MECHANIZATION of agriculture has proved a great success in the U.S.A., U.S.S.R. and several European countries. Would mechanization of Indian agriculture turn out to be as successful? The analysis below tries to provide an answer to this question. For the following pages, the vague term of farm mechanization is defined as application of any kind of improved implements and machines—whether operated by manual labour, bullock power or motor power—during the process of agricultural production.

Previous to any investment, the farmer has to decide the way in which the available capital should be invested so as to bring about the highest returns. Taking the conditions of India into consideration, the different forms of investment in agriculture can be placed, according to the returns to be expected, in the following order: (i) investment in irrigation (since water is scarce in most parts of the country); (ii) investment in improved manure (farm yard manure and artificial fertilizers) and improved seeds; (iii) improved methods of production, which can be achieved by increased input of cheap manual labour or by application of cheap manually worked or bullock drawn implements. Only after achieving these improvements does it seem to be advisable to go in for tractors and modern farm equipment.

Choice of Machines

Mechanization affects the coat structure of agricultural production by:

(i) Saving labour (manual and bullock)
(ii) Easying jobs
(iii) Increasing yield
(iv) Saving land
(v) Facilitating the opening up of new land.

Most implements and machines bring about several of these effects simultaneously. A tractor, for instance, saves animal and human labour-hours and at the same time makes jobs (e.g., ploughing) easier too. If the tractor actually replaces several draught cattle on the farm, the land formerly needed to grow fodder for the bullocks becomes free for the cultivation of food or cash crops. In regions with scarcity of draught cattle, the tractor facilitates the cultivation of waste land or reduction of fallow land. A threshing machine saves labour hours of bullocks and labourers and decreases loss of grain during the process of threshing. A drilling machine saves seed and increases yield. These examples may suffice to demonstrate the different effects achieved by different machines and implements.

No doubt machines and implements which increase the yield or diminish losses of farm production are desirable not only from the point of view of higher income for the individual farmer but also in the interest of the country as a whole, to increase the food supply for its rapidly growing population. Since these implements and machines are available at comparatively low prices or can be used by several farmers on a cooperative basis, they are within the reach even of own cry of small holdings, which constitute the majority of Indian farms. Thus, simple and cheap models of seed drills, threshing machines (the Japanese pedal thresher, for instance), pumps driven by electric or diesel motors, mould-board ploughs (on Irrigated land only, on non-irrigated fields it might harm the crops by increasing moisture evaporation), etc., will prove economical on the whole. These, therefore, deserve mass introduction into Indian agriculture.

Prospects for Tractors

But what about the tractor and other modern farm equipment, which are more complicated, more costly and mainly labour saving? No doubt these machines are far beyond the financial reach of the owners of small holdings (78 per cent of Indian farms are below 10 acres). Even if these small farmers could afford to buy them (with Government assistance or cooperative effort) their benefit to these small farms would be doubtful. They would increase the cash expenditure of the farmer and render superfluous the plentiful and cheap manual labour provided by members of large joint families, without providing sufficient opportunities of alternative productive employment.

But could such modern equipment as tractors and harvester combines be used economically on larger sized farms? Though these form a minority of only about 1.4 per cent of Indian farms, they comprise a considerable absolute number. Here one may feel tempted to quote the Russian example, where mechanization of agriculture caused an enormous increase in production. But one should not forget that in Russia land was available in abundance and labour was scarce. Also the process of mechanization aimed at freeing labour from agriculture to supply the labour force needed by rapidly growing industries. In India, on the other hand, land is scarce and labour is cheap and abundant. Even the larger sized farms of India are much smaller than the collective farms of Russia. To replace masses of agricultural labourers in India by machines would aggravate the problem of rural unemployment.

C T O 's Experience

The C T O may be quoted as proof of successful introduction of tractors and heavy machinery in Indian agriculture, but if one studies its working minutely, its poor economic results become clear. The work of reclaiming jungle, bush and kans infested land was done by C T O on a non-profit non-loss basis. The charges per acre for different operations were: Rs 165 for Jungle clearance, Rs 94 for bush clearance and Rs 55 for deep ploughing. Since jungle and bush land have to be ploughed after clearance, the cost per acre of reclamation came to Rs 220 for jungle land, Rs 155 for bush land and Rs 55 for kans infested land.

