

Scope, Progress and Constraints of Farm Mechanization in India

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ABSTRACT

In the context of increasing commercialization of agriculture, mechanization is very important. There has been increase in the use of farm machinery in Indian Agriculture as it contributed to the increase in output due to timeliness of operations and increasing precision in input application. Most of the mechanical inputs have displaced human and bullock labour, which is socially unjustified. Some states like Punjab, Haryana excelled in farm mechanization, but have experienced it as over-investment. There cannot be going back from mechanization but we frame suitable policies such as liberalizing land lease market, encouraging cooperative management and custom hiring of machinery, imparting training to the farmers regarding such investment, encouraging standard service inputs, devising machinery problem from small farmers and dry land cultivation.

1. INTRODUCTION

The technological improvements in Indian agriculture since mid sixties have brought about revolutionary increase in agricultural production. Interestingly, the growth rate of foodgrain production particularly in case of wheat and rice was much higher than the growth rate of population. The country was facing acute food shortages till eighties has now become not only self-sufficient but also a net exporter of foodgrains. This has been made possible due to evolution of high yielding crop varieties, increased use of chemical fertilizers, development of irrigation facilities and plant protection measures accompanied by effective price support programmes of farm products. The increased use of purchased inputs in agriculture necessitated to raise their use efficiencies through mechanization. The increase in the use of human and bullock labour and rising wage rates and cost of up-keep of bullock further made the case of farm mechanization still stronger.

2. SCOPE OF MECHANIZATION

Farm mechanization has been helpful to bring about a significant improvement in agricultural productivity. Thus, there is strong need for mechanization of agricultural operations. The factors that justify the strengthening of farm mechanization in the country can be numerous. The timeliness of operations has assumed greater significance in obtaining optimal yields from different crops, which has been possible by way of

mechanization. For instance, the sowing of wheat in Punjab is done up to the first fortnight of November. A delay beyond this period by every one week leads to about 1.50 quintals per acre decrease in the yield (11). This is also correct in the case of other crops and for other farm operations like hoeing, irrigation, harvesting, threshing and marketing which need to be performed at appropriate time otherwise the yield and farm income is affected adversely.

Secondly, the quality and precision of the operations are equally significant for realizing higher yields. The various operations such as land leveling, irrigation, sowing and planting, use of fertilizers, plant protection, harvesting and threshing need a high degree of precision to increase the efficiency of the inputs and reduce the losses. For example, sowing of the required quantity of seed at proper depth and uniform application of given dose of fertilizer can only be possible with the use of proper mechanical devices. However, when such operations are performed through indigenous methods, their efficiency is reduced. Thirdly, the time taken to perform sequence of operations is a factor determining the cropping intensity. So as to ensure timeliness of various operations, it is quite inevitable to use such mechanical equipments which have higher output capacity and cut down the number of operations to be performed. This has helped in increasing area under cultivation and increase in cropping intensity.

Higher productivity of land and labour is another factor, which clearly justifies farm mechanization. Not

only the output per hour is more, the total labour requirement is also reduced. The displaced labour may of course be absorbed in the other alternatives created by the increased mechanization such as manufacturing, repair and service shops and the sale services. Thus, it only results in the shifting of the labour from one vocation to the other. As production increases with mechanization of the farm operations, it creates a good scope for commercialization of agriculture.

Normally, there are good chances to reduce the cost of production if farm operations are mechanized as it saves labour, both human and bullock. In the absence of mechanization, the ever-increasing wage rate of human labour and cost of upkeep of draught animals could have increased the cost of production much higher. Further, large scale production means less per unit cost on the farms. Moreover, it reduces the weather risk and risk of non-availability of labour and thus wastage is minimized. Timely marketing is also made possible by quick mechanical transportation, cleaning and handling. Further, the area under fodder and feed for draught animals could be reduced due to decline in their use. The land thus released can be brought under commercial crops.

The use of farm mechanization enlarges the employment opportunities both on farms and in non-farm sectors through increase in area under plough, multiple cropping, development of agro-industries and related services. On the other hand, displacement of human labour does take place and demand for semi-skilled labour in place of unskilled labour is increased. Also, the drudgery for human labour is reduced and unhygienic operations such as handling of farm yard manure can be done with machinery.

