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Estimation of a Mechanisation Index and Its Impact on Production and Economic Factors—a Case Study in India

Gyanendra Singh

Mahatma Gandhi Chitrakoot Gramodaya University, Chitrakoot, District Satna, Madhya Pradesh 485 331, India;
e-mail: drgsingh@rediffmail.com

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The major factors that require higher capital investment, *viz*. fertiliser, irrigation and farm power were selected to assess their impact on yield through multiple linear regressions. The standardised regression coefficient has revealed that irrigation (42%) and farm power (32%) significantly contributed in increasing the yield. Both these inputs use mechanical and electrical energy extensively as a part of mechanisation. An index has been suggested based on the ratio of the cost of use of machinery to the total animate and machinery cost for the estimation of the mechanisation. State-level crop-wise secondary data have been adopted from the cost of cultivation of principal crops in India for the assessment of the mechanisation index, and to study its impact on the yield, cost of cultivation and deployment of human and animal power. The analysis has revealed that the human labour cost is still the largest component in the cost of cultivation in the wheat crop, which is the most highly mechanised crop in India. The analysis has further revealed that, although 78·5% farm power was contributed by the mechanical sources, the mechanisation index based on cost of use of machinery was 14·5%. In other words, the share of cost of the human and animal energy in the total operational cost was 85·5%. The crop-wise mechanisation index varied from a lowest value of 8·22% in sorghum and paddy to a highest value of 30% in wheat. The analysis also revealed that the states having higher mechanisation indices incurred a lower cost of cultivation of the wheat crop on quintal basis due to increased yield. As the level of mechanisation increased, the draught animal use significantly reduced annually by 6·2%, but use of human labour reduced by −0·18% only, from 1971–72 to 1996–97.

1. Introduction

Mechanisation technologies keep changing with industrial growth of the country, and socio-economic advancement of the farmer. Whereas declining interest in agriculture of the landowners and non-availability of the agricultural labour for field operations may be one of the major socio-economic issues in highly industrialised nations, increasing land and labour productivity with dignity are the mechanisation requirements of the developing countries. Mechanisation technology is, therefore, location-specific and dynamic. The quality of inputs of mechanisation, and consequently land and labour productivity in both situations, may differ considerably (Gifford & Rijk, 1980; Singh 1997, 2000; Singh & Chandra, 2002).

Mechanisation planning requires the quantitative assessment of a mechanisation index, and its impact on agricultural production (yield) and economic factors (cost of cultivation, deployment of animate and mechanical power, and economic advantage). The index should incorporate the relevance and economic utility of using equipment with animate and electro-mechanical power for different farm operations in different crops. Various methods of measurement of mechanisation have been used in different countries (Rijk, 1989). Some of the methods are elaborate and take into consideration production factors. An attempt has been made in this paper to perform quantitative assessments of: (i) supplementation of animate power with electrical-mechanical power; (ii) estimation of a mechanisation index based on economic factors; and (iii) impact of mechanisation on deployment of human labour and animal draught, cereal yield, and cost of cultivation.

2. Review of assessment of mechanisation

Several authors have studied the status of mechanisation with reference to the intensity of power or energy availability, and its impact in increasing the agricultural and labour productivity. Giles (1975) reviewed power availability in different countries, and demonstrated that productivity was positively correlated with potential unit farm power. The NCAER (1981) assessed the impact of tractorisation on the productivity of land (yield and cropping intensity), and economic growth (income and employment). The trends for European and Asian countries were, however, distinctly different. Binswanger (1982) defined the status of mechanisation by the growth of mechanically power-operated farm equipment over traditional human and animal power-operated equipment. Rijk (1989) reviewed the growth of mechanisation in different Asian countries, and suggested computer software (MECHMOD) for the formulation of strategy for mechanisation policy based on economics of use of animate and mechanical power for different field operations.

Singh and De (1999) reviewed the methodologies adopted by several authors to express a mechanisation indicator. For macro-level planning, a mechanisation indicator I_m based on the ratio of electrical and mechanical power over total farm power was introduced as a measure of qualitative assessment of modernisation of agriculture, Eqn (1):

$$I_m = P_M/(P_H + P_A + P_M) \tag{1}$$

where: I_m is the mechanisation indicator; P_M is the total electrical and mechanical power; P_H is the human power, and P_A is the draught animal power.