So long as the prices of agricultural products were high, farmers were ready to pay these charges in long term instalments to the State Governments, which in turn advanced the amount to the C T O. The much higher costs of reclamation of jungle land were rewarded by a level of productivity higher than that of land cleared from kan. In fact, there were so many applications for land reclamation that the
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C T O was not in a position to satisfy all of them. After overcoming initial difficulties, the C T O worked successfully and economically, reclaiming about 47,000 acres of bush and jungle land and 1,20,000 acres of kans infested land during the period 1947 to 1953-51.

When in 1956 the prices of food grains went down due to considerable increase in production, farmers were not prepared to pay the charges for land reclamation demanded by the C T O for covering its costs. There were only a few applications for reclamation and it was feared that the large equipment of the C T O might have to remain idle. In order to keep the costly apparatus running, Central and State Governments subsidised the reclamation work, so that the farmer had to pay only Rs 180 per acre of jungle land, Rs 78 per acre of bush land, and Rs 40 per acre of kans infested land. Even then the CTO had to look for work and some units lay idle.

The experience of the C T O demonstrates how heavy farm equipment was employed successfully but it also shows that the economies of this enterprise were so slender that it was thrown over by a mere fluctuation of prices of agricultural products, though it must be admitted that reclamation work offers a number of extremely difficult conditions. Thus, from the experience of the CTO alone, one can argue neither for nor against the use of tractor and modern farm machinery in India. In fact, it hardly serves any purpose to quote isolated experiences or to list the arguments for and against the application of tractors and allied machinery in India. Since the arguments are of a qualitative nature, they have to be estimated subjectively, and the conclusion arrived at, too, are bound to be subjective in nature.

**Relative Costs**

We, therefore, propose another approach to decide the question: An objective analysis of the costs of mechanization and the returns to be expected from it. This analysis will be assisted by a comparison of Indian conditions with those prevalent in Germany where tractors and modern farm machinery are widely and successfully used. Due to the nearness of land in both the countries, the conditions of Germany seem to be especially well suited for a comparison with those prevalent in India. The costs of tractor mechanization are: (i) fixed costs, i.e., depreciation and rate of interest on the capital invested and (ii) variable costs, i.e., fuel and lubrication, repairs and wages.

The interest cost depends on the rate of interest and the purchase price of the machine. Table (1) demonstrates that the prices of the most important agricultural machines and implements are about equal in the two countries. For agricultural cost calculations in India, a rate of interest of 4 per cent of the full purchase price is generally used, while in Germany, one usually calculates at 4 per cent of half of the purchase price. The use of a fixed rate does not seem to be in accordance with actual facts, since the Indian farmer who takes a loan for the purchase of a tractor will have to pay a much higher rate if he has to borrow the amount from a village money lender. On the other hand, the rate of interest to be paid may be less than 4 per cent in the case of loans from Government or cooperative credit societies. By and large, the rate of interest to be paid by the Indian farmer will be higher than that paid by his German counterpart, since rural credit is well organised in Germany, whereas in India credit on favourable terms is available to the farmer to a very limited extent only.

The depreciation charge on machinery is dependent not only on the purchase price but also its life time. According to FAO investigations, the average life time of a tractor is 12 years in America and Germany and 7.5 years in England. In Indian cost calculations, a short-
er life time of 5 years to generally assumed for a tractor, since service and repair facilities are not as good as in Western countries and there is not a shortage of trained personnel for careful handling of the machines. Due to this shorter life time the yearly depreciation charge is higher in India than in Germany. These conditions as well as higher prices for spare parts and difficulties in their procurement result in higher repair costs in India.

The price of fuel oil in India is higher than in Germany but that of diesel, oil is about the same in both countries (see Table 1). Tractor-fuel cost is, thus, about the same in both countries, if diesel engines are used. So far as the wages of tractor drivers are concerned, even on the basis of one driver and one cleaner in India and a driver only in Germany, the wage cost in India is only about 1/3 to 1/4 of that in Germany. The result of the cost comparison is:

Cost of fuel are about the same in both the countries,
Costs of wages for the driver are lower in India; and
Costs of interest on capital invested, depreciation and repairs are higher in India.