3. CONSTRAINTS IN MECHANIZATION

It is true that farm mechanization has shown good results as of raising the agricultural production and improving the standard of living of cultivators within very short period. But a number of arguments have been advanced against farm mechanization such as:

1. Small size and scattered holdings of the farmers stand in the way of mechanization. As a result of this, farm machinery generally remains under-utilized.
2. Majority of small cultivators are poor who are not in a position to purchase the costly machinery like tractors, combine harvesters etc.
3. The use of tractor operated machinery may render some of the draft cattle population surplus. Studies under AICRP on Energy Requirement indicate that tractor owning farms do use draft animals for certain jobs. Like-wise farms using animate

sources of farm power, use tractor on custom service for certain jobs.

4. The farm machinery have large turning radius and thus require comparatively larger farm for economical use. Mechanization may lead to structural change in agriculture in respect of the occupational distribution in the rural economy. No doubt, the increasing farm mechanization is going to increase employment in secondary and tertiary sectors but it does displace labour in farm operations.
5. Lack of proper knowledge of farmer to purchase farm machinery, operate and maintain it properly leads to wrong choice, makes it uneconomical and risky too.
6. There is great shortage of diesel in the country as a whole. Thus, to use so extensive oil based farm machinery is not desirable.
7. The lack of repair and replacement facilities especially in the remote rural areas is another hindrance in efficient small farm mechanization.
8. Due to the seasonal nature of the agriculture, the farm machinery remains idle for much of the time. Thus, idle machinery means unnecessary high costs unless proper alternate use of such machinery in the off-season is made.

According to Verma, Singh and Mittal (1994), the chief bottlenecks of farm mechanization can be cited under following three heads:

A. Research development and testing of farm machinery and equipment, particularly suitable to small farms, dry farming, for operations such as paddy transplanting, sugarcane and fodder harvesting, spraying tall plants such as fruit and forest trees, cotton, sugarcane etc., sugarcane planter, cotton picking and so on.

B. Manufacture, standardization and quality control: Poor quality and lack of matching and standard designs of equipment and acute shortage of testing facilities.

C. Education, training and Popularization of farm equipment: Inadequate training facilities for farmer-users and artisans, inadequate service centers and lack of regulations on custom hiring services.

4. PROGRESS OF FARM MECHANIZATION

The traditional farm tools and implement mainly relied on use of animate power. Improved farm tools, implements and machinery, which use both animate and mechanical power were devised from time to time. The average size of farm holding being small, animate power is widely used in many parts of the country. Mechanical power is making its impact in Indian agriculture with steady increase in land and labour productivity.

The traditional animal operated country plough although give low output and require higher number of field operations are still being used by majority of the farmers. Animal drawn cultivator and puddler have gained popularity showing an annual growth rate of 3.11% and 7.93% respectively due to higher output and better quality of work (Table 1). Improved implements such as M.B. plough, puddler, disc harrow, peg tooth harrow, spring tine harrow and patella harrow, being more efficient, have been adopted. Use of sowing/planting devices for line sowing have also shown a growth rate of 6.5% as it helped the farmers in better management of costly inputs of seed and fertilizers. The growth in the number of sprayers and dusters for plant protection has also been significant. The number of draught animals has shown decline during the past few decades as a consequence of farm mechanization and high cost of animal upkeep.

The trend in population of farm machinery is presented in Table 2. Irrigation is one of the major energy-intensive operation. With the increase in gross irrigated area, the number of irrigation pumps has swelled from 20 thousand in 1950-51 to about 12.51 million in 2000-01. Electric pumps are preferred than diesel engine operated pumps due to lower cost and higher energy-use efficiency. Therefore, the growth rate of electric pumps was 8.20% as against 4.89% in diesel pumps. One of the major problems has been the lack of adequate and timely availability of electricity in rural areas due to which the diesel engines are kept as stand-by source of irrigation.

The farmers are increasingly using power sprayers and dusters. The estimated population during 1995-96 was 0.25 million and is expected to be 0.31 million in 2000. Tractor is the basic machine on which most of the farm mechanization depends. The number of tractors was just 8000 in 1950-51, which steeply went up to 2.64 million in 2000-01 showing a growth rate of 10.3%. Power tiller was introduced in the country in the sixties, but could not gain popularity like tractor due to its limitation in the field and on the road (Singh et al. 1999). The power tillers are being used presently in rice and sugarcane producing areas of Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, West Bengal, Bihar and Maharashtra. The increase in their population is shown in Table 2.

Prime movers for irrigation are also used for operating threshing, chaff cutting, cane crushing equipment. Tractors are also used as stationary power source for such purpose. Use of power thresher, especially for wheat crop, became very popular in the seventies even among small farmers.