A higher mechanisation indicator based on electrical power and stationary engines as per Eqn (1) might only reveal mechanisation of stationary operations. From a qualitative drudgery reduction point of view, a mechanisation index I_{TP} based on mechanical tractive power P_{Mt} could be a better measure, Eqn (2):

$$I_{TP} = P_{Mt}/(P_H + P_A + P_M) \tag{2}$$

A major defect in quantifying a mechanisation indicator based on the ratio of mechanical tractive farm power to total farm power is that it does not bring to light the actual use scenario. Whilst unit farm power could be considered as indicative of potential power availability, it may not necessarily be fully utilised on the farms. This may depend upon availability of diesel and electricity, and adequate workload. The majority of the farmers in developing countries use tractors for transport of agricultural and non-agricultural commodities. Mechanisation index I_E expressed by the percentage of machine work E_M to the sum of manual E_H, animal E_A and machine work E_M expressed in energy units, as suggested by Nowacki (1978), has been accepted for model forecasting using Eqn (3):

$$I_E = E_M/(E_H + E_A + E_M) \tag{3}$$

Higher levels of mechanisation are preferred by farmers to ensure timeliness, to increase yield of crops, and to reduce the cost of cultivation, provided the farm size is large enough to use the machine and sufficient labour at reasonable wages are not available when required. To maximise profit, alternative mechanisation technologies are adopted using animate and mechanical power sources to accomplish different field operations for different crops (Singh, 1992, 1997; Singh & Chandra, 2001; Singh & Singh, 2003; Government of India, 1961, 1971, 1981, 1991). The mechanisation index based on Eqn (3), therefore, does not emphasise on quality output and associated cost factors for the matrix of energy sources.

3. Materials and methods

A mechanisation index based on the matrix of use of animate and mechanical energy inputs could be given by incorporating cost factors in to Eqn (3):

$$I_{mij} = \frac{C_{EMij}}{(C_{EHij} + C_{EAij} + C_{EMij})} \tag{4}$$

where: I_{mij} is the mechanisation index of the ith crop in the jth state; C_{EMij} is the cost of use of machinery in the ith crop in the jth state; C_{EHij} is the cost of use of human labour in the ith crop in jth state; and C_{EAij} is the cost of use of animal labour in the ith crop in the jth state.

Equation (4) requires component-wise details of cost of the cultivation of different crops. State or national-level weighted average I_m can be calculated, Eqn (5):

$$I_{mij} = \frac{\sum_{i=1}^{n_i}\sum_{j=1}^{m_j} A_{ij} I_{mij}}{\sum_{i=1}^{n_i}\sum_{j=1}^{m_j} A_{ij}} \tag{5}$$

where: A_{ij} is the area under the ith crop in the jth state; n_i is the number of states from where data collected for different crops; and m_j is the number of crops for which data are collected.

Secondary data related to production and economic factors were obtained from the 'Cost of Cultivation of Principal Crops in India' (1991, 1996, 2000), and 'Agricultural Statistics at Glance' (2003) published by the

Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Government of India, New Delhi. Crop-wise and state-wise data on the cost of cultivation were available on the basis of a three-stage stratified random sampling design from all the economic farm holding groups, commissionary as the first stage, village as the second stage and farm holdings as the third stage, demarcated into homogenous agro-climatic zones based on cropping pattern, soil type, and rainfall.

The paid-out cost included hired labour (human, animal, machinery), depreciation, maintenance cost, material input costs (seed, fertiliser, manure, pesticide, irrigation), and land revenue or rent paid for leased land. The imputed cost included the value of family labour, managerial input of the farmer, rent of owned land, and interest on owned fixed capital. The weighted average cost of cultivation was calculated for major crops in Indian Rupees on area basis INR/ha by taking into account the cost of cultivation of a particular crop and the area under the same crop or yield basis INR/tonne by taking into account the cost of cultivation of a particular crop and the total production of the grains in respective states as:

(a) cost of cultivation in INR/ha

$$C_{ha} = \frac{\sum_{i=1}^{n_i} C_{ha} A_i}{\sum_{i=1}^{n_i} A_i} \tag{6}$$

(b) cost of cultivation, INR/tonne

$$C_t = \frac{\sum_{i=1}^{n_i} C_{ti} P_i}{\sum_{i=1}^{n_i} P_i} \tag{7}$$

where: C_{ha} is the weighted average cost of cultivation at an all-India level, INR/ha; C_t is the weighted average cost of cultivation at an all-India level, INR/t; n is the number of states from where cost of cultivation data are collected for a crop; C_{hai} is the average cost of cultivation for a crop for the ith state, INR/ha; C_{ti} is the cost of cultivation for a crop for ith state, INR/t; A_i is the area under cultivation of a crop in the ith state in million ha; and P_i is the total production of the crop in the ith state in million tonne.

