

FARM POWER AND MACHINERY MANAGEMENT



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Farm Power and Machinery Management

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Module 1. Role of mechanization and its relationships to productivity, employment, social and technical changes

Lesson 1. Role of Mechanization in Indian Agriculture

The Indian agriculture is multidimensional perspective. On one hand it includes highly mechanized farms of Punjab, Haryana and Western Uttar Pradesh and on other, it is characterized by small fragmented land holding, hill farming, shifting cultivation which in general managed through animate source of energy. Out of total 329 million hectare geographical area of the country, 165.6 million ha is available for cultivation and during last three decades the net sown area has remained around 142 million ha. Out of an estimated 142 m ha net cultivated area around 40% is irrigated and rest is rain fed. The productivity of rain fed areas is very low as compared to the irrigated areas. The contribution of the rain fed areas to the overall production is about 44% of total farm output. During the Green Revolution phase of 1965-75, the use of high yielding varieties, fertilizer, and chemicals coupled with mechanical energy and improved agricultural practices increased the cropping intensity and productivity of the crop. This required farm machines to ensure timeliness of operation, precise and judicious application of inputs, handling, and storage and value addition to farm inputs at village level. In Indian agriculture, human, animal and mechanical power is utilized for different on-farm and off-farm activities. Farm mechanization status is often expressed in terms of power availability per unit area of any country.

Agriculture occupies an important place in Indian economy. It produces sufficient food to meet the needs of a teeming population and even to export it. The spectacular rise in agricultural production in the last four decades is largely a result application of new technology, increased use of improved seeds, chemicals and fertilizers, irrigation and mechanization, coupled with incentives for production and greater access to credit. This has put Indian agriculture in world ranking (Table 1).

Table 1: Global Ranking of India in farm production & productivity.

Crop	Production Rank	Productivity Rank
Paddy	2nd	12th
Wheat	2nd	9th
Maize	6th	15th
Total cereals	3rd	36th
Groundnut	2nd	12th

Rapeseeds	4th	28th
Pulses	1st	44th
Potato	3rd	26th
Sugarcane	2nd	9th
Fruits	2nd (10.5% share)	-
Vegetables	2nd (9.7% share)	-
Tractor in use	4th	-

India has made remarkable progress in the development of Agricultural Mechanization technology. The fact that Indian agriculture was powered by about 185 million agricultural workers, 71 million draught animals, over 12 million motors and engines and 1.2 million tractors during the year in 1990-91 (Table 2). This figure changed to about 243 million agricultural workers, 53 million draught animals, over 25 million motors and engines, and 4 million tractors during the year 2009-10 reflects the unique Indian approach to mechanization. Nearly 36% of the power in agriculture was contributed by inanimate power sources in 1984-85, which reduced to 24% in 1994-95 and further reduced to 13% in 2009-10.

Farm mechanization status is often expressed in terms of power availability per unit area of any country. The total farm power availability in 1975-76 was 0.48 kW/ha, which has increased to 1.73 kW/ha in 2009-10 (Table 3). As the power availability increased on Indian farms, cropping intensity increased and side-by-side cropping pattern also changed. Now the more emphasis is being given on oil seeds & pulses, fruits and vegetable crops, hill agriculture, plantation crops and crops for diversification from rice-wheat to maize, cotton, sugarcane etc. The average supply of power to agriculture should be increased to 2.0 kW/ha by the year 2015 to achieve the planned production level. Appropriate and selective mechanization of production agriculture, post-harvest management and value addition using a proper blend of conventional and renewable energy sources facilitates in enhancing productivity. Estimated contributions of improved agricultural tools and equipment in augmenting total food production of India and other relevant parameters are given in Table 3. During the past four decades a large number of farm tools, implements and machines have been developed for different farm operations such as land leveling, seed bed preparation, sowing and planting, weeding and hoeing, plant protection, harvesting, threshing, dehusking, decorticating, etc. The rate of growth, however in animal operated machinery has remained low as compared to tractor or power operated machinery. Table 4 indicates the level of mechanization of farm operations in India. The other benefits of agricultural mechanization i.e. the contribution of mechanization are given in Table 5.

Table 2: Status of farm power sources in India.

Year	Agril Workers		Draft Animals		Tractors		Power Tillers		Diesel Engines		Electric Motors	
	Number (million)	Power (million kW)	Number (million)	Power (million kW)	Number (million)	Power (million kW)	Number (million)	Power (million kW)	Number (million)	Power (million kW)	Number (million)	Power (million kW)
1960-61	131.10	5.8	80.4	30.6	0.037	1.00	0	0	0.230	1.298	0.200	0.74
1970-71	125.70	6.21	82.6	31.39	0.168	4.38	0.0096	0.054	1.7	9.52	1.6	5.92
1980-81	148.0	7.46	73.4	27.89	0.531	13.86	0.0162	0.091	2.88	16.13	3.35	12.39
1990-91	185.30	9.17	70.9	26.94	1.192	31.11	0.0323	0.181	4.8	26.88	8.07	29.86
1999-00	206.19	10.6	60.0	22.8	2.369	61.83	0.1046	0.586	5.9	33.04	12.85	47.55
2000-01	213.83	10.7	60.3	22.9	2.531	66.06	0.1147	0.642	6.226	34.86	13.25	49.03
2001-02	234.09	10.9	59.3	22.5	2.643	68.98	0.1232	0.690	6.523	36.53	13.601	50.32
2002-03	235.26	11.1	58.4	22.2	2.736	71.41	0.1333	0.747	7.053	39.5	13.921	51.51
2003-04	236.44	11.2	57.5	21.8	2.855	74.52	0.1449	0.811	7.028	39.36	14.21	52.58
2004-05	237.62	11.4	56.5	21.5	2.992	78.09	0.1555	0.871	7.595	42.53	14.467	53.53
2005-06	238.81	11.47	55.8	21.2	3.153	82.29	0.1659	0.929	7.627	42.71	14.75	54.57
2006-07	240.00	11.63	54.9	20.86	3.37	87.96	0.1785	1.000	7.822	43.8	15.054	55.7
2007-08	241.00	11.7	54.0	20.52	3.553	92.73	0.1921	1.076	7.900	44.24	15.8	58.46
2008-09	242.21	12.10	53.32	20.26	3.689	96.28	0.2221	1.244	8.173	45.77	16.203	59.95

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2009-10	243.42	12.17	52.65	20.01	3.915	102.18	0.2571	1.439	8.456	47.35	16.616	61.48
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Note: 1 Human = 0.05 kW, Draught animal = 0.38 kW, Tractor = 26.1 kW, Power tiller = 5.6 kW;

Electric motor = 3.7 kW, Diesel engine = 5.6 kW

Table 3: Cropping intensity and power availability on Indian farms

Year	Cropping intensity (%)	Food grain productivity (t/ha)	Power available (kW/ha)	Power per unit production (kW/t)	Net sown area per tractor (ha)
1975-76	120	0.944	0.48	0.51	487
1985-86	127	1.175	0.73	0.62	174
1995-96	130	1.491	1.05	0.70	84
2004-05	135	1.652	1.47	0.89	47
2005-06	136.4	1.715	1.50	1.02	45
2006-07	138.1	1.756	1.54	1.01	42
2007-08	138.7	1.860	1.62	0.87	40
2008-09	139.02	1.909	1.67	0.87	38
2009-10	139.22	1.798	1.73	0.96	36

