be to estimate the output of foodgrains forgone as a result of diverting land and water resources from foodgrain to fodder crops.[8] To illustrate, if green fodder accounts for 50 per cent of the feed and fodder costs and the resource cost of green fodder in terms of the value of wheat and maize forgone is estimated at 60 per cent higher than the cost of green fodder, the revised costs for feed and fodder would be Rs. 875.2 per pair. This would give an estimate of the overall 'economic cost' of Rs. 1,213.8 per pair as compared to Rs. 15,738 per tractor. Using these estimates, a judgment regarding the relative economics of bullock vis-a-vis tractor can be made if (*i*) the net cultivated area covered by a pair of bullocks and one tractor is known and (*ii*) it is assumed that all the other agricultural operations except irrigation can be performed by the available bullock power and tractor power. On the basis of the survey results reported in the paper by Mishra, Pandey and Pandey regarding existing use pattern, 4.389 hectares of net cultivated area could be covered by one pair of bullocks while the corresponding area for a tractor was 27 hectares. This would mean that if size distribution of holding was not a constraint, one tractor could be equivalent to six pairs of bullocks. Assuming that one bullock pair would continue to be maintained for use in the event of tractor breakdown, etc., the farming

8. For detailed discussions on these aspects, see Ramesh Bhatia, *op. cit.*; K. N. Raj, "Mechanization of Agriculture in India and Sri Lanka " in Mechanization and Employment, International Labour Organisation, Geneva. 1973; S. R. Bose and E. H. Clark, "The Cost of Draft Animal Power in W. Pakistan," *Pakistan Development Review*, Vol. X, No. 2, Summer 1970.

needs of 27 hectares of land can be met either by six pairs of bullocks or by one tractor plus one pair of bullocks. The economic cost of six pairs of bullocks would be Rs. 7,283. The corresponding costs of one tractor plus one pair of bullocks would be Rs. 16,952. Hence, a comparison of these costs shows that using bullock power would be more economic if the benefits from the activities other than farm operations on these 27 hectares are equal in the two cases. This leads us to the important aspect of custom service for the bullocks and tractors. These issues can be discussed more appropriately in the framework of benefit-cost analysis of using tractors vis-a-vis bullocks.

N. V. Namboodiri and K. Padmanabhan have confined their paper to two major aspects: (*i*) private benefit-cost analysis of tractor technology and bullock technology at the existing farm situation in 50 selected farms in Anand taluka of Gujarat State and (*ii*) the profitability of replacing bullock technology with tractor technology and the benefit accrued from there. They find that the "present value of contribution in tractor technology was positive both with and without custom service but negatively contributed by bullock technology." However, in tractor technology the *net* present value of contribution, net of the present value of investment of Rs. 48,031, was negative (Rs. —14,879) without custom service. Since custom service accounted for about 20 per cent of the annual income in tractor technology, the net present value of contribution was positive (Rs. 50,386) with custom service. They conclude that "custom service was one of the major sources of income generating activity in tractor technology and it can be supported by the fact that with limited farm size, huge investment cannot attain a profitable net return through crop production alone." It may be mentioned that in their analysis, there is no attempt to demonstrate that higher net output per hectare as well as income from crop production in tractor technology can in fact be attributed to the use of tractor, *per se*, after adjusting for the variations in the quantity and quality of irrigation, cropping pattern, quality of labour and management, use of HYV seeds and the application of fertilizers.[9] Also, the earnings from custom service (Rs. 11,822) in this sample seem to be higher than those reported by S. P. Misra in Madhya Pradesh (Rs. 3,428 to Rs. 6,015).

In the case of bullock technology they find that the net present value of contribution was negative, *i.e.*, Rs. —15,023. This is on account of the fact that although the total income from crop production and the sale of water (Rs. 15,454 per year) is higher than the cost of cultivation (Rs. 6,250), the authors' estimate of its net contribution (net of rental value of Rs. 10,500) is negative (Rs. —1,296 per year). Thus, the net contribution from bullock technology would be positive if rental value as 10 per cent of land is ignored or re-estimated on some other basis. Besides, the authors have also assumed the life span of tractors and implements as ten years and for bullocks and

9. For details on these questions, see C. H. Hanumantha Rao: Technological Change and Distribution of Gains in Indian Agriculture, The Macmillan Company of India Ltd., Delhi, 1975, Chapter 5; Amartya Sen: Employment, Technology and Development, Oxford University Press, London, 1975, Appendix D; P. S. Vashistha, "Impact of Farm Mechanization on Employment and Output," Paper presented at 12th Indian Econometric Conference, Kanpur, 1972.

implements as five years. The adjustment in the life of bullocks to 8-10 years and ignoring the rental value of land would significantly alter the profitability of bullock technology.