5. FARM MECHANIZATION AND EMPLOYMENT

The use of different machines in agriculture has different types of impacts on employment of human and bullock labour. On the basis of data collected under the cost of cultivation scheme, the use of bullock labour has gone down significantly on the three major crops in Punjab as a result of fast mechanization (Table 6). Although the cost of human labour has gone up but there is considerable decline in the quantity of labour use. For example, in case of wheat, paddy and cotton, the use per hectare was 558.72, 961.44 and 810.65 hours in 1974-75 which declined to 301.15, 450.54 and 605.73 hours in 1998-99 respectively. On the other hand, the cost of farm machinery use has gone up manifolds.

Aggarwal and Mehra (1973) reported an estimated displacement of casual labour by cost of combine harvester in Ludhiana district to the extent of 9 man days per acre. Rao (1974) studied the relative cost of traditional and mechanical methods of harvesting and threshing wheat. It was reported that harvester combine displaces labour on a large scale and was costliest from social point of view. Mishra & Sundram (1975) assessed the cost and benefits of harvester combines. It was estimated that the use of harvester combine resulted in saving of about 15 man-days of unskilled labour per acre. The study also compared the cost of harvester combine with other alternative technologies and found it to be unprofitable unless farmers take third crop in a year.

Here, it is worth mentioning that it is wrong to say that all sorts of mechanization are unjustifiable. For example, the use of pump sets has established the fact that labour displacement by them is more than compensated by the increased demand for labour in the field of irrigation and other operations. Thus, the question of farm mechanization and unemployment is basically concerned with the use of tractors, threshers, combine harvesters etc. However, these machines bring timeliness and remove drudgery for farm operations, reduce unit cost of production in proving competitiveness.

6. ECONOMICS OF FARM MECHANIZATION

It is of utmost importance to examine whether the use of machines has been economical or not. On the basis of a study covering 203 farmers having 218 tractors in different districts of Punjab (Singh & Jindal, 1983) it was brought out that the total use of the tractor, which on an average came out 397 hours per annum is much less than the possible extent of 1000 hours. The cost per hour turned out to be very high due to high fixed cost,

which can be reduced by increasing the hours of working of the tractor. If it finds work for 600 or more hours per annum, the cost per hour can be lowered significantly. The overall average cost/hour, which was Rs.103.04 by its existing quantum of work i.e. 397 hours declines to Rs.91.77, Rs.86.26 and Rs.82.97 by working per 600, 800 and 1000 hrs. per annum. The machine becomes economical only if it is gainfully employed for rather than accounting for its unproductive use. Custom servicing increases annual use of farm machinery.

The committee set up by the Planning Commission (1975) observed that harvester combines were generally demanded by big cultivators and it displaced a large number of agricultural labour in the harvesting season when the opportunities of employment in agriculture were higher for them. The committee justified the use of harvester combine only if their contribution to production arising out of saving in grain from vagaries of weather and shattering and from multiple cropping and change in cropping pattern was substantial.

Laxminarayana et al. (1981) concluded that there is no social gain due to the use of harvester combines in terms of increase in cropping intensity or farm productivity. On the other hand, there is net social loss in terms of considerable labour displacement that would seriously jeopardize the employment opportunities of the casual labour force and more particularly migratory labour coming from labour surplus areas.

Singh (1986) on the basis of a sample of 35 combine harvesters studied, reported that the average area covered by a combine harvester of small size was 192.1 acres of wheat and 173.6 acres of paddy. With an average rate of Rs.210 per acre, annual gross return of Rs.76,203 was estimated while the annual fixed and operating costs worked out to Rs.48,538 thus showing a net profit of Rs.27,664 during 1984-85.

Asian Productivity Organisation (1983) recognized time saved, freedom from over burdened work, improvement in social status, increase in overall production, timeliness of operations, reduction in cost, increase in the number of croppings and adoptions of inter-cropping as gains. Increased debt, cost of fuel and repair, unemployment, disparity in income were considered as losses due to farm mechanization.

7. INTER-REGIONAL VARIATION

Singh (1979) studied the growth of tractorization in different districts of Punjab during the years 1960-61 to 1976-77. The author reported that the annual growth of tractors was 24.57% in the period 1961-66 which increased to 45.75% during 1966-72 and again declined to 16.49% during the period 1972-77. Ropar district witnessed the highest annual growth rate of 87.69%