4. Results and discussion

4.1. *Effect of major inputs on food grain yield*

Food grain yields vary from state to state, and within the state due to agro-climatic variations, technological diversities, and socio-economic disparities. It may be assumed, however, that under similar agro-climatic situations, identical inputs adoption (seed, fertiliser, irrigation, and plant protection chemicals), and technological support (machinery, power and energy), farmers should be able to achieve similar productivity. All these conditions could be simulated at the farm level but may be difficult to accomplish at the national level due to resource constraints. Therefore, major factors that require higher capital investment, *viz*. fertiliser, irrigation and farm power, were selected to assess their impact on yield through multiple linear regressions. The inputs used and the food grains data were collected from all the states for a reference year (1996–97). The regression Eqn (8) fitted well with a value for the coefficient of determination as R^2 of 0·79, statistically significant at the 1% level:

$$Y_{fg} = 491 + 4{\cdot}0X_f + 14X_i + 342X_p \tag{8}$$

where: Y_{fg} is the all-India average food grain yield in kg/ha; X_f is the average fertilizer consumption in kg/ha; X_i is the irrigated area in %; and X_p is the average farm power available in kW/ha, in respective states.

The standardised regression coefficients of Eqn (8) reveal that the comparative influence of irrigation on yield is much higher in increasing crop yield (42%), followed by power (32%) and fertiliser (26%) (Appendix A).

4.1.1. *Trend in use of farm-power and its impact on food grain yield*

Animate power may be adequate to ensure timeliness on small farms, but for large farms, supplementation with mechanical and electrical power would be necessary. Singh and De (1999), and Alam and Singh (2003) analysed that as the farmers shifted from traditional to scientific agriculture and increased the cropping intensity, use of tractors, engines, and electric motors along with matching equipment has increased. Table 1 gives the details of the growth of different farm power sources in India. It has increased to 170·89 million kW (1·21 kW/ha) in 2000–01 from 45·29 kW (0·32 kW/ha) in 1971–72. The share of mechanical power has increased from 41·54% of the total farm power to 82·85%, and mechanical tractive power (tractor and power tiller) from 8·46% to 32·85%, during this period. Human labour and draught animals that largely provided motive and stationary farm power (58%) in 1971–72 is reduced to 17% in 2000–01. Actual use of animate power on an areal basis has also declined: manual energy from 643·5 down to 549·8 h[manual]/ha; and draught animal energy from 181·6 down to 58 h[animal pairs]/ha, during the period from 1970–71 to 1996–97 at the all-India level, combining all crops.

Table 1
Share of animate, mechanical and electrical power sources in total farm power

Power source	*Farm power, GW (% share to the total farm power)*			
	1971–72	*1981–82*	*1991–92*	**2000–01*
Manual power	6·29 (13·89)	7·58 (10·79)	9·33 (7·71)	11·76 (6·80)
Animal power	20·19 (44·58)	17·10 (24·33)	19·43 (16·05)	17·69 (10·23)
Tractor	3·70 (8·17)	12·95 (18·43)	32·75 (27·05)	56·75 (32·80)
Power tiller	0·13 (0·29)	0·26 (0·37)	0·48 (0·40)	0·98 (0·57)
Diesel engine	8·06 (17·80)	16·12 (22·94)	23·87 (19·71)	33·8 (19·54)
Electrical	6·86 (15·14)	16·15 (22·98)	34·84 (28·77)	51·21 (29·60)
Others (combine harvester, sprayers)	0·06 (0·13)	0·11 (0·16)	0·38 (0·31)	0·79 (0·46)
Total farm power	45·29 (100)	70·27 (100)	121·08 (100)	172·98 (100)
Specific power, kW/ha	0·32	0·50	0·85	1·22

* Estimated.

However, due to agro-ecological diversities, high population density, and socio-economic disparities, a diverse mechanisation scenario is seen in India. *Figure 1* reveals the diversity of tractor intensity in different states, which varies from 1·92 tractors/1000 ha in Assam to 71·43 tractors/1000 ha in Punjab, with an all-India average of only 17·03 tractors/1000 ha. It is observed that the wheat-growing northern regions have a higher concentration of tractors than other regions. The use of combined harvesters is also much more prevalent in the northern regions, especially for harvesting wheat and paddy. Small and marginal farmers in all the regions of the country experience constraints in the use of machinery due to the smaller size of fields and limited capital resources. India has 165 million ha of cultivable land owned by more than 106 million farm holders with an average land holding size of 1·57 ha. The medium (4–10 ha) to large group of farm holders (>10 ha) owned 44·4% of the total area, with an average farm holding size of 8 ha. These farms are suitable for cultivation by mechanical power sources on an ownership basis or on a custom hire basis.