Thus, in India, the costs of using tractor and modern farm equipment will be higher than in Germany.

Returns from Mechanization

Since the machines in question are primarily labour saving, the costs of human and animal labour replaced and their ratio to the costs of tractor and machines labour are of eminent importance in estimating the economies of application of modern machinery. Comparing the conditions of the two countries under consideration (Tables I and II), we find that the wages for agricultural labourers in India are about 1/5 to 1/13 of what they are in Germany, but the cost of animal power (of equal strength) is about the same. But on the basis of an equal number of working hours per year, an hour of tractor power is about thrice as dear in India as compared with Germany. See Table II).

Thus even if a tractor and its implements replace a few hours more of human or animal labour due to more labour intensive methods employed in India, the net return to be expected from application of labour saving machines is lower in India than in Germany. From this it is clear that machines aiming at the replacement only of human labour have the least chances of economic working in India, but there is a better chance that machines which mainly replace draught cattle may prove economical.

Tractor Vs Draught Animals

From Table II we learn that a motor-hp-hour of a highly utilized tractor is cheaper than a bullock-hp-hour (2 bullocks equivalent to 1 motor-hp) of insufficiently utilised bullocks: in case of equal utilization (equal number of working hours per year) the motor-hp-hour proves to be cheaper than the bullock-hp-hour. Table III goes on to compare the cost of shallow ploughing and Table IV that of heavy ploughing and transportation performed alternately by motor or animal power.

### Table II—Costs of Motor and Animal Power in India & Germany

<table>
<thead>
<tr>
<th></th>
<th>Cost per hp-hour</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs per tractor hour in India:</strong></td>
<td></td>
</tr>
<tr>
<td>(40 hp 4%; rate of interest, 5 years life time)</td>
<td></td>
</tr>
<tr>
<td>2000 w hrs per yr</td>
<td>0.13</td>
</tr>
<tr>
<td>1000 w hrs per yr</td>
<td>0.37</td>
</tr>
<tr>
<td>500 w hrs per yr</td>
<td>0.55</td>
</tr>
<tr>
<td><strong>Costs per tractor hour in Germany:</strong></td>
<td>0.13</td>
</tr>
<tr>
<td>(40 hp 4%; rate of interest, 12 years life time)</td>
<td></td>
</tr>
<tr>
<td>1000 w hrs per yr</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>Costs per bullock-hp-hour in India:</strong></td>
<td></td>
</tr>
<tr>
<td>(1 pair of bullocks equivalent to 1 hp including wages for bullock driver)</td>
<td></td>
</tr>
<tr>
<td>2000 w hrs per yr</td>
<td>0.41</td>
</tr>
<tr>
<td>1000 w hrs per yr</td>
<td>0.70</td>
</tr>
<tr>
<td><strong>Costs per horse-hp-hour in India:</strong></td>
<td>0.79</td>
</tr>
<tr>
<td>(1 pair of horses equivalent to 2 hp including wages for horse driver)</td>
<td></td>
</tr>
<tr>
<td>1000 w hrs per yr</td>
<td></td>
</tr>
</tbody>
</table>

Source: Subbaraja: 'Mechanization of Indian Agriculture', Indian Journal of Agricultural Economics, 1949. P 104. Institute for Farm Management of the University of Gottingen, Germany.

### Table III—Costs of Shallow Ploughing by Animal and Motor Power in India

<table>
<thead>
<tr>
<th></th>
<th>Cost per acre (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Draught Power used</strong></td>
<td></td>
</tr>
<tr>
<td>Bullock</td>
<td>5.25—11.0</td>
</tr>
<tr>
<td>Elephant</td>
<td>6.5</td>
</tr>
<tr>
<td>Tractor:</td>
<td></td>
</tr>
<tr>
<td>12 hp</td>
<td>2.0</td>
</tr>
<tr>
<td>40 hp</td>
<td>7.50—12.5</td>
</tr>
</tbody>
</table>

Note: The costs calculated include depreciation and interest of animals, tractors and implements as well as wages and operating expenses.