S. P. Misra's paper studies the impact of tractorisation in Gadarwara tehsil of Madhya Pradesh with the help of data collected for 40 bullock operated and 60 tractor operated farms. Tractor farms have been further classified on the basis of proportion of area irrigated. It has been found that in unirrigated farms the intensity of cropping was 100 per cent on the bullock farms as compared with 105 per cent on the tractor farms. On the tractor farms, the intensity of cropping increased as the size of irrigated area increased. The incremental income generated on the tractor farms also increased significantly with an increase in irrigation, *i.e.*, Rs. 21,225 on the unirrigated farms and Rs. 36,804 on farms where 22-25 per cent of the area is irrigated. He finds that with tractorisation there has been considerable decrease in the employment of human labour—about 17 per cent in maize and 58 per cent in wheat. The utilization aspect of bullock labour indicates substantial reduction—about 65 per cent in maize and 90 per cent in wheat.

As a result, the number of bullocks maintained on the tractor farms is half of those maintained on the bullock farms. The savings as a result of introduction of tractor are estimated as Rs. 3,734 on human labour, Rs. 10,707 on bullock labour and Rs. 12,000 on the cost of six bullock-pairs not required on the tractor farm. Since the expenditure on use of 100 hours of tractor @Rs. 15 per hour is only Rs. 15,000, the conclusion is that "a surplus of Rs. 11,442 is made due to the introduction of tractors." Apart from the method of estimation of savings due to tractorisation,[10] there is no attempt to analyse the divergence between 'private' and social profitability or to study the overall employment and income distribution implications of introduction of tractors.[11] The paper by D. G. Parkale and S. D. Kulkarni also presents the private costs of using tractors of different sizes in Ahmednagar district in Maharashtra. They find that the costs of fuel, lubricants, repairs and labour account for around 70 to 76 per cent of the total costs and these costs increase with the size of tractor. The fixed costs in their estimates are rather low since interest charges are very low. The net returns per hour of tractor use increase as the size of the tractor increases.

To recapitulate, it may be mentioned that although a number of studies have been conducted on this important issue of mechanization in Indian agriculture, there has not been a single attempt at a detailed social benefit-cost analysis of tractorisation by isolating its yield impact as well as by re-valuation of various components of costs such as diesel, dry fodder, green fodder, capital and unskilled human labour.

10. There seems to be some double counting involved here since the reduction in the costs of bullock labour has been taken @ Rs. 10 per pair day for 1,070 days as well as for the saving in capital cost of purchasing six bullock-pairs.
11. See Raj Krishna, "Measurement of Direct and Indirect Employment Effects of Agricultural Growth with Technical Change," 1972, (mimeo.).

IV

ECONOMICS OF IRRIGATION FROM DIFFERENT SOURCES

Of the six papers considered in this group, two have analysed the economics of diesel engines vis-a-vis electric motor for well irrigation, one has analysed the comparative economics of irrigation from Persian wheel and *charsa* while the rest have studied the impact of different sources of irrigation on farm practices.

T. V. Moorti and K. K. Verma have analysed the data of 26 tube-wells run by diesel engines and 16 run by electricity in Rudrapur and Khatima blocks of Nainital district in Uttar Pradesh. The data on cost components revealed that although the equipment cost of diesel engines are higher than electric motors, yet the capital cost of installing a diesel engine is lower than that of installing an electric motor in a tube-well on account of higher costs of pump house required for the latter. Thus, the investment costs of electric motors to the farmer were higher than those of diesel engine even though the costs of connection and distribution of electricity are not charged to the farmer. The energy charges for electric motors fixed @ Rs. 15 per H.P. were much higher than the costs of diesel and mobil oil. However, there was a substantial variation in the running hours—300 hours for electric motor of 5 H.P. and 145 hours for a diesel engine of 5 H.P. Since the discharge capacity of the two tube-wells was same (0.71 cusec) the total output of water delivered in the case of tube-well with electric motor is more than twice the water delivered by the tube-well operated with diesel engine. This resulted in the cost of water (per unit) being 15 per cent less in the case of electric motor as compared with diesel engine. Although no data are given, it is mentioned that "the running hours for diesel tube-wells were nearly half that of electric tube-wells mainly because the diesel pumping sets were owned by the small farmers (size of farm 7.5 acres)."