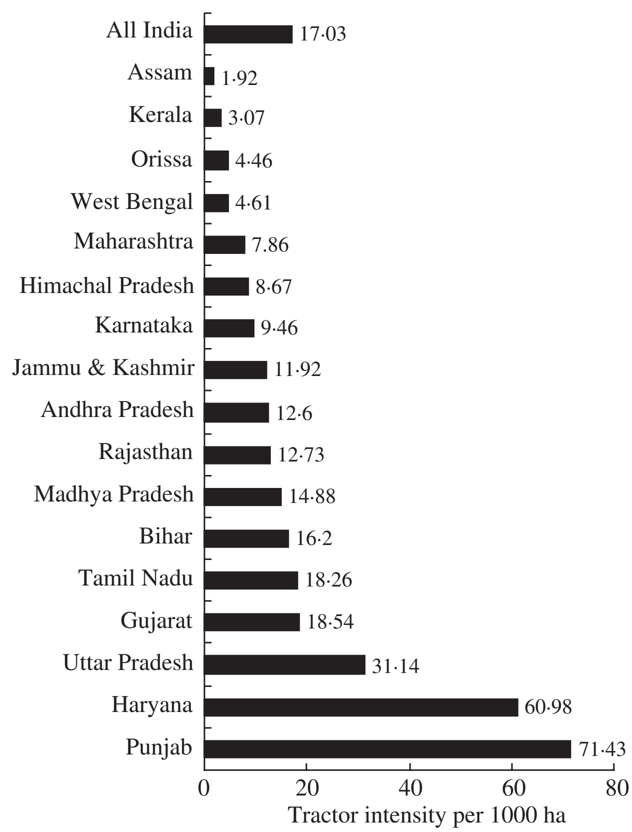

Fig. 1. Statewise tractor intensity in India in 2003–04

It is a fact that yields are affected more by agricultural inputs. However, there is strong evidence to suggest that higher productivity requires more power. Farmers using sophisticated self-propelled machinery in advanced countries may require higher farm power per unit area. Developing countries relying on human and animal power-operated equipment might achieve economical yield, if adequate irrigation, quality seeds and soil nutrients are available (Giles, 1975). State-wise variability in food grains yields Y_{fg} in kg/ha, and potential unit farm power availability P in kW/ha for the year 1996–97 is shown in *Fig. 2*. The correlation regression equation is given with a value for R^2 of 0·75 as:

$$Y_{fg} = 708{\cdot}97 + 911{\cdot}65P \tag{9}$$

Based on Eqn (9), the yield level in Punjab, which had the highest farm power availability of 3·59 kW/ha in 2000–01, could be estimated at 3982 kg/ha, and this compares well with the recorded food grains yield of 4032 kg/ha.

4.2. *Share of cost of machinery in the total cost of cultivation*

One of the objectives of mechanisation is to reduce the cost of cultivation. The weighted average cost of cultivation of major crops at an all-India level is given in Table 2. It reveals that the cost of the human labour input in the total cost of cultivation varies from 22·62% for Bengal gram to 34·4% for rice, and draught animal labour from 2·1% for sorghum to 14·2% for red gram. The share of the cost of use of machinery varied from 3·2% for groundnut to 11% for wheat. Rapeseed-mustard (10·6%), Bengal gram (9·3), and soya bean (6·8%) record a higher share of cost of machinery, indicating higher levels of use in the mechanisation in these crops. The cost of use of machinery in other crops recorded is less than 4·5%, thereby indicating that these crops are less mechanised: sugarcane, 3·3%; rice, 3·7%; sorghum, 4·3%; and red gram, 4·4%.