during 1961-66 whereas, Gurdaspur district attained the maximum growth of 135.54% during 1966-72. Tractor density, which was quite low being 1.31% prior to Green Revolution, moved up to 18.03% in 1976-77. Umesh and Mathew (1990) studied the growth in production, imports and sales of tractors in Indian agriculture over the period 1960-61 and 1987-88. The study revealed that tractorization had proceeded much faster in states such as Punjab and Haryana, which have gone through green revolution while many other states had not made much progress. Sisodia (1973) found that there had been substantial increase in the population of tractors in the state of Madhya Pradesh and the number, which was 1,311 in 1956-57, increased to 3,544 in 1969-70. District-wise analysis showed that tractor population recorded significant increase in almost all the districts, and seven districts accounted for more than 50% of the total tractor population in the state during 1969-70. Indore district recorded the maximum growth rate and in terms of gross cropped area, the number of tractors per 10,000 acres of gross cultivated land increased steadily from 0.30 in 1956-57 to 0.70 in 1969-70. The district-wise distribution of tractors for the year 1987-88 was also examined by Chatha & Grewal (1991). The study revealed that tractor population in different districts was quite skewed and it varied between 37.73 and 84.61 per thousand hectares of cultivated land in Gurdaspur and Ludhiana districts respectively. Singh (1992) revealed that number of tractors in Punjab increased from 10,636 in 1965-66 to 2,75,000 in 1990-91. Ropar district attained the maximum growth rate. The tractor density in the state increased from 10 per thousand hectares in 1971-72 to about 60 per thousand hectares in 1988-89. The inter-district tractor concentration revealed that the intensity of tractor population was largely correlated with the availability of irrigation facilities and the districts with more intensity of irrigation had higher concentration of tractors. Rank correlation analysis indicated that agricultural productivity and irrigation were important determinants of tractorization

The farm mechanization is dependent mainly upon the size of operational holding, land topography, availability of credit facilities and per hectare profitability which in turn is affected by per ha yield, cropping intensity, market prices etc. For the country as a whole, there were 63.47 tractors per thousand of cultivated hectares or 45.91 per thousand of cropped hectares in 1999-2000 (Table 4). The intensity of tractors in the hilly areas such as Sikkim, Tripura, Mizoram, Arunachal Pradesh, Assam was low because of operational problems of farm machinery and low crop yields. On the other hand, plain areas of the country

viz. Punjab, Haryana, Gujarat, Uttar Pradesh and Rajasthan states had high intensity of tractors. A simultaneous view of percentage of farms having more than 4 hectare holdings indicated that Punjab, Haryana, Rajasthan and Gujarat states have high tractor density, perhaps due to higher percentage of large farms.

Even though the Punjab state excelled the other states in terms of tractor intensity, yet within the Punjab state district-wise intensity of tractorization as presented in Table 5 is highly variable. The number of tractors in the state registered fast growth but still there are some districts which have low intensity. For example in Mukatsar district it was as low as 10.65 tractors per thousand of cultivated hectares. Conversely, intensity of tractors in Faridkot was as high as 397.5 tractors per thousand of cultivated hectares, Bathinda (180.54), Ludhiana (147.68) and Patiala (138.81). Therefore, the economic rationale of tractors use in the area would be the basis to suggest a policy for making advances for this purpose.

8. DEMAND PROJECTIONS

A number of studies were carried out to project the demand for tractors in the country and in some specific states. National Council of Applied Economic Research (1974) studied the demand for wheeled tractors in the country during the fifth plan period. A single equation model was used to estimate the stock demand of tractors for 1973-74 and 1978-79. The variables tried in the model were relative price of the tractor, irrigated area, agricultural production and gross cultivated area. The study projected the stock demand level between 2.42 and 2.44 lakh tractors. Further, the annual demand for 1973-74 as 38 to 40 thousand units was estimated rising to about 79 thousand by 1978-79. Sharma (1998) projected that the demand for tractors in India to be 2258 thousand in 2024-25.

Quite a number of studies to estimate the future demand for tractors in Punjab were carried out. Singh (1979) revealed that the stock of tractors would be in the range of 1.4 to 1.6 lakhs in the Punjab state at the end of 1990-91, keeping in view the given level of technology. Singh and Jain (1981) fitted econometric model to estimate the demand for tractors. They found that the agricultural productivity and the labour force were found to be the important variables in the estimation of demand for tractors in the Punjab state. However, the influence of variables such as price of the tractors and irrigation was low. It was estimated that the stock of tractors in Punjab by the end of the century would vary between 1.70 to 2.40 lakhs. The annual absorption of tractors could lie in the range of 10,000 to 16,000 which was considered quite compatible with the