It may be mentioned here that a comparison of the economic cost (to the society) of providing water through tube-wells with electric motor or diesel engine would be valid only if (*a*) the capital costs of all the assets required in each case are included, *i.e.*, the costs of connection for an electric motor which might ordinarily be borne by the State Electricity Board should be included in the cost of tube-well operated by electricity; (*b*) the operating costs, in each case, should be re-estimated by using the 'accounting prices' for diesel and electricity reflecting their true scarcities and resource costs;[12] and (*c*) selecting the sample farms which are more or less comparable in terms of farm size and other assets.

12. The price of diesel would be estimated after deducting the excise duty and correcting for shadow price of foreign exchange. The shadow price of electricity would include the annualized costs of generation, transmission and distribution and would account for high transmission and distribution losses and low load factor for agricultural demand. For details on these points, see Ramesh Bhatia and Meera Mehta, "Tube-well Irrigation: Economic Analysis of Technical Alternatives," *Economic and Political Weekly*, Vol. X, No. 52, December 27, 1975.

In the paper by M. R. Patel and S. B. Singh, data for 111 pumpsets in two talukas of Mehsana district have been analysed. The investment cost for lifting water per horse power was Rs. 863 in electric tube-well (ETW), Rs.564 in electrified dug-cum-bore-well (EDBW) and Rs. 653 in dieselised dug-cum-bore-well (DDBW). It has been observed that operating cost per hour for ETW, EDBW and DDBW was Rs. 14.95, Rs. 4.66 and Rs. 5.54 respectively. The total cost per hectare-centimetre was Rs. 27.15 for ETW, Rs. 20.31 for EDBW and Rs. 23.09 for DDBW. This shows that although the average discharge capacity of ETW is about 2½ times that of DBW, the unit cost for ETW is relatively higher.

T. V. Moorti in his paper comparing the economics of Persian wheel and *charsa* finds that the cost of Persian wheel worked out to be Rs. 155 per 1,000 cubic metres (M^3) and that from a *charsa* at Rs. 240 per 1,000 M^3. This is because the delivery capacity of a well with Persian wheel in the sample was 12 M^3 as against 8.45 M^3 for a well using *charsa* although both these equipments are driven by bullock power. It would be useful to analyse if the differences in discharge capacity were on account of the lifting capacity of the two methods or due to availability of water in the wells. If the latter reason is more important, a re-adjustment in the relative costs would be necessary.

H. G. Goswami has studied the energy requirements of 32 farmers owning diesel pumpsets in Purnea district of North Bihar. His results show that (*a*) an average cropped acre for full irrigation consumed 70 H.P. hours worth of energy, (*b*) fuel consumption for full irrigation per acre worked out at 27.5 litres (or 0.39 litre per H.P. hour). His estimates show that "an average farm holder would be needing energy worth 2,629 H.P. hours to irrigate all of his crops per year for which 1,149 litres of diesel would be required as fuel." The consumption of diesel fuel estimated is about three times the level of present consumption.

The paper by T. K. T. Acharya, R. T. Patil and R. E. Waghmare shows that the per hectare cost of irrigation for wheat was maximum under well irrigation with diesel engine (Rs. 441) followed by well irrigation with electric motor (Rs. 293), lift irrigation on river (Rs. 214), sewage irrigation (Rs. 189) and canal irrigation (Rs. 66). In the case of sugarcane and tomato the highest cost per hectare was in well irrigation with diesel engine and the lowest was for canal irrigation. It was observed that the cropping intensity was relatively higher (191 per cent and 196 per cent) for well irrigation and canal irrigation compared with that for sewage and lift irrigation on river (165 per cent and 144 per cent). T. V. Moorti's paper on impact of different energy sources of irrigation on farm practices in Aligarh concludes that since the water availability from the State tube-well is more uncertain, those farms could not put larger area under the high-yielding varieties of crops. As a result of this, fertilizer use was less on the State tube-well farms which was reflected in lower crop yields. However, it may be noted that lower crop yields on the State tube-well farms need not be attributed to uncertainty of water alone. There may be factors such as farm size, tenurial status, access to credit, fertilizers and other inputs which may account for variations in acreage under the HYV seeds and average yields. Thus, the above studies point towards the need for a comprehensive analysis of the impact of sources of irrigation along with other agro-economic variables.