Table 4: Level of mechanization

S. No.	Operation	Percentage
1	Tillage Tractor Animal	40.2 15.6 24.7
2	Sowing with seed drill/seed-ferti-drill Tractor Animal	28.9 8.3 20.6
3	Irrigation	37
4	Thresher wheat Paddy and others	47.8 4.4
5	Harvesting: Reaper Combine	0.56 0.37
6	Plant protection	34.2

Table 5: Contribution of Agricultural Mechanization

Benefits	Value
Saving in seed	15-20%
Saving in fertilizer	15-20%
Saving in time	20-30%
Reduction in labours	20-30%
Increase in cropping intensity	5-20%
Higher productivity	10-15%

Mechanization of Horticulture Crops: Horticulture is the key area for diversification of agriculture in this region. Equipment for mechanization of orchard crops for pit making, transplanting of saplings, spraying, pruning, harvesting of fruits etc need to be identified/imported/designed, manufactured, introduced and popularized. Vegetable crop production needs to be mechanized. There is very little mechanization except for the potato crop. Equipment for seedbed preparation is available. However, equipment for planting, transplanting of seedlings, row cultivation, irrigation, spraying, harvesting, picking/digging need to be introduced by importing, modifying, designing and manufacturing. Use of plastic mulch reduces water requirement and checks weed growth. Equipment for laying plastic mulch, low plastic tunnels for cultivation of vegetables, cut flowers etc are required to be introduced and popularized. Green house technology has good scope in India for growing seedlings, flowers, high value off-season vegetables and some fruit crops. This technology needs to be promoted as a part of diversification efforts. Equipment for mechanization of

cultivation in green houses needs to be introduced and popularized. R&D efforts need to be intensified. The futuristic farm equipment e.g. Vegetable precision drills and seedling transplanters, Vegetable harvesters and diggers for root crops are needed for this zone.

Mechanization of Hill agriculture: The hilly terrains in many areas though having heavy rainfall face acute shortage of water both for human beings and plants. Ironically, most of the operations are done manually with age old hand tools. Scarcity of moisture due to quick runoff necessitates introduction of efficient, light and low cost powered tools and machinery to improve timeliness of field operations. Plot size (generally less than 10 x 10 m), undulating terrain, growing crop on bench terraces, coupled with economic conditions, are major bottlenecks in use of mechanical power in the hilly regions. Women folk constitute major working hands in hill agriculture. Except ploughing, all other operations are performed by women mainly. Efficient, hand tools and light power machinery, capable of doing operations from tillage to threshing, are required keeping women-machine anthropometric data in mind. The valley areas of hills are fit for introducing power tillers of 8-12 hp and even tractors of lower horsepower with matching equipment.

Agricultural mechanization and engineering technology are slated to play a pivotal role for the success of the Indian agriculture to bring about a turn-around in agriculture in this region. There is growing trend to introduce higher horsepower tractors (> 40 kW and above). This trend is influenced by the emerging trend for custom hiring, contract farming and to reduce the cost of cultivation. Contract farming is essential to produce raw materials for agro-processing units proposed to be set-up in rural areas. This trend is to be encouraged, as it would save the farmers from gravely indebtedness by spending heavily in acquiring expensive machinery like tractors, sprayers, combine-harvesters etc. This would also call for revising the agricultural credit policy, which requires mortgaging of land to get the loans. This policy deprives the small farmers, landless laborers and unemployed youths from getting loans for buying the tractors and other machines for custom-hiring jobs. Indian farmers have adopted mechanization inputs especially, irrigation, tractor, and threshing. Custom Hiring of mechanization inputs is getting popular for which high capacity machines need to be developed. Agriculture Service Centres need to be developed in rural areas for marketing and service supports of inputs including engineering inputs. Quality of Machines need to be improved through material selection and manufacturing.



Lesson 2. Farm Power Availability and Productivity in India

Mechanization in agriculture holds the key for sustainable development in the terms of increasing the production by timely farm operations, reducing losses, reducing the cost of operations by ensuring better management of costly inputs and enhancing the productivity of natural resources besides it helps in reducing drudgery in farm operations. Mechanized agricultural practices and operations have been adopted by the farming community at varying level of adoption, which represents the varying scenario across different regions in the country. Farm Power is an essential input in agriculture for timely field operations for operating different types of farm equipment and for stationary jobs like operating irrigation equipment, threshers/ shellers/ cleaners/ graders and other post harvest equipment. The source of farm power includes human, animal, tractors, power tillers, diesel engine and electric motor. Information about the availability of these power sources under time-series is very essential in planning and prediction level of farm mechanization as this directly and indirectly provides vast potential for manufacturers, entrepreneurs, sales and repair etc. During last 50 years the average farm power availability in India has increased from about 0.30 kW/ha in 1960-61 to about 1.78 kW/ha in 2011-12. Over the years the shift has been towards the use of mechanical and electrical sources of power, While in 1960-61 about 92.31% farm power was coming from animate sources, in 2009-10 the contribution of animate sources of power reduced to about 13.00% and that of mechanical and electrical sources of power increased from 7.70% in 1960-61 to about 87% in 2009-10. Food grains productivity is positively associated with unit power availability. It is visualized that the additional requirement of food grains in future will be met, to a great extent from the demand of tractors, power tillers and other machinery.

The country witnessed unprecedented growth in agriculture that helped country to graduate from hunger to self-sufficiency in food grains by increasing the food grain productivity from 0.636 t/ha in year 1965-66 to 1.798 t/ha in 2009-10, resulting for export with surplus. This growth is mainly due to the agricultural technology during green revolution period which is back-up by agricultural scientists including agricultural engineering, supported by positive policy support, liberal public funding for agricultural research and development and un-tired work of farmers. Power is needed on the farm for operating different tools, implements and during various farm operations. While mobile power is used for doing different field jobs, the stationary power is used for lifting water and operating irrigation equipment; operating threshers, shellers/decorticators, cleaners, graders and for other post harvest operations. The mobile farm power comes from human, draught animals, power tillers, tractors and self-propelled machines; whereas the stationary power is obtained from oil engines (diesel, petrol, kerosene) and electric motors. Availability of adequate farm power is very crucial for timely farm operations for increasing production and productivity and handling the crop produce to reduce losses. With the increase in intensity of cropping the turnaround time is drastically reduced and it is not possible to harvest and thresh the standing crop, on one hand, and prepare seed bed and do timely sowing operations of subsequent crop, on the other hand, in the limited time available, unless adequate farm power is available. Similarly for precision farming, increasing area under irrigation, conservation tillage, straw

management and diversification in agriculture, more power is required. There has been close nexus between farm power availability and increased productivity. Those states where availability of farm power is more have, in general, higher productivity as compared to other States.

The key factor in farm mechanization is the introduction of mobile mechanical power, i.e., tractor, power tiller and associated machinery. As know that Sardar Joginder Singh (1897-1946), then Agriculture Minister in the Punjab Government (1926-37), introduced the steam tractors in India in 1914 for reclamation of wasteland and eradication of '*Kans*'. Demand of tractors in the country was met through import until 1961 when Eicher Tractors Ltd. and Tractors and Farm Equipment Ltd started manufacturing tractors with foreign collaborations. To meet the additional domestic demand, importation continued up to 1977. Meanwhile many other industries started manufacturing tractors with foreign know how such as Gujarat Tractors Ltd (1963), Escorts Ltd (1966), International Tractors (India) Ltd. (1966), and Hindustan Machine Tools Ltd (1977). Punjab Tractors Ltd. started their production with indigenous technology in 1974. Many more industries started manufacturing tractors since then with indigenous and foreign know how.