growth of labour force and agricultural productivity. Chatha and Grewal (1991) analysed the growth pattern of tractorization for the previous period and used it for estimating the future demand for tractors in Punjab. It showed that demand for tractors in the state during the year 2000-01 and 2030-31 would be 4.10 lakhs and 5.60 lakhs respectively. The study concluded that the saturation point of the demand for tractors would be reached sometime during the period 2010-11 and afterwards only the replacement demand would continue which worked out to be around 25 to 32 thousand tractors annually. Singh (1992) brought out that the total annual demand for tractors in Punjab would vary from 15,000 to 17,000 during the period 1988-89 to 1994-95 and it would be between 19,200 and 25,500 during the period 1994-95 to 2000-01. Sethi (1992) examined the optimum land use pattern and normative demand for tractors in Punjab and concluded that the normative requirements of tractor use were marginally higher than the existing tractor use and tractorization in the area had reached a point where it could meet the normative demand for tractor use. It was also observed that the adjustments to tractor density in the region of study had almost reached a saturation point and the demand for tractors in such a case would be mainly for replacement of tractors.

9. FACTORS AFFECTING USE OF TRACTOR

Naidu and Rao (1977) studied the trend in farm mechanization in India and the variables associated with it. It was observed that there was dramatic rise in the number of tractors during the period of mid-sixties due to Green Revolution. Tractorization was found to be positively correlated with variables such as percent of double cropped area to percentage of net area sown, percentage area irrigated to the net area sown, percentage area under high-yielding varieties to the net area sown, percentage area of holding with more than twenty hectares to net area sown, wages of agricultural labour and annual growth rate of agricultural output. However, there was negative correlation of tractors with agricultural labour per 100 acres of net area sown and working animals per hundred acres of net area sown. It was observed that tractorization was significantly associated with higher level of high-yielding varieties and HYV's were positively correlated with irrigation. Thus the interaction between tractors, high-yielding varieties and irrigation had led to the observed association between tractors and rate of growth of agricultural output.

Sandhu (1977) examined the growth and determinants of tractorisation in Punjab. The study revealed that the number of tractors in the state increased 12 times over a period of about one and a half decade i.e. 1961 to 1975.

Rank correlation of tractor density with some important variables was established and found that the variables such as rural literacy, irrigation and cropping intensity, whose significance in determining tractorization was not clear under static technology, because important in the context of dynamic technology.

Singh (1979) studied the determinants of tractorization in Punjab using both rank correlation analysis as well as functional analysis. The study concluded that variables such as farm size distribution, agricultural productivity, irrigation, rural literacy, wages of agricultural labour were positively correlated with tractor density. However, there was a negative correlation of tractor density and tractor price, labour density and draft animal density.

Singh and Jain (1981) estimated the utilization of tractor in Punjab and observed that the utilization of tractor was positively correlated with irrigation facilities and it was estimated that the increase in irrigation facilities by 25% could lead to an increase in the tractor use by about 6% and when irrigation facilities were doubled, the tractor use increased to about 9%. The study concluded that the tractor density was higher in those areas where relatively more irrigation facilities were available.

Gujja et al. (1985) studied the determinants of tractorization in arid areas of Western Rajasthan and found that the agricultural productivity, size of holding, labour density, draught animal density and rural literacy were important factors that had a positive impact on the tractorisation in the area. It was suggested that a concrete policy to provide sufficient tractors would help to increase agricultural productivity without replacing human labour and draught animal power.

Singh and Jindal (1993) conducted a study to find out the various aspects of utilization of existing tractors in Punjab agriculture. The study revealed that more than 80% of the tractor use was made for productive purposes on the own farms and 8.09% of its total use was made for custom hiring work while 6.60% of its use was made for social purposes. It was found that tractor use was dependent mainly on the cropping pattern of the area, farm size, type of soil, cropping intensity etc. and nearly 30% of its use was made for ploughing operation alone. Marketing, planking and sowing together also accounted for about one third of the total use.

Kumar et al. (1995) observed that growth in tractors during 1967-72 was attributed to uprise of wheat high-yielding variety seeds in Punjab; however, the latest increase in tractors was due to the steady adoption of mechanized field ploughing by small and marginal farmers by hiring-in tractors.