V

ECONOMICS OF BIO-GAS PLANTS

The economics of a bio-gas or gobar gas plant has been examined by S. Bhavani in the framework of social benefit-cost analysis. The joint benefits from a bio-gas plant are the supply of gas mainly used for cooking as well as the supply of manure. Bio-gas used for cooking has been evaluated in terms of the equivalent 'accounting price' of coal which will be used in the absence of bio-gas. The NPK nutrient content in manure from the unit has been evaluated using import (*c.i.f.*) prices of various fertilizers after adjusting for a 30 per cent premium on foreign exchange. The costs of the bio-gas plant include the investment costs of the unit and the 'opportunity cost' of cow dung has been estimated under three assumptions regarding its present use as manure and domestic fuel. The conclusions of the study are: the economics of a bio-gas plant depends upon (*a*) the use to which cow dung was put before the installation of the unit and (*b*) the fertilizer nutrient content in manure available from the unit as against that in farmyard manure (FYM). It has been shown that in a case where the value of bio-gas manure remains the same as in the case of FYM, the benefit-cost ratios (B-C ratios) are much lower than the cut-off rate of unity. This shows the need for a comprehensive analysis of the social benefits and costs of these units before a large-scale subsidy programme is undertaken.

VI

ENERGY REQUIREMENTS OF ALTERNATIVE FARMING SYSTEMS FOR SMALL FARMER

The paper by Ajay K. Sanghi and Melvin G. Blase is an attempt to analyse alternative farming systems for a small farmer in their entirety for energy intensiveness, resource use and economic returns. They feel that a study of the entire farming system rather than looking at its components will also help to shed light on the question of the desirability of animal power *vs.* mechanical sources of power on Indian farms. A Basic farming system for a small farmer having 2 hectares of operational holding consists of 2 bullocks, four cows or buffaloes, a Persian wheel system for irrigation and eight family farm workers.

The HYV wheat and HYV rice rotation is chosen as part of the Basic farming system. It is also assumed that the irrigation needs for rice are only 0.43 metre, the rest of it being supplied by rainfall. The water requirements of HYV wheat are 0.39 metre. It is shown that the energy requirements for field operations of a two-hectare farm, at least for the crops not having heavy water requirements, can be met by the Basic system. The system is also able to supply the input requirements with the exception of chemical fertilizers and seed for a high level of food production. Such a system maximizes the use of the farm's biological energy resources and assures a relatively high level of income with a minimum of risk (from inputs dependent on commercial energy sources) and capital requirements. The biggest bottleneck in this Basic system is the ability of the Persian wheel to meet heavy water requirements of 0.86 metre for the rice crop. Hence the Basic system I assumes that the inadequate supply of water for the rice crop results in a 30 per cent decline in rice yield. They suppose that the farmer is able to invest in and manage a tube-well with the Basic system, then he is able to increase his rice yield by 30 per cent by providing maximum water requirement for both the crops by operating the tube-well for 368 hours in a year. Even with a 30 per cent increase in yield of rice, the net income to the farmer is Rs. 9,382 which is higher than the net return in the Basic system I but less than the net return in the Basic system. However, due to the economic cost of electricity (Re. 0.90 kwh), the economic (social) return is only Rs. 8,094 which is even less than the economic return of Basic system I. Besides, tube-well irrigation is vulnerable from energy price fluctuations and particularly from power failure. It may be noted that the correct comparison of net returns has to be between Basic system I *with* and *without* the tube-well. The net economic returns in the Basic system I with tube-well would be very sensitive to the assumptions regarding the additional yield from a 100 per cent increase in water availability for rice crop and the economic cost of electricity. It may be mentioned that the assumptions made in the paper are rather conservative in the case of increase in yield while the estimate of economic cost of electricity (Re. 0.90 kwh) is on the high side.

The authors mention that the calculations similar to those done in the case of tube-well can be done by integrating tractor in the Basic system or a tube-well and a tractor minus two bullocks in the Basic system. They conclude that "in both of these systems the net return to the farmer and society will become smaller than the net returns in the basic system, Basic system I and Basic system II (with maize-wheat rotation)." However, they find that a small farmer can increase his net returns and standard of living by integrating a gobar gas plant with one of the Basic systems. The net income to the farmer from a 60 cubic feet gobar gas plant is estimated as Rs. 247 when he pays only a fraction (Re. 0.20 kwh) of the economic cost of electricity and Rs. 2,501 if measured in terms of the full economic cost of electricity (Re. 0.90 kwh). Although bio-gas does provide the farmer with a clean energy source and may have other intangible benefits, its profitability from the viewpoint of direct benefits and costs (to the society) evaluated at 'accounting prices' has yet to be demonstrated as concluded in the paper by S. Bhavani. There is need to discuss both the assumptions involved in the quantification of benefits in terms of bio-gas and manure from the units as well as the 'resource costs' of installing and operating the units.