Sources of power: The different sources of power available on the farm for doing various mobile and stationary operations are as under:

Mobile Power

- Human (men, women, children)
- Draught animals (bullocks, buffaloes, camels, horses and ponies, mules and donkeys)
- Tractors
- Power tillers
- Self propelled machines (combines, dozers, reapers, sprayers etc.)

Stationary Power

- Diesel/oil engines (for pump sets, threshers, sprayers and other stationary operations)
- Electric motors (for pump sets, threshers, sprayers and other stationary operations)

Human Power: Agriculture has been the main occupation of the rural people and largely dependent on use of animate power sources. Human energy is predominantly used for all operations in agriculture. Before green revolution, animate energy had been widely used for various farm operations like seedbed preparation, sowing, inter-cultivation, harvesting, threshing and transportation to and from the field. Wider job opportunities in urban areas have set in a trend of rural youth preferring to take up other profession than cultivation. However, in specific situations as hill agriculture, shifting cultivation, *tal* and *diara* land cultivation, human energy would continue to serve as principal source of energy. Even in specialized operations as rice transplanting, harvesting of cotton, horticultural and plantation crops, human power is the only source of energy in agriculture.

The labour/land ratio has been steadily increasing over time and thus technological changes through mechanization process have been land-saving in nature with focus on increasing land productivity. Mechanization process in India thus did not follow the process of creating surplus labour from agricultural sector for consumption in the industrial sector, as had been in the cases of countries like USA and Japan.

While the population of agricultural workers as percentage of rural population has gone down from about 69.4% in 1951 to about 55% but in absolute terms, due to increase in overall population, the number of agricultural workers available in rural areas has increased from 116 million numbers in 1960-61 to 243 million numbers in 2009-10 and thereby registered an annual compound growth rate of about 1.5% during the last 50 years. These agricultural workers are engaged in different farm operations and depend on agriculture for their livelihood, even when they are not fully employed throughout the year. Due to too much involvement of labour in different farm operations, the cost of production of most of the crops in our country is quite high as compared to developed countries.

Human power availability for agriculture had been 0.043 kW/ha in 1960 and reached 0.162 kW/ha in 2000 at an annual compound growth rate of 3.37 per cent. The growth rate decreased to -1.4 per cent between 2000 and 2009 with a reduced power availability of 0.145 kW/ha in 2009-10 (Fig. 1).

Draught Animal Power (DAP): Draught animal power, available mainly as progenies of milch animals, has long remained an important source of tractive energy for production agriculture, rural agro-processing and transport in India and other developing countries of Asia, Africa and Latin America. Traditional agriculture in India largely depended upon this power source for farm operations like tillage, sowing, weeding, water lifting, threshing (by animal trampling), oil extraction, sugarcane crushing and transport. With modernization of agriculture production systems and use of mechanical power sources, draught animal use has drastically reduced in power intensive operations as water lifting, oil extraction and threshing. The choice of farm power to be used for an operation is largely decided by the available time period, alternatives available (including custom hiring services) and associated economics. In sloppy hill regions and on small farms machines like tractor or combine are difficult to operate, and thus draught animal use besides human is likely to continue as major power source. Increased cost of maintenance of animals has also brought in compulsions among the farmers to reduce draught animal ownership as far as practicable. Apart from the economic importance, livestock still continues to have symbiotic bond with rural people.

Draught animals, particularly bullocks, are still the predominant source of mobile power on about 60% of the cultivated area consisting of about 85 million ha. They are very versatile and dependable source of power and are used in sun and rain under muddy and rough field conditions. They are born and reared in the village system and maintained on the feed and fodder available locally. They are ideal for rural transport where proper roads are not available. They reduce dependence on mechanical sources of power and save scarce petroleum products. Their dung and urine are also used as indirect source of energy-farmyard manure, biogas. They also help in maintaining ecological balance. Under Indian conditions where majority of the people are vegetarian and even amongst non-vegetarians, majority of them don't eat beef, draught animals as byproduct of milch animals, will continue to be available for draught purposes in future also. About 4-5 decades back most of the farm

operations, water lifting, rural transport, oil extraction, sugarcane crushing, chaff cutting etc, were being done using draught animals only. But with the modernization of agriculture, development of *pucca* roads connecting village and availability of electricity in those villages, most of the jobs earlier being done using draught animals, except field operations, are now being done using other convenient and cheaper options. Over the years the annual use of draught animals is going down. While earlier a pair of animals was being used for about 1200-1800 hours annually, their average annual use has now come down to about 250-500 h only, that too for tillage, sowing, weeding and a little bit of rural transport on *kuchha* roads. The time series population of draught animals during 1960-61 to 2007-08 is given in Table 1, which shows that the population of draught animals during the last 20 years has been going down. This declining trend of draught power was more visible especially in those states where the demand of tractors and power tillers has gone high. It has been observed that on an average a tractor is replacing about 5 pairs and power tiller about 2 pairs of animals. Draught animal population, mainly derived from bovines, was 80.40 million in 1960-61 and reduced to 52.65 million numbers by 2009-10 during the same period. Although the bovine population in the country has been steadily increasing, the population of animals actually available for work has shown a different trend over the period of time.

With decreasing population of draught animal, and a very slow increase in net-cropped area in the beginning, draught animal power availability in India decreased from 0.229 to 0.224 kW/ha between 1960 and 1970. During the next decades, the power availability further reduced to 0.200 kW/ha in 1980, 0.162 kW/ha in 2000 and 0.145 kW/ha in 2009 (Fig. 1).

Mobile Power from Tractors and Power Tillers: For meeting the increased demand of mobile power for timely farm operations and increased intensity of cropping, additional power is available mainly from tractors and power tillers. Self-propelled reapers and combines also provide mobile power specially for harvesting operations. In 1947 central and state tractor organizations were set up to develop and promote the supply and use of tractors in agriculture and up to 1960, the demand was met entirely through imports. There were 8,500 tractors in use in 1951, 20,000 in 1955 and 37,000 by 1960. Local production began in 1961 with five manufacturers producing a total of 880 units per year. By 1965 this had increased to over 5000 units per year and the total in use had risen to over 52,000. By 1970 annual production had exceeded 20,000 units with over 1,46,000 units working in the country. Five new manufacturers have started production since 1997. In 1998 Bajaj Tempo, already well established in the motor industry, began tractor production in Pune. In April of the same year New Holland Tractor (India) Ltd launched production of 70 hp tractors with matching equipment. Larsen and Toubro have established a joint venture with John Deere, USA for the manufacture of 35-65 hp tractors at a plant in Pune, Maharashtra and Greeves Ltd is producing Same tractors under similar arrangements with Same Deutz-Fahr of Italy.