Costs of ploughing by elephant from Subbaraja: 'Mechanization of Indian Agriculture', Indian Journal of Agricultural Economics, 1949...P 104.

Costs of ploughing by bullock according to authors mentioned above and others.
According to Table III, the cost of shallow ploughing by bullock power and a 40 hp tractor fluctuates within the same range, but a lighter tractor (12 hp) does the same job cheaper than draught animals (bullock or elephant). But for light transport, bullock power turns out to be cheaper. In deep ploughing and heavy transport, the heavy tractor proves cheaper than bullock power. If we compare (see Table V) the relative cost of pumping water for irrigation purposes by motor and bullock power, we come to the conclusion that the electric motor performs the job cheapest. Unfortunately, its applicability at present is limited to the few Indian villages where electric power is available. A pump driven by diesel engine works cheaper than bullocks with mothe, but with a Persian wheel the bullocks perform the job of drawing water from a well at less cost than the diesel engine does.

Size of Tractor

The comparisons above show that it is not possible to generalize whether the machine works cheaper than the bullock or vice versa; in fact certain jobs are performed cheaper by motor power, others by bullocks. It is frequently argued that a 40 hp tractor replaces 40 pairs of bullocks. A cost comparison based on this assumption turns out to be in favour of the tractor. But such a calculation is justified only if the tractor is used exclusively for heavy ploughing, which will be possible in exceptional cases only (for example, Central or State Tractor Organizations or contractors). On an average farm, the tractor will have to perform plenty of jobs where it replaces only 24 (heavy transport) or even 3 pairs (light transport) of bullocks, for according to experience in Germany only 32 per cent of a farm's total requirements of draught power are needed for ploughing.

Thus a tractor is cheaper than bullocks only if the tractor is engaged for more than 1000 hours per year in heavy haulage (ploughing and heavy transport). From this it is obvious that a tractor will be economical only if worked on that minimum area of cultivated (ploughed) land as to provide a minimum of 1000 hours per year of heavy work. But before we can arrive at definite conclusions in this respect, another question has to be answered.

For the heaviest types of jobs, like jungle clearance and breaking up of new land, there is no doubt that heavy tractors are required. The CTO uses tractors up to 150 hp for these jobs. For contractors engaged in deep ploughing, a medium size of between 40 and 80 hp will be sufficient. For an average farm, the size of a tractor to be bought may be estimated by the following considerations: The costs, fixed as well as variable, of a light tractor are lower than those of a heavy one. A tractor, therefore, should be as small as possible, but on the other hand it must have sufficient power to perform the heavy jobs on the soil. The size of the tractor required thus depends on the type of soil. For light sandy soils, 15-20 hp will be sufficient, but for heavier soils 30-40 hp will be required. Farms using more than one tractor should have tractors of different sizes, the heavier ones for the heavier job of deep ploughing, the lighter ones for lighter jobs. Before buying a tractor, it will prove useful to try different sizes of hired tractors in ploughing the heaviest soil on the farm under unfavourable conditions, to find out the size of the tractor required.

One should refrain from buying a tractor if one is not in a position to buy the necessary tractor implements like mould board plough, disc harrow, cultivator and trailer as well. Without proper dimensioned implements which assure full utilization of the tractor's power, efficient and economic use of the tractor is not possible.

## Table IV—Costs of Performance of Different Jobs by Tractor or Bullock Power Alternately

<table>
<thead>
<tr>
<th>Kind of Job</th>
<th>Bullock pair equivalent of 40 hp Tractor</th>
<th>Cost per working hour (Tractor)</th>
<th>Bullock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy ploughing</td>
<td>40</td>
<td>5.20</td>
<td>16.4</td>
</tr>
<tr>
<td>Heavy transport</td>
<td>6 tons</td>
<td>5.20</td>
<td>9.8</td>
</tr>
<tr>
<td>Light transport</td>
<td>1 ton</td>
<td>5.50</td>
<td>1.2</td>
</tr>
</tbody>
</table>

### Preconditions of comparison:

(i) Cost per working hour in case of 2,000 working hours per year,
(ii) One pair of good bullocks moves 1 ton of load with a speed of 4 miles per hour,
(iii) Heavy transport by tractor with 2 trailers of 3 tons each and speed of 12 miles per hour possible only on good (paved) roads,
(iv) Light transport by tractor, 1 ton with speed of 12 miles per hour on kucha roads.