10. POLICY MEASURES

Mechanization in Indian agriculture is the need of the time but its use has to be viewed from angles of unemployment problems of human and animal force and vast majority of small and uneconomical farms. To rationalize the existing farm machinery is important as seen from the high variability in inter-regional distribution, it is imperative to suggest some policy issues such as;

1. The total use of the farm machinery, which on an average is much less than the prescribed norms. Therefore, there is need to enhance its productive use as a result of which, the fixed cost can be reduced significantly. The use of the machinery for social purposes, which is otherwise unproductive and thus needs to be minimized to the possible extent.
2. The use of the tractor for custom hiring should be encouraged through legislative measures. The various problems faced by the farmers in this process such as uneven distribution of tractors, uniform cropping pattern in the area, social symbol attached to the ownership of tractors and the payment problems should be further probed into for their minimization.
3. The distribution of tractors from area to area should be normalized so that the custom hiring is increased. Further, the small farmers having operational holding of less than 4 hectares need to be discouraged to own the tractors unless they have substantial grounds to make economical use of it. However, to solve the problems of mechanization of smaller holdings, the possibilities can be:
 - (a) Cooperative management of farm machinery;
 - (b) Financing of second hand tractors for small farmers;
 - (c) Extension services to advise the suitability of various makes, models and horse powers for different size of operational holdings;
 - (d) Devising smaller machinery suitable for small farms which constitute the vast majority of farmers but the machinery has to be effective and less costly.
4. Suitable crop planning on the farm and in the area can be quite useful to gainfully employ the tractor. The monoculture of crops and varieties in the area results in high seasonal fluctuation in its use.
5. There is need to revamp the tenancy legislation so that the land lease market is encouraged and the size of the tractor operated farms is increased to justify the existing farm machinery.

6. Technical know-how should be provided to the farmers with respect to appropriateness of farm machinery for the situation and for its proper use.
7. A standardization and quality-marking centres of farm equipment should be established in potential areas of the country.
8. The farm machinery suitable for different types of soil and operations for important crops should be developed and manufactured.
9. The useful farm equipment should be identified and imported to cut down time and expenditure on research.
10. Training relating to farm machinery and equipment should be imparted to the farmers and artisans.
11. Service units should be encouraged and mobile service units should be started. Adequate and soft loans for such purposes should be provided.

The above analysis indicates that most of the negative arguments against farm mechanization can easily be solved without much difficulty. But there is no dispute regarding the need to strengthen mechanization to boost the agricultural production and productivity to stabilize the economy. Production and productivity, on the other hand, cannot be enhanced with primitive and traditional operations. Thus, keeping in view all facts in mind, selective mechanization is the need of the hour. In other words, considering the huge size of population, a policy of selective mechanization will be most suitable where the labour displacement effects should be minimum. Thus, full-scale mechanization is not needed as in other developed countries of the world. However, the large holdings can safely be mechanized. Besides, machines suitable for small farms and those suitable for large cooperatives and state farms can be introduced. On small farms, the use of second hand tractors and operations through custom hiring of farm machinery can be taken up on large scale.

REFERENCES

- Aggarwal, P.C. and Misra, M.S. (1973). The combine harvester and its impact on labour: A Study in Ludhiana. *Indian J. Industrial Relations* 9(2).
- Asian Productivity Organisation (1983), *Farm Mechanization in Asia*, APO, Tokyo.
- Chatha, I.S. and Grewal, S.S. (1991), "A study of tractorisation in Punjab", Department of Economics and Sociology, Punjab Agricultural University, Ludhiana.
- Datt, S. and Sundharam, K.P.M. "Indian Economy" S. Chand & Co. Ltd., (1998).
- Gajja, B.L.; Kalla, J.C. and D.L. Vyas (1985), "Determinants of tractorisation in arid areas of Western Rajasthan", *Agricultural Situation in India*, 40(4):257-260.
- Grover, D.K. (1995), "Impact of mechanization on resource productivity in the Punjab agriculture – A case study", paper presented in I.S.A.E. seminar during 27-28 April, 1995 held at Khalsa College, Amritsar.
- Kumar, N. et al. (1995), "Farm mechanization and its impact on Punjab agriculture", paper presented in I.S.A.E. Seminar report, Khalsa College, Amritsar.
- Lekhi, R.K. and Singh, Joginder, "Agricultural Economics", Kalyani Publishers, New Delhi, July 2002.
- Mishra, P. and Sundram. (1975). Some aspects of the economics of harvest combines in Punjab. *Economic & Political Weekly*. 10(39).
- N.C.A.E.R. (1974), "Demand for tractors", N.C.A.E.R. Publication, New Delhi.
- PAU, Ludhiana, Directorate of Extension Education (2002) *Package of Practices for Rabi Crops in Punjab*.
- Pathak, A.S. (1985), "Farm mechanization and productivity", *Productivity*, 23(4): 411-417.
- Planning Commission, Govt. of India (1975). Expert committee on combine harvesters, Report (Mimeographed).
- Sethi, K. (1992) "Optimum land use pattern and normative demand for tractors in a growing economy-a case study of Ludhiana district", unpublished M.Sc. Thesis, Punjab Agricultural University, Ludhiana.
- Sharma, B.M.; Goyal, S.K. and G.P. Sharma (1992), "Input use efficiency on tractor and bullock operated farms in Aligarh district of Uttar Pradesh", *Indian Journal of Agricultural Economics*, 47(3): 487.
- Singh, B. (1979), "Demand for tractors in Punjab", unpublished M.Sc. thesis, Punjab Agricultural University, Ludhiana.
- Singh, B. and Singh K. (1983), "Demand for tractors in Punjab", *Agricultural Situation in India*, 38(2): 63-71.
- Singh, Gajendra et al. (1997) "Use of Energy in Agriculture and Future needs" Third Agricultural Science Congress, PAU, Ludhiana, (Proceedings)
- Singh, J. (1986) *Economics of combine Harvesters*. Progressive Farming, XXII(8), PAU, Ludhiana.
- Singh, J. and Jindal, B.R. (1993), "Tractorisation of Punjab agriculture-socio economic considerations", A Report, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana.
- Singh, K. and Jain, K.K. (1981), "The normative land use pattern, resource allocation and tractor absorption capacity of a growing economy: A closed model approach", *Indian Journal of Agricultural Economics*, 36(2): 1-15.
- Singh, R. (1992), "Growth, regional variation and demand projections for tractors in Punjab", Unpublished M.Sc. Thesis, Punjab Agricultural University, Ludhiana.
- Sisodia, J.S. (1973), "Tractors in farm mechanization in Madhya Pradesh, 1956-70", *Agricultural Situation in India*, 28(4): 209-217.
- Sharma, M. (1998) *A quantitative Analysis of Demand for Tractors in India with particular reference to Punjab*, M.Sc. thesis, PAU, Ludhiana.
- Verma, S.R., Mittal, J.P. & Singh, Surendra (1994) *Energy Management and Conservation and Energy in Agricultural Production and Food Processing*, USG Publishers and Distributors, Ludhiana.