India presently is the largest manufacturer of tractor in the world. There are more than 20 manufacturers of tractors in the country producing about 60 models of tractors in different hp ranges. Tractor population in India has grown from 0.037 million in 1960-61 to 3.464 million units in the year 2009-10 at an annual compound growth rate of about 10 per cent during the last 50 years. Farm power availability from tractors has consequently increased from 0.007 kW/ha in 1960 to 0.218 kW/ha in 1990 at an annual compound growth rate of about 12 per cent. The growth rate in the next decade decreased to 8 per cent. Farm power

availability in the year 2000 was 0.47 kW/ha, reaching to 0.639 kW/ha in 2009 at an overall growth rate of 9.65 per cent during the last 49 years (Fig. 1).

Power tiller, or two-wheel tractor, came in India with import of two units from Japan in 1961. There are mainly 2 manufacturers of power tillers in the country producing about 6 models in the range of 5.97-8.95 kW (8-12 hp). In addition to them there are many others who are importing Chinese make of power tillers and selling in the country. The total sale of power tillers in the country during 2007-08 was 21106 units. The major sales of power tillers are in the States of West Bengal, Tamil Nadu, Karnataka, Assam, Kerala, Orissa and Maharashtra. Farm power availability from power tiller has consequently been meagre. It was 0.001 kW/ha in 1981, and rose to 0.05 kW/ha in 2000 and 0.008 kW/ha in 2009. Thus, it increased by about 8 times during the period of 1980 to 2009.

Stationary Power from Diesel Engines and Electric Motors: Stationary power sources in agriculture comprise of diesel engines and electric motors used for irrigation equipment, operating threshers and other stationary machines. Diesel engine and electric motor are widely used by the farmers mainly for lifting irrigation water, apart from operating stationary farm machines like threshers and chaff cutters. The populations of these prime movers have increased tremendously since the green revolution.

Diesel engine population in the country increased 34.35 times between 1960-61 and 2009-10. While the annual compound growth rate had been 11.86 per cent during the period 1960-61 to 1985-86, with increased availability of electricity it reduced to 7.65 per cent during the period of 1960-61 to 2009-10. Farm power from diesel engines increased from 0.009 kW/ha in 1960 to 0.246 kW/ha in 2000 and further to 0.312 kW/ha in 2009, registered an annual compound growth rate of 7.50 per cent during the last 49 years.

The rural electrification programme launched by the Government of India in the mid sixties undertaken through the Rural Electrification Corporation has helped in making available electricity to 18.5 per cent villages in 1970-71 and increased to almost 100 per cent villages by 2007-08. Preferential supply to rural sector at subsidized price has led to rapid increase in use of electric motors in the agricultural sector. Electric motor population thus increased 79 times between 1960-61 and 2007-08 at an impressive annual compound growth rate of 9.53 per cent. Farm power availability consequently increased exponentially from 0.006 kW/ha to 0.412 kW/ha between 1960 and 2009 with an annual compound growth rate of about 9 per cent during the last 49 years.

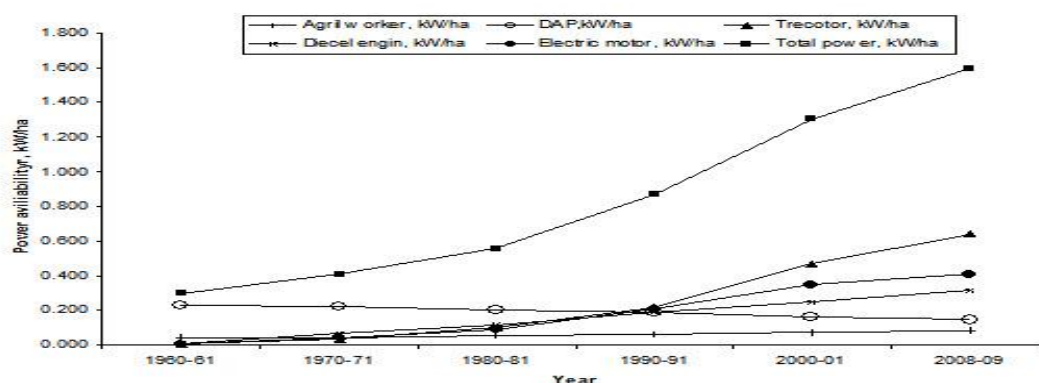


Fig. 1. Power availability scenario from different source in Indian agriculture.

Animate and Mechanical Power Scenario: For adoption of higher level of technology to perform complex operations within time constraints and with comfort and dignity to the operators, mechanical power becomes essential. Thus, the extent of use of mechanical power serves as an indicator of acceptance of higher level of technology on farms. Over the years the shift has been towards the use of mechanical and electrical sources of power, while in 1960-61 about 92.31% farm power was coming from animate sources. In 2008-09 the contribution of animate sources of power reduced to about 14.20% and that of mechanical and electrical sources of power increased from 7.70% in 1960-61 to about 85.30% (Fig. 2).

Farm Power Availability and Food Grains Productivity Relationship: Food grains productivity in India has increased from 0.710 t/ha in 1960-61 to 1.856 t/ha in 2008.09, while farm power availability has increased from 0.296 kW/ha to 1.600 kW/ha during the same period. Thus, food grains productivity is positively associated with unit power availability in Indian agriculture (Fig. 3). The relationship between food grains productivity and unit farm power availability for the period 1960-61 to 2008-09 were estimated by log linear function, with highly significant value of coefficient of determination (R^2) as following:

$$Y_{\text{fgs}} = 674.18 \ln(X_{\text{ps}}) + 1480.8$$

$$R^2 = 0.989$$

Where,

Y_{fgs} = food grains productivity of India, kg/ha, and

X_{ps} = power availability in India, kW/ha

This indicates that productivity and unit power availability is associated linearly. It is also evident that farm power input has to be increased further to achieve higher food grains production, the composition of farm power from different sources to be properly balanced to meet its timely requirement for various farm operations.

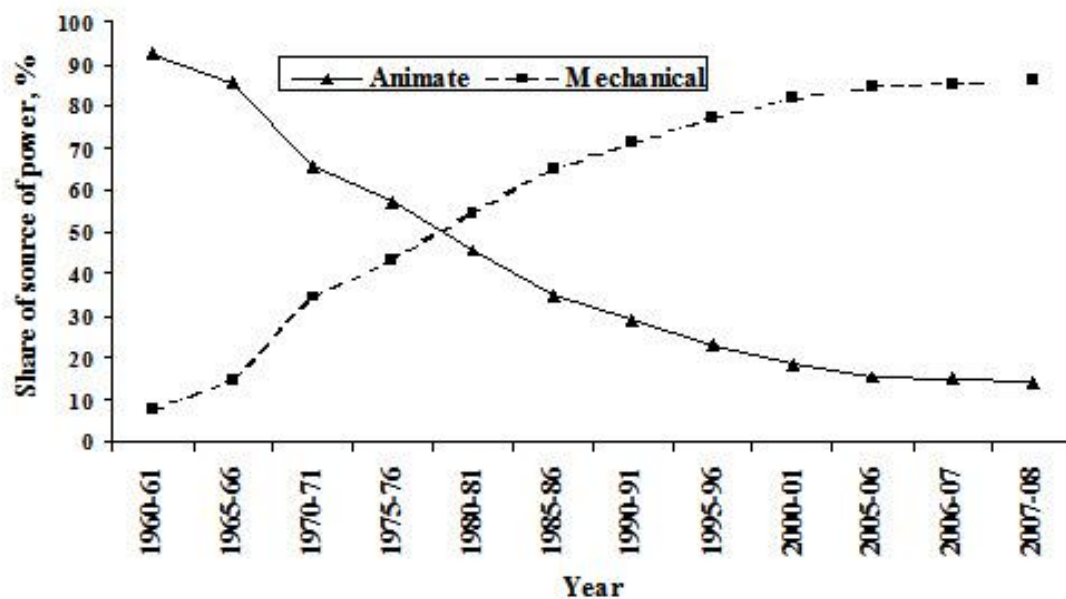


Fig. 2: Animate and mechanical power scenario in Indian agriculture.