Minimum Area Required

The minimum size of holding required for economic use of tractors in India is given by different authors as 100 to 200 acres. But we shall try to approach this problem from a different angle. A farm should be sufficiently large to provide heavy work for the tractor for a sufficient number of hours per year (at least 1000), for only then will tractor power be cheaper than bullock power. On a farm with double cropped area, the soil has to be ploughed twice (one deep ploughing before the rainy season, one shallow ploughing for the winter crop); in addition, at least one operation of the harrow or cultivator for pulverising lumps and destroying weeds. According to German experience, these operations require 120 motor-hp-hours per hectare for ploughing, 60 motor-hp-hours per hectare for shallow ploughing and 28 motor-hp-hours per hectare for heavy work. According to these figures, the motor-hp-hours per hectare required for heavy work come to (i) for double cropped land 120 motor-hp-hours for ploughing before the rainy season, 28 motor-hp-hours for disc harrowing or cultivator and 60 motor-hp-hours for shallow ploughing for the winter crop, i.e., a total of 208 motor-hp-hours per hectare; (ii) for single cropped land, 120 motor-hp-hours for ploughing before rainy season and 28 motor-hp-hours for disc harrowing or cultivator, i.e., a total of 148 motor-hp-hours per hectare.
With these figures as the bases Table VI indicates the acreage of single and double cropped area required for employing tractors of different horse power for 1000 hours per year in heavy jobs, to make them economic in comparison with bullock power. A 20 hp tractor, for instance, requires 250 acres of double cropped land or 330 acres of single cropped land, respectively, to be more economical than bullock power.

This minimum area required for the economic use of a tractor is not to be taken as an absolute limit. In exceptional cases as, for instance, on intensely cultivated vegetable farms near the cities, it will be possible to employ a tractor economically on a much smaller area than the minimum size calculated above. For, on these farms, the soil is too valuable to be used for the production of bullock fodder, and due to the garden-like method of cultivation two-wheeled tractors of 10 or even 5 hp can be used. Due to market-oriented production resulting in higher cash income, vegetable farms will be in a position to meet the higher cash expenses (for purchase, maintenance and running) of the tractor. Besides, the tractor equipped with a trailer may facilitate daily selling of the products directly to the consumers in the city, which will yield higher returns than selling to wholesalers or shopkeepers. Furthermore, in case of extreme scarcity of manual labour (high wages) or draught animals, it may also be economical to use a tractor on farms below the minimum size.

Conclusions

From the above analysis, we can derive the following conclusions regarding the economies and possibilities of farm mechanization in India:

(1) Simple and cheap implements operated by manual labour or bullock power and aiming at increasing the yield or diminishing the losses during the process of agricultural production deserve mass introduction into Indian agriculture.

(2) Investment of capital in modern farm equipment of the labour saving type seems to be advisable only after achieving those improvements which prompt a higher return.

(3) The successful application of modern farm equipment in Russia, U.S.A or other countries cannot be regarded as an argument for large scale application of those machines in India, since conditions prevalent in this country in respect of availability of land and labour are basically different.

(4) The Central Tractor Organization can at the most be quoted as an example of successful application of heavy equipment for the specific purpose of land reclamation.

(5) The costs of mechanization in India are higher than in Germany, a country with highly mechanized agriculture.

(6) Since wages of agricultural labour are considerably lower in India, lower returns are to be expected from the process of farm mechanization.

(7) Due to low wages, the possibilities of economic working of only manual-labour-replacing machinery are the least bright.

(8) The different methods for drawing water from wells for irrigation purposes can be grouped according to rising costs as follows:

(i) electric motor;
(ii) bullocks with persian wheel;
(iii) diesel engine; and
(iv) bullocks with mothe.