Table 1. Growth of population of animal operated implements

Implement	(Number in million)					
	1966-67	1976-77	1981-82	1986-87	1995-96*	Growth rate (%)
Wooden plough	39.92	41.03	43.04	43.03	44.16	0.33
Steel plough	3.52	6.52	6.69	8.86	12.72	4.94
Cultivator	-	-	4.26	4.97	6.54	3.11
Puddler	2.72	2.06	2.32	3.30	6.25	7.93
Sowing devices	1.13	4.86	5.62	6.47	8.18	6.50
Cane crusher	0.62	0.78	0.69	0.72	0.72	0.35
Sprayer & duster	0.21	1.55	1.55	1.67	1.86	6.83
Draught animals (pairs)	40.82	41.25	35.79	36.80	32.38	-1.50

Source: Livestock Census *Estimated by Singh, Gajendra et al. (1997).

Table 2. Trend of Machinery population in Indian Agriculture

Machinery	(Number in million)						
	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01*	Growth rate%
Tractor	0.008	0.030	0.090	0.428	1.233	2.641	10.3
Power tiller	-	-	0.017	0.080	0.095	0.118	7.76
Combine harvesters	-	-	-	-	0.003	0.006	
Electric pump	0.02	0.10	1.029	4.33	8.91	12.514	8.20
Diesel pump	0.083	0.230	1.546	3.101	4.659	5.940	4.89
Power sprayer/duster	-	-	0.045	0.124	0.200	0.311	7.10

Source: Singh, Gajendra et al. 1997 *Estimated by Singh, Gajendra et al. (1997).

Table 3. Growth of Mechanical Power operated Agricultural Machinery

Implement	(Number in thousand)						
	1971-72	1976-77	1981-82	1986-87*	1995-96*	2000-01*	Growth rate (%)
Combine (tractor)	3.5	5.6	12	37	61.5	109	15.41
Harvester (self propelled)	4.5	3.0	3.0	18.0	35.0	55.7	10.63
M.B. & disc. Plough	573	925	1429	2392	4004	5427	9.85
Disc. Harrow	556	1292	1892	3574	6751	9826	12.35
Cultivator	815	1766	3150	5956	11558	18444	13.57
Seed drill/ Seed fert. drill	246	640	1606	2777	7301	12609	17.38
Planter	85	244	305	443	643	798	9.06
Leveller	494	1201	4140	7008	11861	15912	13.72
Potato digger	-	-	569	878	1355	21813	22.00
Total threshers	2058	5041	10250	13638	19089	22104	9.08
a) Wheat thresher	1825	4278	8319	11599	16172	18763	8.90
b) Paddy thresher	136	575	1318	1148	1622	1767	9.86
c) Other threshers	97	188	613	891	1295	1574	10.71
Sugarcane crusher	872	1045	1208	1512	1892	2133	3.76

Note : *Estimated by Singh, Gajendra et al. (1997).
Source: Livestock Census & Indian Agriculture in Brief.