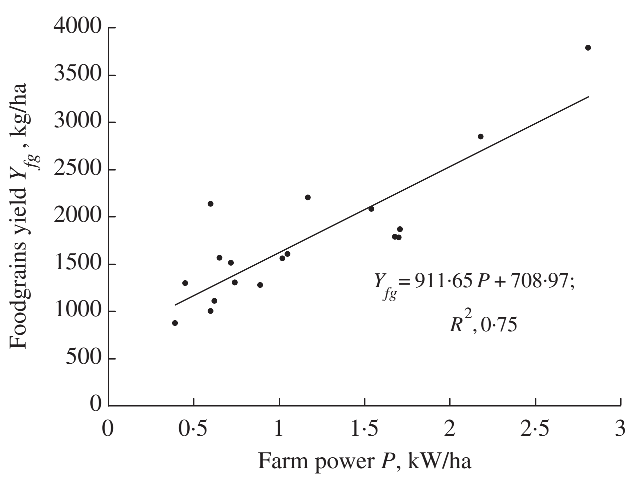

Fig. 2. State-level variability in farm power, kW/ha and food grains yield, kg/ha; R^2, coefficient of determination (data 1996–97)

Singh and Chandra (2002) observed that increased cost of inputs and operational cost resulted in increased cost of cultivation of most of the crops. Trends in operational and different input costs for the 1971–72 to 1996–97 period are shown in *Figs 3* and *4* for the wheat crop, which is the most highly mechanised crop in the country. *Figure 3* shows that human labour cost has increased at a growth rate of 8·96%, even though labour use has rather marginally reduced, with an annual negative growth rate of 0·18%. Also, the cost of use of draught animal energy during this period has recorded a growth rate of 9·6%, even though draught animals use has significantly reduced, with a negative growth rate of 6·22%, annually. The annual growth rate in cost of use of machinery component is recorded as 13·36%.

In 1996–97, the weighted average cost of cultivation of the wheat crop at an all-India level was recorded as INR 12,523/ha, of which the share of use of human, animal and machinery cost constitutes 38%. *Figure 5* shows share of costs of different components: fixed cost, 33·7%; manual labour, 23·4%; fertiliser and manure, 12·3%; use of machinery, 11%; seed, 7·6%; irrigation, 6·3%; bullock draught, 3·6%; and insecticide and herbicide, 0·6%. The manual labour cost, thus, is still the largest component in the cost of cultivation of wheat, even though the level of mechanisation for this crop is the highest in the country.

4.3. *Mechanisation index based on the cost of use of machinery*

Values of the mechanisation index I_m for the different crops, calculated as per Eqn (4) are given in Table 2. It

Table 2
Share of mechanisation input to total operational cost at an all-India level (1996–97)

Crop	*Average cost of production, *INR/ha*	*Component of the cost of cultivation INR/ha, (% share of the total cost)*			*Mechanisation index, %*
		Manual	*Animal*	*Machinery*	
(1) Paddy	13 084	4503·7 (34·4)	929·6 (7·1)	490·0 (3·7)	8·27
(2) Wheat	12 523	2926·0 (23·4)	454·5 (3·6)	1379·8 (11·0)	28·99
(3) Sorghum	5247	2176·0 (34·3)	851·0 (13·4)	271·0 (4·3)	8·22
(4) Bengal gram	7389	1669·0 (22·6)	494·0 (6·7)	688·0 (9·3)	24·13
(5) Red gram	8431	2445·0 (29·1)	1176·0 (14·2)	366·4 (4·4)	9·19
(6) Groundnut	13 977	4099·0 (29·3)	1009·5 (7·2)	466·4 (3·2)	8·37
(7) Rapeseed-mustard	9019	2226·0 (24·7)	344·0 (3·8)	954·0 (10·4)	27·07
(8) Soya bean	9386	2170·0 (23·1)	693·0 (7·4)	635·5 (6·8)	18·16
(19) Sugarcane	24 535	6933·0 (28·3)	516·0 (2·1)	516·0 (3·3)	9·93
All crops combined	11 721	3507·0 (29·9)	745·2 (6·36)	720·0 (6·15)	14·50

Note: *One Indian Rupee, 1 INR ≈ £80.

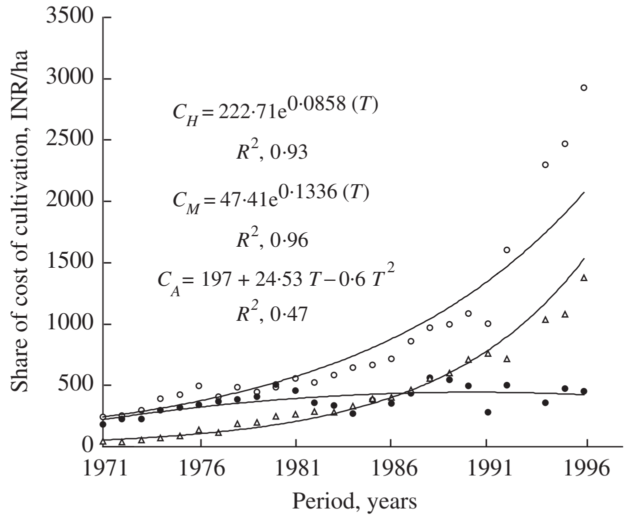

Fig. 3. Trends in the cost of use of manual labour C_H (○), animal draught C_A (●), and machinery C_M (△) in cost of cultivation of wheat; T, elapsed time, years; R^2, Coefficient of determination