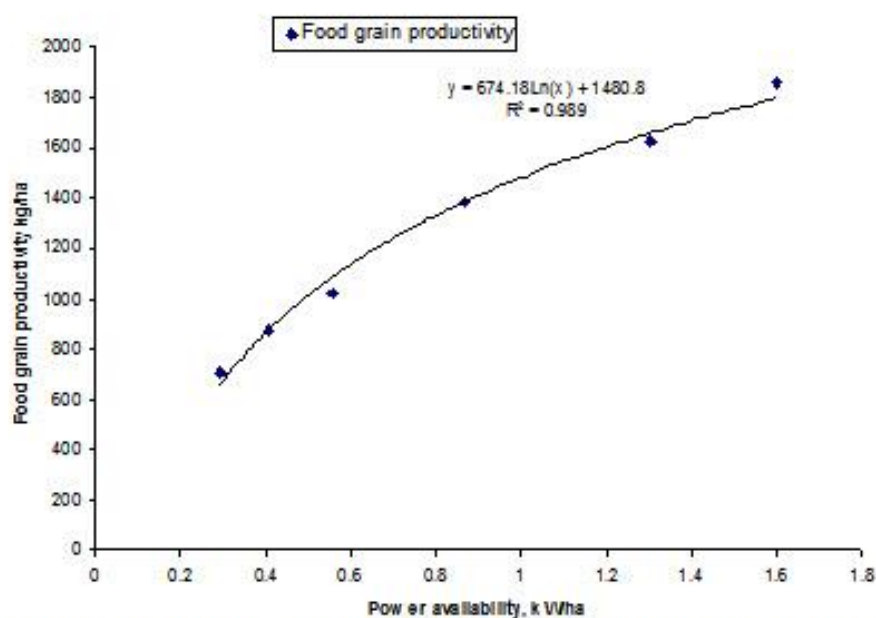


Fig. 3: Food grain productivity and power availability relationship in Indian Agriculture.

Lesson 3. Major Problems Facing Mechanization in Indian Agriculture

India faces major problems in mechanizing Indian Agriculture. i.e.

- (i) Plateau in agricultural productivity and production in main grain-bowl areas.
- (ii) Low annual growth rate of agricultural sector. It is less than 2%.
- (iii) Declining average farm size due to rising demographic pressure.
- (iv) Environmental degradation due to excessive use of agro-chemicals.
- (v) Damage to natural resources like soil, water & biodiversity.
- (vi) Declined total factor productivity.
- (vii) Higher cost of production, higher risk and low returns to farmers.
- (viii) Indebtedness of farmers due to higher cost of production and low profitability.
- (ix) Excessive post harvest losses and low value addition.
- (x) Poor quality of produces and processed products.
- (xi) Lack of modernization of agricultural markets for both, durables and perishables
- (xii) Lack of Minimum Support Price for different commodities.
- (xiii) Inadequate agricultural credit facilities at low interest rates.

The country should follow following strategies for sustainable agricultural production:

- (i) Scientific water resource management through in-situ and ex-situ harvesting and conservation of rainwater and its recycling, consumptive use of rain and groundwater, increasing ground water efficiency through efficient irrigation, ground water recharge as well as ensuring management of watersheds and command areas.
- (ii) Sustainable management of soil resources by devising efficient agricultural production strategies and developing crop models/farming system
- (iii) Integrated nutrient and pest management
- (iv) Adopting farmer-friendly Farming Systems approach instead of Cropping System approach. This approach would call for diversification of agriculture to include livestock, fisheries, horticulture, agro-forestry etc.

- (v) Partnership and participatory research by involving private sectors and NGO's.
- (vi) Promoting agri-business such as processing, marketing, infrastructures and environments.
- (vii) Promoting post-harvest technologies and value addition.
- (viii) Ensuring environmental sustainability.
- (ix) Reorienting agricultural research priorities. It should be program based, demand driven, problem solving and in participatory mode.

Efforts have been made in the past and are continuing to develop region and commodity specific technology packagers for greater efficiency and economic. On the basis of experiences gained and database generated so far, it is possible to claim that farm mechanization and appropriate post-harvest management lead to higher agricultural productivity and profitability (Tables 1 and 2). Engineering interventions/inputs augment overall food availability by 15-25% through production and processing routes.

Table 1: Possible augmentation of food production in India through engineering interventions.

Engineering intervention	Augmentation of total food production and value addition, %
Farm Mechanization	10-15
Post Harvest Management	5-10
Value Addition	25-400

Table 2: Possible contribution of post-harvest management and value addition in augmenting total food production and availability

Post production operation	Level of augmentation
Harvesting at physiological maturity	5-10% additional yield
Cleaning and grading	10-15% higher market price
Drying and storage	10-15% higher market price
Handling and transport	5-10% loss reduction
Milling (Rice)	3-7% higher yield of total rice
Milling Pulse	5-10% higher dal yield
Value addition	25-400% depending upon the commodity and products
PHT is commodity and location specific.	

Major Constraints of Farm Mechanization: India faces major constraints in mechanizing farm operations such as:

- (i) Power availability varies highly from one state to the other as well as according to the agro-climatic regions (Table 3).
- (ii) Annual investment on tractors, power tillers, engines as well as farm equipment for production agriculture & post-harvest handling & processing is more than Rs.50,000 crores per annum compared to as combined annual investment of Rs. 24,000 crores on fertilizer, certified seeds and plant protection chemicals. Due to non-availability of farm mechanization policy, inadequate guidance and poor information dissemination, the farmer often faces problems in proper selection, use and management of these costly resources.
- (iii) Average size of operational holdings is shrinking leading to higher percentage of marginal, small and semi-medium holdings. This is making individual ownership of agriculture machinery economically unviable. Following measures are suggested:
- (iv) Establishment of Farmer's Cooperatives and Farm Machinery Utilization Centers to extend the benefits of farm machinery utilization through custom hiring and multi-farm use.
- (v) Encourage training, financial incentives, subsidized loans and low interest credit to encourage procurement of high capacity equipment by custom operators to ensure sufficient turnover and income.
- (vi) Encourage farming for specific crops to produce raw material for processing industries/other organizations.

Table 3: Farm power availability and average productivity of food grains in India in 2001.