Table 4. State-wise density of tractors in India

State/UT	No. of Tractors	%	No. of Tractors per thousand of		% farms with >4 ha size
			Cultivated area (ha)	Cropped area (ha)	
Andhra Pradesh	43705	1.65	3.98	3.21	8.2
Arunachal Pradesh	333	0.01	1.80	1.33	33
Assam	6992	0.26	2.59	1.77	4
Bihar	89438	3.39	12.04	8.90	3
Goa	439	0.02	3.09	2.57	4.2
Gujarat	230050	8.71	23.78	21.50	22.4
Haryana	230959	8.74	63.66	36.54	17.9
Himachal Pradesh	6821	0.26	12.42	7.03	5
Jammu & Kashmir	5765	0.22	7.86	5.33	1.7
Karnataka	101000	3.82	9.63	8.20	13.2
Kerala	6357	0.24	2.80	2.18	0.5
Madhya Pradesh	268455	10.16	13.53	10.32	19.1
Maharashtra	163182	6.18	9.20	7.37	14.2
Manipur	873	0.03	6.24	4.04	2.1
Meghalaya	419	0.02	1.90	1.58	8.2
Mizoram	163	0.01	1.50	1.41	1.6
Nagaland	2419	0.09	9.27	8.46	57.2
Orissa	21105	0.80	3.49	2.51	5.1
Punjab	398927	15.10	94.13	49.15	29.4
Rajasthan	334317	12.66	20.80	15.62	29.6
Sikkim	14	0.00	0.15	0.11	11.5
Tamil Nadu	63764	2.41	11.32	9.62	3.3
Tripura	139	0.01	0.50	0.31	1.3
Uttar Pradesh	622404	23.56	35.39	23.39	2.9
West Bengal	34551	1.31	6.35	3.72	1.3
UT's	8632	0.33	63.47	45.91	
All India	2641223	100.00	18.52	13.71	8.7

Source: Statistical Abstract of Punjab, 2002

Table 5. District-wise density of Tractors in Punjab, 2001-02

District	No. of Tractors registered	No. of Tractors per thousand of	
		Cultivated area (ha)	Cropped area (ha)
Hoshiarpur	18392	84.37	50.25
Jalandhar	29120	122.35	70.34
Nawanshehar	2214	21.92	12.65
Ludhiana	45042	147.68	74.45
Ferozepur	55174	116.16	61.10
Amritsar	34830	78.09	42.48
Gurdaspur	13883	47.54	27.77
Kapurthala	15212	111.85	57.62
Bathinda	53980	180.54	96.05
Patiala	42060	138.81	71.17
Sangrur	49350	108.46	55.95
Rupnagar	10169	80.71	48.19
Faridkot	52868	397.50	214.04
Moga	3907	19.54	9.97
Muktsar	2491	10.65	5.59
Mansa	8565	41.99	23.21
F.G.Sahib	3567	34.63	18.39
Punjab	440824	103.29	55.51

Table 6. Use of Human labour, Bullock labour and Machinery in Punjab Agriculture

Crop/year	(per hectare)				
	Human labour (Man hours)	Animal labour (pair hours)	Human labour (Rs /ha)	Bullock labour (Rs /ha)	Machine labour (Rs/ha)
Wheat					
1974-75	558.72	101.66	503.11	225.67	113.84
1984-85	467.90	30.83	825.56	158.86	600.89
1994-95	338.32	3.72	2354.99	51.63	1182.02
1999-2000	301.15	0.86	3006.72	23.83	2621.40
Paddy					
1974-75	961.44	97.58	881.64	211.81	44.44
1984-85	895.05	38.26	1531.72	216.72	463.81
1994-95	543.96	3.79	2999.51	51.78	1053.54
1998-99	450.54	0.99	3716.70	23.71	2164.17
Cotton					
1974-75	810.65	70.75	734.23	185.97	85.03
1984-85	824.85	53.84	1356.36	245.58	244.75
1994-95	773.66	4.15	4099.58	85.72	382.20
1998-99	605.73	5.25	4967.56	130.30	1446.90

Source: Reports of Commission for Agricultural Cost and Prices, Govt. of India.