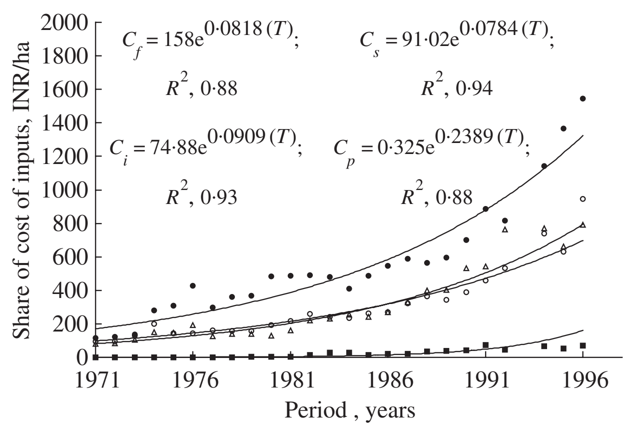

Fig. 4. Trends in the cost of use of seeds C_s (○); fertiliser C_f (●); irrigation C_i (△); and plant protection C_p (■) in the production of wheat in INR/ha; T, elapsed time, years; R^2, coefficient of determination

reveals that the mechanisation index at an all-India level is only 14·5%, even though 78·5% of the total farm power is contributed by mechanical and electrical power sources. However, not all crops are uniformly mechanised. Crop-wise values for I_m varies from 8·22% in sorghum and paddy to a highest value of 30·00% in wheat. Rapeseed-mustard (27·07%), gram (24·13%) and soya bean (18·16%) record higher levels of mechanisation. The I_m for paddy crop, which occupies the largest area under cultivation (43·43 million ha), is only 8·27%. Eastern and southern parts of the country, which grow more than 70% of the paddy, have hardly been

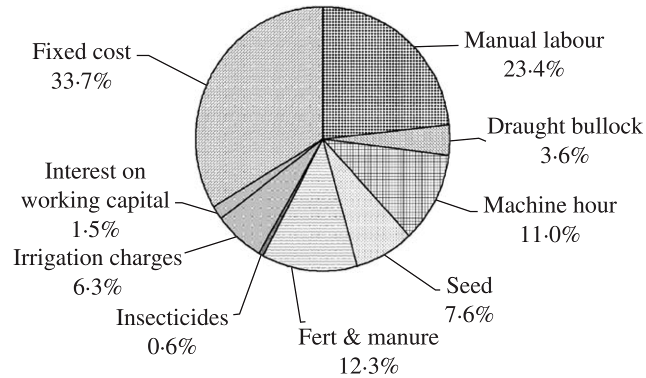

Fig. 5. Share of different inputs in the total cost of cultivation C_T, INR 12 523/ha of wheat crop in India (data 1996–97)

mechanised. Even in the northern parts of the country mainly seedbed preparation, sowing, threshing and combined harvesting are mechanised on selected farms. Transplanting, which is labour intensive and full of drudgery, is still practised with manual labour, and mechanical transplanters are undergoing pilot introduction in a few selected states.

4.4. *Impact of the mechanisation index on the food grain yields*

More than 86% of the area under wheat crop is irrigated (1996–97), and more than 91·2% area is under high yielding varieties in India. The level of mechanisation is also highest for this crop. All these inputs have contributed in increasing the yield from 1380 kg/ha in 1971–72 to 2679 kg/ha in 1996–97. Correlation of the mechanisation index on the yield of wheat crop was studied by adopting state-wise variability in the mechanisation index I_m in % and wheat crop yield Y in kg/ha for the year 1996–97 (*Fig. 6*). It reveals that yield Y and mechanisation index I_m are positively correlated with a value for R^2 of 0·58 [Eqn (10)]. In other words, states having a higher wheat crop yield have also adopted higher levels of mechanisation.

$$Y = 741{\cdot}23e^{0{\cdot}044(I_m)} \qquad (10)$$

4.5. *Effect of mechanisation index on deployment of manual and animal labour*

Displacement of manual labour is usually viewed as a negative aspect of mechanisation, especially in developing countries. Mechanisation index and deployment of manual labour and draught animals in the cultivation of wheat have been analysed for the period 1971–72 to 1996–97 (*Fig. 7*). It is evident that manual labour and