Name of the State	Farm Power Availability (kW/ha)	Foodgrain productivity (kg/ha)
Punjab	3.50	4,032
Haryana	2.25	3,088
Uttar Pradesh	1.75	2,105
Andhra Pradesh	1.60	1,995
Uttranchal	1.60	1,712
West Bengal	1.25	2,217
Tamil Nadu	0.900	2262
Karnataka	0.90	1,406
Kerala	0.80	2,162
Assam	0.80	1,443

Bihar	0.80	1,622
Gujarat	0.80	1,169
Madhya Pradesh	0.80	907
Himachal Pradesh	0.70	1,500
Maharashtra	0.70	757
Rajasthan	0.65	884
Jharkhand	0.60	1,095
Jammu & Kashmir	0.60	1,050
Orissa	0.60	799
Chhattisgarh	0.60	799
All India	1.35	1,723

Focal Areas of Agricultural Mechanization: The country needs to give more focus on followings to achieve satisfactory mechanization:

- (i) Mechanization of Rain-fed Farming
- (ii) Mechanization of Horticulture Crops
- (iii) Mechanization of Sugarcane Cultivation
- (iv) Mechanization of Cotton Cultivation
- (v) Mechanization of Pulses
- (vi) Mechanization of Oil Seeds
- (vii) Precision Machinery for Important Cropping Systems
- (viii) Mechanization of Seed Production & Processing
- (ix) Protected Cultivation Technology and Environmental Control
- (x) Resource Conservation Machinery
- (xi) Alternate Fuels for Diesel Engines and Tractors
- (xii) Post-harvest processing equipment for loss reduction and value addition

Lesson 4. Farm mechanization index

Many terms are in vogue to express the extent of farm mechanization in a farm, a region, state or a country. The terms include level of mechanization, degree of mechanization, mechanization indicator, etc. The level of mechanization is essentially the extent of use of mechanical power sources and equipment on a farm. One of the most widely used indices of the level of mechanization is the power availability per unit area i.e. kW/ha, provided matching equipment and gadgets were available and deployed to an optimum level. Thus, a farm with higher power availability, say, 2 kW/ha would have a higher level of mechanization than a farm with relatively less power availability per hectare, say 1.0 or 1.5 kW/ha. The degree of mechanization, on the other hand, implies the extent to which a given operation in the crop production system is mechanized. By computing the degree of mechanization, the cumulative degree of mechanization or mechanization indicator is computed.

Sidhu (2001) developed a system dynamics model of energy use in crop production in Punjab. He also developed relations for calculating the level of mechanization for the four major crops of Punjab, namely wheat, paddy, maize and cotton, on yearly basis. The degree of mechanization of a single operation in a crop for a particular year was calculated on the basis of the number of machines available per year to perform the various operations within the recommended time period. This value for a single operation was then multiplied by its energy consumption ratio for each operation and its weighted mean was computed to obtain the degree of mechanization for the crop for that year. The relation developed was as under:

$$DOM_i = \frac{\sum_{j=1}^n \{DOM_{ij}\} \times EC_{ij}}{\sum_{j=1}^n \{EC_{ij}\}} \quad (i = 1, 4) \quad - (1)$$

where

i represent the crop (i=1 implies wheat, i=2 implies paddy, i=3 implies maize, i=4 implies cotton)

DOM_i = Degree of mechanization of i^{th} crop for a particular year.

n = number of major operations (=6).

DOM_{ij} = Degree of mechanization of j^{th} operation for the i^{th} crop.

EC_{ij} = Energy consumption weight of j^{th} operation for the i^{th} crop.

There were some limitations in the farm mechanization indices developed by the various researchers. The model developed by Sidhu (2001) also did not give the correct picture as the level of mechanization of paddy was calculated to be greater than that of wheat even though

the nursery sowing and transplanting operations for the paddy crop were still carried out manually.

An attempt was made to develop a farm mechanization indicator by Khurana Rohinish based on parameters that influence the level of mechanization of various farm operations necessary for raising a crop, viz., number of machines and equipment available for a given area, extent of use of these equipment, time saving as well as economic benefits accruing from the use of these machines. For proceeding with the development of the farm mechanization indicator, the agricultural operations for most of the crops were divided into four categories viz seed-bed preparation and sowing/planting, irrigation, weeding and spraying and harvesting and threshing. These classes were defined keeping in view the fact that as the composite machines was available and these were being used for two or more number of operations simultaneously. For example, strip-till drill and no-till drill combine the tillage and sowing operations, and similarly a harvester combine combines the harvesting and threshing operations. Application of weedicide, pesticide or insecticide in many crops is done by spraying by the use of same equipment.

Computation of mechanization index: The assumptions made for determining the degree of farm mechanization are:

- (i) There are sufficient numbers of tractors available with the farmers to which various agricultural machinery can be attached for completing the different farming operations in time.
- (ii) Standard correlation equations such as quadratic, Wood's curve, Robb's parabolic, Nadler's curve etc. have been used to predict the numbers of agricultural machinery.
- (iii) The farm machines to be introduced later in the study period are assumed to take a straight line growth.
- (iv) The operations performed and their replication frequencies have been generalized on the basis of information collected from farmers, researchers, and extension specialists.
- (v) One working day was taken equal to 8 hours.
- (vi) The hand tools being the basic implements using manual labour have not been considered while estimating the degree of mechanization.
- (vii) The farm machinery for different crops occurring during the same period is assumed to be distributed proportionately over the cropped area in the state.

With these assumptions the degree of mechanization was calculated as mentioned in the following steps:

1. Calculation of cost of operation for an agricultural machine

$$\frac{C_{om/c}}{F} = \frac{R_i}{C_{h_i}} \quad - (2)$$

where:

$C_{om/c}$ – the cost of operating i^{th} machine, Rs/ha

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Fr – fraction of total crop area operated upon by the machine

R – replications of the machine required to complete the particular farm operation

$Ch_{m/c}$ – hiring cost of the machine, Rs/ha

i – the number of different machines available for the operation

2. Calculation of cost of operation with the complete set of machines available for that operation

$$[C_{o_{op}}] = \sum_{i=1}^n \{C_{o_{m/c}}\}_i \quad - (3)$$

where:

C_{op} – Total cost for one complete operation, Rs/ha

i – number of different machines available for the operation

3. Calculation of mechanization level for a single machine.

$$[O_{M_{m/c}}] = \frac{CAF \times N \times Cap \times H \times D}{A \times R} \quad - (4)$$

where:

$OM_{m/c}$ – the mechanization level for one machine

CAF – crop area factor defined as the ratio of crop area to the total area

N – number of machines in the state

Cap – effective field capacity of the machine, ha/h

H – hours of daily work

D – number of days available for performing the operation

R – replications of the machine required

A – crop area, ha

4. Calculating the mechanization level for a given operation:

A number of machines are used to perform the operation, the mechanization level for one operation was calculated as:

$$[L_{M_{op}}] = \frac{\sum_{i=1}^n \{[O_{M_{m/c}}]_i \times [C_{o_{m/c}}]_i\}}{[C_{o_{op}}]} \quad - (5)$$

where:

LM_{op} – the mechanization level for a operation

n – the number of different machines used to complete the operation

$OM_{m/c}$ – the mechanization level for each of the n machines calculated separately

i – the number of different machines available for the operation

5. Calculating the total cost of operation of all the machines

$$[C_{o_T} = \sum_{k=1}^4 \{C_{o_op}\}_k] \quad - (6)$$

where:

C_{op} – total cost of one complete operation by n different machines, Rs/ha

k – number of operations (= 4)

C_{o_T} – Total cost of all the operation for a crop, Rs/ha

6. Calculating the weighted level of mechanization of each operation:

$$[W_{L_k} = \frac{L_{M_k} \times C_{o_op}}{C_{o_T}}] \quad - (7)$$

where:

W_{L_k} – weighted degree of mechanization for k^{th} operation

LM_k – mechanization level of the operation calculated earlier for k^{th} operation

C_{op} – cost of the k^{th} operation, Rs/ha

C_{o_T} – Total cost of operation of a crop, Rs/ha

k – number of the operation, ($k=1,4$)

7. Calculation of the degree of mechanization for the crop for a given year:

$$[D_{M_crop} = \sum_{k=1}^4 W_{L_k}] \quad - (8)$$

where:

W_{L_k} – weighted degree of mechanization for k^{th} operation calculated separately

DM_{crop} – Degree of Mechanization for the given crop in a particular year

The methodology developed for calculation of the degree of mechanization was used to evaluate the mechanization index for different farm operations for the two main crops, viz., wheat and paddy for the state of Punjab. The data for the calculations pertained to the period 1985-2003. The farm operations with mechanization index below 0.50 were taken to be less mechanized i.e. low level of mechanization and those with mechanization index above 0.75 were considered highly mechanized i.e. higher level of mechanization. Since there is nexus

between farm productivity and degree of mechanization, the operations with low level of mechanization (<0.50) would require greater attention from researchers.