To recapitulate, the paper by Sanghi and Blase provides a useful framework for analysing the economics of energy requirements of different farming systems by quantifying various implications in terms of capital cost, foreign exchange outflows, vulnerability to price variations, employment generation and income distribution. The following conclusion deserves a detailed discussion by the Group: that the energy requirements of a two-hectare farm for field operations and irrigation, at least for the crops not having heavy water requirements, can be met by the Basic system comprising of eight men, two bullocks, four cows and a Persian wheel.

VII

ISSUES FOR DISCUSSION

In the light of the foregoing review, the Group may find it useful to focus the discussions on the following issues:

1. What should be the scope and coverage of energy use studies in agriculture? More specifically, should the scope of these studies be extended to cover the entire farming system including crop production, fodder output, livestock maintenance, processing of output and domestic cooking, etc.?

2. Should these energy studies be confined to analysing direct energy use in agricultural operations alone? Or should indirect energy consumption in the manufacture of chemical fertilizers, tractors, electric motors, diesel engines and agricultural machinery be included as energy use in the agricultural sector?

3. What is the appropriate methodology for estimating these direct and indirect energy requirements of various levels of mechanization in agricultural operations?

4. What are the advantages and disadvantages of using various methods of comparing and aggregating energy provided by different sources such as animal labour and mechanical power? For economic analysis of energy use, is it appropriate to aggregate energy obtained from different sources by converting actual energy consumed in terms of tonnes of coal replacement (tcr)?

5. How does energy consumption per hectare change with the increase in the size of farm? Is there a pattern in energy consumption of different crops?

6. What is the evidence to show that non-availability of energy has resulted in lower growth rate of agricultural output?

7. Is it possible to demonstrate that after correcting for the quantity and quality of irrigation, crop intensity and yield are positively related with the timely availability of energy from different sources?

8. Does tractorisation, *per se*, result in higher intensity of cropping, yield and output? What is the evidence to show that tractor farms have higher cropping intensity and yield when corrections for differences in quantity and quality of irrigation, quality of management and access to better inputs have been made?

9. Is there a divergence between the private profitability and social profitability of using tractors? What are the factors which determine the private and social profitability of using tractors?

10. What are the major components of costs of using bullocks and tractors for farm operations? How should one estimate the 'economic costs' (to the society) of using dry fodder, green fodder, concentrates, unskilled labour used for livestock maintenance, capital and diesel required for tractors, etc.?

11. What is the first round reduction in human labour and bullock labour when a tractor is used in place of bullocks for land preparation, sowing and threshing, etc.?

12. What are the overall employment and income distribution implications of replacing human and bullock labour by tractors?

13. What are the farmers' costs and 'economic costs' (to the society) of using Persian wheel, *charsa*, diesel engine and electric motor for irrigation through dug wells and dug-cum-bore-wells?

14. What is the relative economics of using electric motor vis-a-vis diesel engine with a tube-well when the capital costs of electric connection are included and the costs of electricity and diesel oil are estimated by using 'accounting or shadow prices' in place of market prices?

15. What is the impact of various sources of irrigation on crop intensity, cropping pattern, output and employment after isolating the effect of other agro-economic variables?

16. What are the crucial assumptions determining the private and social profitability of bio-gas units? How does the installation of a bio-gas unit affect the rest of the farm economy?

17. What are the possibilities of improving the efficiency of the conventional farm system through providing better implements used by animals so as to conform to the resource endowments of the small farmer?

18. If mechanization of farm operations is to be introduced, what would be the relative ranking of using diesel engines/electric motors (for irrigation), tractors, threshers and harvest combines?

19. What are the advantages of studying alternative farming systems in their entirety by incorporating the analysis of energy intensities, resource endowments and economic returns from the viewpoint of the farmer as well as that of the society? Under what conditions the energy requirements of a two-hectare farm for field operations and irrigation can be met by a farm system comprising of eight farm workers, two bullocks, four cows and a Persian wheel?