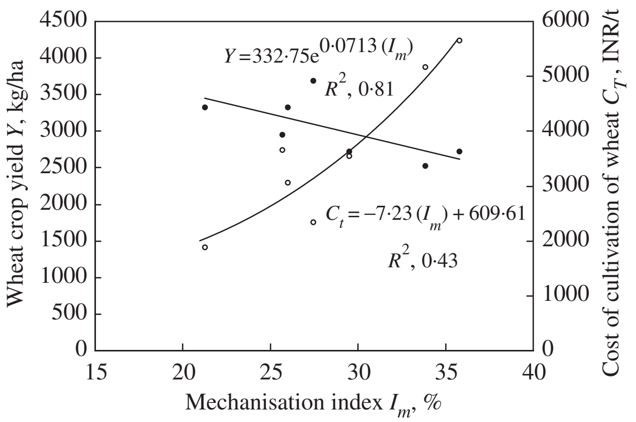

Fig. 6. Trends in yield Y in kg/ha (○ and cost of cultivation of wheat C_T, INR/t (●) as influenced by the mechnisation index I_m (statewise data1996–97); R^2, Coefficient of determination

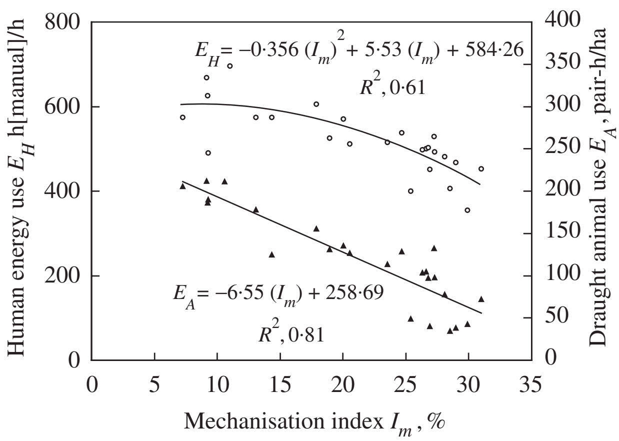

Fig. 7. Trends in deployment of human labour E_H (○) and animal draught E_A (▲) as influenced by the mechanisation index I_m in cultivation of wheat

animal draught use are negatively correlated with mchanisation index. Manual labour deployment has declined marginally from 490 down to 468 h[manual]/ha, recording a negative growth rate of 0·18%, annually. In other words, mechanisation in India has not produced a significant impact in reducing manual labour deployment. However, regression Eqn (11) has a negative coefficient with a second-order term that might have a greater influence at higher values of the mechanisation index in the future. This was also reported by Mesna and Jhamtani (2003). The use of draught animals on the other hand has significantly reduced from 190 down to 38 h[animal pair]/ha, recording a negative annual growth rate of 6·22% [Eqn (12)]. The increased cost of use of draught animals compared to mechanical power has encouraged the farmers to use tractors, especially on custom hire systems for tillage, sowing and threshing operations:

$$E_H = 584{\cdot}26 + 5{\cdot}53 I_m - 0{\cdot}356 I_m^2 \quad (11)$$

$$E_A = 258{\cdot}58 - 6{\cdot}55 I_m \quad (12)$$

with values for R^2 of 0·61 and 0·81, respectively.

4.6. *Impact of mechanisation on cost of cultivation*

Investment in mechanised agriculture is always more than that for traditional agriculture. However, higher land and labour productivity with the use of appropriate mechanisation technology increase the yield, thereby reducing the cost of cultivation on a yield basis. Statewise average cost of cultivation of wheat crop on a yield basis C_t in INR/t and mechanisation index I_m for the year 1996–97 is plotted in Fig. 6 to study the impact of mechanisation. The data have been compiled from the eight major states covering 85% of the total area under wheat cultivation. Even though the value of the coefficient of determination is small (R^2, 0·43), it is significantly correlated. It is seen that states having a higher mechanisation index incur a lower cost of cultivation on a yield basis.

5. Conclusion

Farm power intensity (kW/ha) alone is not adequate to assess the quality of mechanisation, as it does not have a time dimension. The index, however, facilitates future farm power planning. A mechanisation index based on the share of machine work to the sum of manual, animal and machine work is generally used for model forecasting. However, due to the quality of output and the associated cost factor of farm power sources, the mechanisation index may lead to erroneous conclusions of economic advantage.