In the state of Punjab, almost all the operations for cultivation of wheat crop have been mechanized to an extent that there are two or more alternate technologies available for each of the selected operations. Tillage and sowing is the most mechanized operation for wheat (Fig. 1). The level of mechanization of tillage and sowing operation of wheat increased from 0.66 in 1985 to reach high level of mechanization at 1.16 in the year 2003. This has mainly been because of the rapid increase in the number of tillage machinery such as disc harrow, cultivator and rotavator, and large scale use of seed-cum fertilizer drills for sowing of wheat. Further there has been introduction of new machines such as strip-till drill and zero-till drill for the tillage and sowing of wheat resulting in a further increase in the mechanization index. This is expected to increase to 1.19 by the year 2010.

The next most mechanized operation for wheat is the harvesting and threshing operation. The level of mechanization of harvesting and threshing operation for wheat was high at the start of the study period i.e. 1985 at 1.02 because of use of threshers at a large scale and combines to a limited scale (Fig. 1). This further increased to 1.10 by the year 2003 mainly due to the large scale use of combines in Punjab fields on custom hiring reaching a figure of 1.11 by 2010.

The weeding and spraying operation is the least mechanized operation for wheat. The level of mechanization in 1985 was low at 0.38 (Fig. 1). This increased to a high level of mechanization at 0.81 in the year 2003 because of large scale use of knap sack sprayers only for spraying which are available in very large numbers in Punjab. Although, tractor sprayers are available, but these are used only in the cotton crop.

There are sufficient number of both diesel engine and electric motor driven tubewells, due to which the level of mechanization for the irrigation operation in wheat remains between medium and high levels of mechanization, increasing from 0.66 in the year 1985 to 0.94 in the year 2003 (Fig. 1).

The composite affect of the level of mechanization of the various operations led to the overall level of mechanization of the wheat crop. The mechanization index for wheat for the year 1985 was medium at 0.69, when the mechanization level of tillage and sowing operation was also at medium level (Fig. 1). The mechanization index became high in the year 1987 and increased beyond unity in the year 1996, reaching 1.05 by the year 2003. The overall mechanization index is expected to reach 1.13 by the year 2010.

Paddy is the major crop of kharif season, occupying nearly 60-65 percent of the cropped area. The tillage operation for paddy is done using the abundantly available machines like the cultivators and plankers. Some newly developed machines like the rotavators and the pulverizing rollers are also being used after being introduced lately. However, the nursery sowing and transplanting operations are still done manually even though paddy transplanters have been introduced. Due to this the level of mechanization for tillage and sowing was 0.56 in 1985, which increases to unity in 1994 and still rises to 0.96 by the year 2003, mainly because of the increasing numbers of tillage machinery available for the seed-bed preparation (Fig. 2). This would further increase to nearly 0.97 by 2010. The high number

of machines available for tillage and puddling keeps the level of mechanization of tillage comparable to that of wheat. The level of mechanization for irrigation operation was at 0.66 in 1985 rising up to a medium level of mechanization at 0.78 in 2003, which is less than that of wheat. This is because of the number of irrigations required for paddy is very high (up to 27 irrigations), even though there are a large number of tubewells available.

Similar to wheat, weeding and spraying in paddy is the least mechanized operation with the level of mechanization which was 0.38 in 1985, which may increase to 0.64 by the year 2003, that too with only the knap-sack sprayers being used in the operation (Fig. 2). Harvesting and threshing operation, similar to wheat crop, is a highly mechanized operation, with its level of mechanization 0.80 in 1985, and reaching 0.98 in the year 2003 and it was predicted to increase to 1.02 by the year 2010. Combines, now, are quite extensively being used for harvesting of paddy.

The mechanization index for paddy was medium at 0.64 in 1985 due to the manual transplanting operation and low level of mechanization of weeding and spraying operation (Fig. 2). This increased to high level of mechanization in the year 1990 due to the increasing number of tillage machinery available in the state of Punjab. The mechanization index for paddy presently is 0.87 and is expected to rise to 0.90 by the year 2010.