(9) A tractor works cheaper than animal power only if:
(i) equipped with tractor implements which ensure full utilization of tractor power in heavy jobs like ploughing, disc harrowing, cultivating, heavy transport; and
(ii) engaged for more than 1000 hours per year in these heavy jobs.

(10) The minimum size of a tractor required depends mainly on the type of soil and can be stated as: up to 150 hp for jungle clearance, 60 to 100 hp for breaking up of new land (deep ploughing), 30 to 40 hp for farms with heavy soils and 10 to 15 hp for farms with light sandy soils.

Table V—Relative Operational Cost of Irrigation
(Lifting 6,000 gallons per hour)

<table>
<thead>
<tr>
<th></th>
<th>Total cost (Rs)</th>
<th>Running cost*</th>
<th>Repairs (Rs)</th>
<th>Depreciation (Rs)</th>
<th>Interest (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Motors (2hp)</td>
<td>0.38</td>
<td>28.10</td>
<td>2.25</td>
<td>3.61</td>
<td>4.32</td>
</tr>
<tr>
<td>Diesel Engine (5hp)</td>
<td>1.14</td>
<td>61.75</td>
<td>12.50</td>
<td>22.90</td>
<td>17.60</td>
</tr>
<tr>
<td>Persian wheel (owned one pair bullocks)</td>
<td>1.06</td>
<td>91.00</td>
<td>nil</td>
<td>11.00</td>
<td>4.44</td>
</tr>
<tr>
<td>Mothe (owned) 4 pairs bullocks)</td>
<td>3.28</td>
<td>3.28</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Mothe (hired 4 pairs bullocks)</td>
<td>10.00</td>
<td>1000.00</td>
<td>—</td>
<td>included in hire —</td>
<td></td>
</tr>
</tbody>
</table>

* Includes electric current and /or fuel, grease, wages.

For details see Tables 1–3

Assumptions:
(1) Depth of water level 20 ft.
(2) Working hours 1000 per year.
(3) Life time: electric motor 30 years; diesel engine 20 years; Persian wheel 10 years. Electric motor will last longer with greater care.
(4) Interest at 4 per cent per annum.
(5) Purchase prices: electric motor Rs 1051; diesel engine Rs 4400; Persian wheel Rs 800—1000.

Source: Catalogues and dealers.


(11) The minimum area required for economic use of tractors of different hp can be read from the following Table:

<table>
<thead>
<tr>
<th>Tractor hp</th>
<th>Double cropped</th>
<th>Single cropped</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>120</td>
<td>160</td>
</tr>
<tr>
<td>20</td>
<td>250</td>
<td>330</td>
</tr>
<tr>
<td>30</td>
<td>370</td>
<td>500</td>
</tr>
<tr>
<td>40</td>
<td>500</td>
<td>670</td>
</tr>
<tr>
<td>50</td>
<td>620</td>
<td>820</td>
</tr>
<tr>
<td>60</td>
<td>740</td>
<td>1000</td>
</tr>
</tbody>
</table>

(12) Cheap implements worked by manual labour or bullock power as well as the electric motor for drawing water from wells for irrigation purposes will work economically on all Indian farms.

(13) Tractor and its implements will find economic application in India only if used on larger sized farms i.e., farms above 320 acres, which comprise less than 1 per cent of the farms in India, and if engaged in heavy jobs only. Economic use of tractors below this minimum farm size will be possible in exceptional cases, for instance, on intensely cultivated vegetable farms or in areas with shortage of draught animals, as in parts of Central India and Rajasthan.

(14) Purely labour saving machinery, e.g., harvester combines will work economically only on a few very big sized farms of India suffering from shortage of manual labour.

If Indian agriculture is mechanized within the above economic limitations, it will prove beneficial and there will be no need to fear increasing rural unemployment and underemployment since the application of labour saving machinery will be restricted to the few larger sized farms and to regions with shortage of labour. But even for pushing forward the process of mechanization of Indian agriculture up to this desirable extent, there are—especially for equipping the majority of small Indian farms with improved implements—several well-known obstacles such as shortage of cheap credit, small size of majority of farms, lack of facilities for repairs and shortage of trained personnel for proper handling of machines, etc. The removal of these obstacles will be possible gradually.