A mechanisation index based on the ratio of cost of use of machinery to the total cost of use of human labour, draught animals and machinery has been suggested for estimation. For the assessment of the mechanisation index, and to study its impact on yield, cost of cultivation and deployment of human and animal power, crop-wise secondary data have been adopted from the cost of cultivation of principal crops in India. The analysis revealed that, even though 78·5% farm power was contributed by mechanical and electrical power sources the mechanisation index at an all-India level was only 14·5%, and it varied from 8·2% in sorghum and paddy to a highest value of 29·00% in wheat. It also revealed that the states having higher crop yields have adopted higher levels of mechanisation to ensure timeliness and to reduce the cost of cultivation on a yield basis as observed in the state of Punjab. The analysis has further revealed that as a consequence of adoption of mechanisation reduction in the use of human labour has not been significant, but the use of draught animals has reduced at a negative annual growth rate of 6·22%, during 1971–72 to 1996–97.

The level of mechanisation index in the country is very low in other crops *viz*. paddy, sugarcane, groundnut *etc*. and therefore, plenty of scope exists to introduce mechanically operated equipment. Inputs for mechanisation require long-term investment for creating support services infrastructure for manufacture, marketing, after-sale service network, training, demonstration, and credit support. The Government of India is conscious of these facts and has taken adequate measures to promote mechanisation by providing financial incentives to the farmers and to the farm machinery industries to manufacture quality farm machinery.

References

Alam A; Singh G (2003). Status and future needs of farm mechanisation and agro-processing in India. Technical Bulletin No. CIAE/2003/96, Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal

Binswanger H P (1982). Agricultural mechanisation: a comparative historic perspective. World Bank Report ARU-1, Washington

Gifford R C; Rijk A G (1980). Guidelines for agricultural mechanisation strategy in development. Economic and Social Commission for Asia and the Pacific (ESCAP), Regional Network for Agricultural Machinery

Giles G W (1975). The reorientation of agricultural mechanization for the developing countries. FAO Report on Effect of Farm Mechanization on Production and Employment. Food and Agricultural Organisation (FAO), Rome, Italy

Government of India (1961 1971 1981 & 1991). Livestock census reports. Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi

Government of India (1991 1996 2000). Cost of cultivation of principal crops in India. Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi

Government of India (2003). Agricultural Statistics at a Glance. Directorate of Economics & Statistics. Ministry of Agriculture, New Delhi

Mesna S R; Jhamtani A (2003). Impact of mechanisation on employment and entrepreneurship. Agricultural Mechanisation in Asia, Africa and Latin America, **34,** 59–65

NCAER (1981). Implication of tractorisation for farm employment, productivity and income. National Council of Applied Economic Research, Parisila Bhawan, New Delhi

Nowacki T (1978). Methodology used by ECE countries in forecasting mechanisation developments. United Nations Economic Commission for Europe, AGRI/MECH Report No. 74

Rijk A G (1989). Agricultural mechanisation policy and strategy—the case of Thailand. Asian Productivity Organisation, Tokyo, Japan

Singh G (1992). Energy perspective-norms and scenario in agriculture. Journal of Rural Energy, **1,** 1–10

Singh G (1997). Data book on mechanisation and agro-processing in India after independence. Technical Bulletin CIAE/97/71, Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal, India

Singh G (2000). Modernisation of agriculture in India (part I)—farm mechanisation. Agricultural Situation in India, Ministry of Agriculture, New Delhi

Singh G; Chandra H (2001). The paradox of declining agricultural growth co-existing with declining prices of agricultural commodities. Directorate of Economics and Statistics, Department of Agriculture and Cooperation Ministry of Agriculture, Government of India, Agricultural Situation in India

Singh G; Chandra H (2002). Production and economic factors growth in Indian agriculture. Technical Bulletin No. CIAE/2002/91, Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal, India

Singh G; De D (1999). Quantification of a mechanisation indicator for Indian agriculture. Applied Engineering in Agriculture, **15**(3), 197–204

Singh G; Singh R C (2003). Harnessing animal power. Technical Bulletin No. CIAE/2003/93, Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal, India

Appendix A: Standardised regression coefficients of fertiliser, irrigation and power on yield of grains; coefficient of determination R^2, 0·79; number of observations *n*, 17 is given in Table A1

Table A1

Variable	*Regression coefficient*	*Standard error*	*Standardised regression coefficient*	*Calculated 't' value*
Constant	491·00	201·67	—	2·43*
Fertiliser	4·067	3·92	0·26	1·04
Irrigation	13·95	8·12	0·42	1·72
Power	342·02	199·09	0·32	1·12

*Level of significance, 1%.