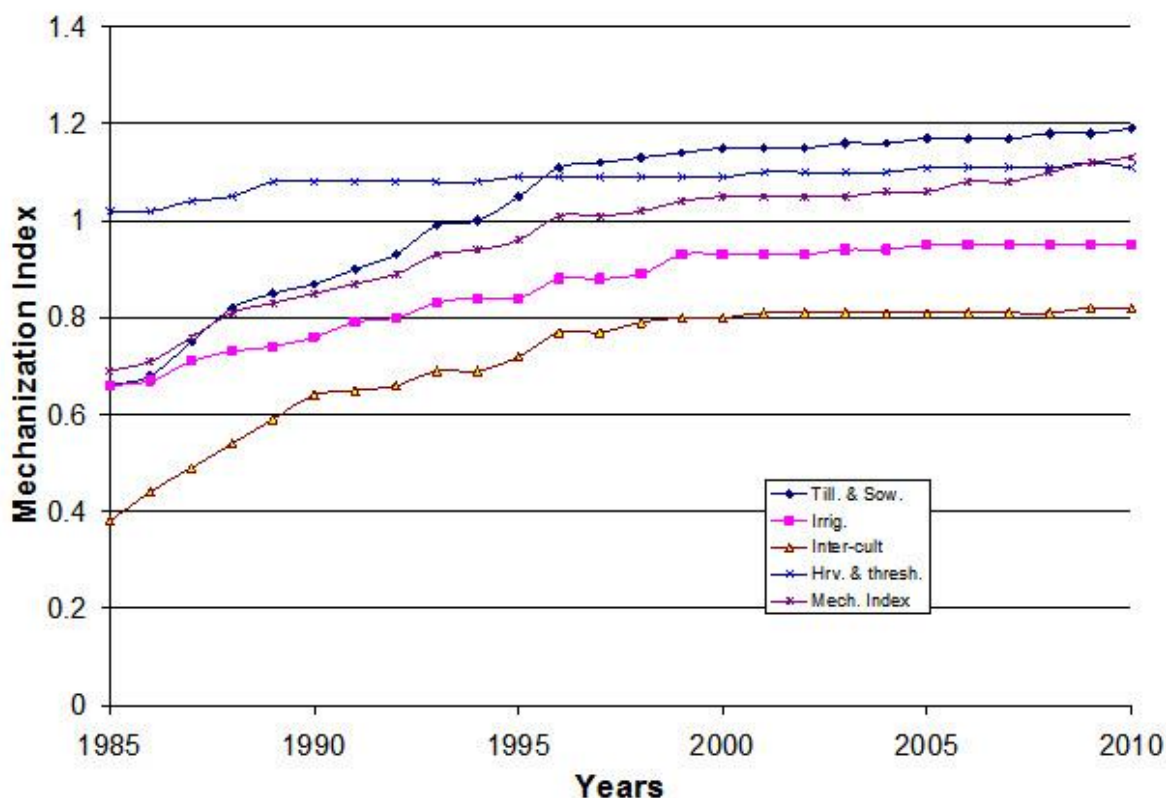


Fig. 1: Mechanization Indicator for the various operations in Wheat Crop

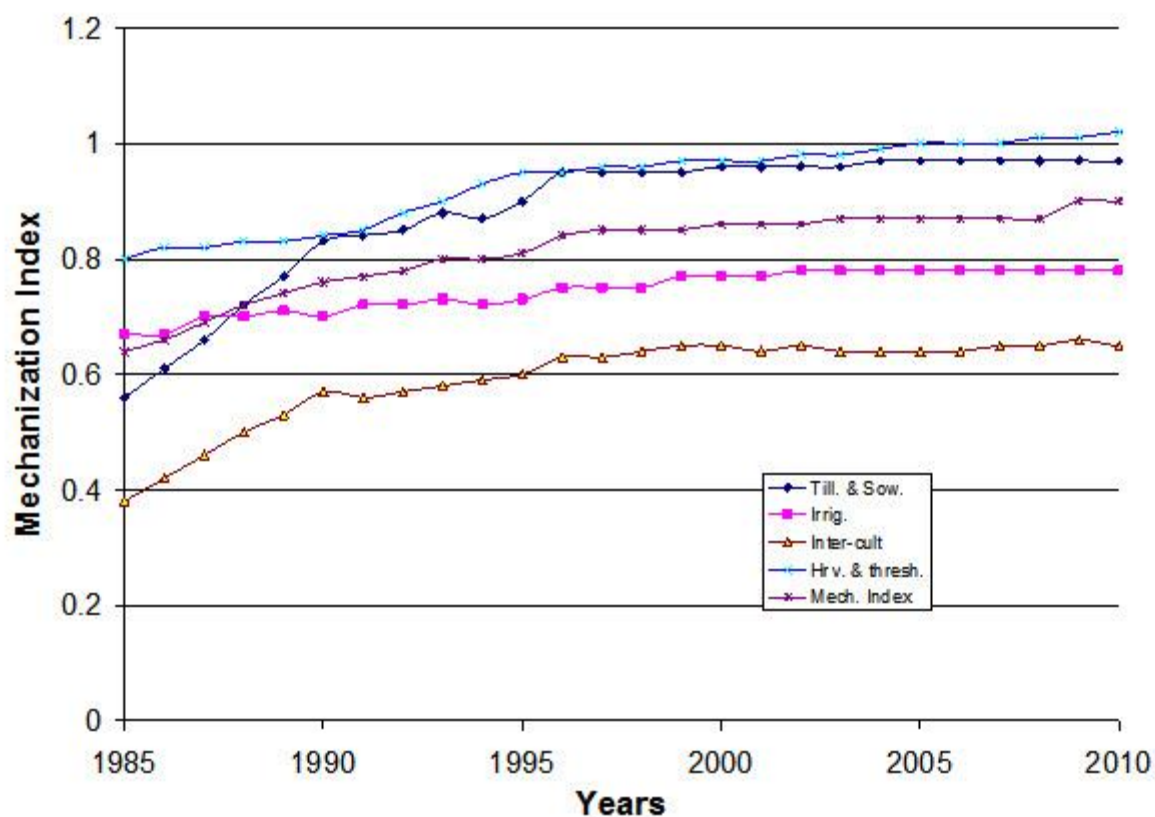


Fig. 2: Mechanization Indicator for the various operations in Paddy Crop

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Lesson 5. Farm mechanization and farm employment in India

The availability of human workforce on the farms has significantly contributed in increasing the worker power availability per hectare on the farms. Human power availability for agriculture had been 0.045 kW/ha in 1970-71 and reached 0.051 kW/ha in 1980-81, reached to 0.079 kW/ha in 2000-01 and 0.086 kW/ha in 2009-10 (Fig. 1). Despite the increase in the total power availability from 0.295-1.73 kW/ha and in tractor power availability from 0.02 to 0.72 kW/ha during 1971-72 to 2009-10, the total agricultural power as well as the total number of agricultural workers has also increased. The man power has steadily increased from 0.045-0.086 kW/ha and the number has increased from 126-243 million during same period.

Even with not much increase in cropping intensity and area under irrigation, the land productivity (for food grains only) has gone up by 117% since 1965-66. Land productivity was 0.636 t/ha in 1965-66 and increased to 1.798 t/ha in 2009-10. This could become possible due to introduction of high yielding varieties in mid sixties and subsequent need based farm mechanization. The cultivable area per tractor was 2162 ha in 1965-66 and has come down to 36 ha per tractor in 2009-10. This is a significant reduction. However, India needs on an average 20 ha cultivable area per tractor of about 30-35 hp. The cumulative effect of this was clearly visible in the employment opportunities been generated in numerous off-farm and on-farm activities.

Mechanization Enhances Cropping Intensity: The agricultural mechanization has made significant contribution in enhancing cropping intensity. The growth in irrigated area and tractor density seem to have direct bearing on the cropping intensity. The cropping intensity in Punjab and Haryana with higher level of mechanization has been estimated as 196 and 170% at present. In other states, the cropping intensity is comparatively low on account of lower level of mechanization. In one of the study a comparison of tractor-owning farms was made in terms of the situation before and after the introduction of tractors. The cropping intensity was reported to be higher after the introduction of tractors. The study revealed that tractor-owning farms had a higher cropping intensity of 137.5 as compared to 131.8 in the case of those without a tractor. Cropping intensity was found to be generally higher on small farms.

A comprehensive study was carried out to ascertain as to what motivates a farmer to own or use a tractor and also the impact of tractorization on rural income and agricultural employment. A sample of 815 farming households from 85 villages of 7 States belonging to three major agro- climatic zones were selected. To study the impact of tractor use on cropping intensity, the land use of tractorised farms was compared with that of bullock farms. The cropping intensity of tractor-owning and tractor-using households in all States was higher than that of bullock farms. An average tractor owner had a cropping intensity of 12 per cent higher than that of bullock farm. Similarly, the cropping intensity of a tractor using household exceeded that of bullock farm by 8 percent.

Mechanization Enhances Overall Employment of Human Labour: The effect of mechanization on labour employment particularly in a labour surplus country like India has been a matter of debate. The available evidences suggest that mechanization has helped in overall employment of human labour. A study concluded that mechanization generated more demand for labour by facilitating more intensive cultivation. Thus, there was hardly any net displacement of human labour after mechanization. It was also concluded that mechanization of agricultural operations, by and large, displaced bullock labour and not human labour. In another study, increased use of tractors was associated with a marked rise in employment due to their effect on cropping intensity. Large scale adoption of high yielding varieties accompanied by higher use level of chemical fertilizers and enhanced cropping intensity raised the demand for farm labour. The permanent labour on tractor holdings showed a decline of 2.2 percent compared to the conventional level. The employment of casual male labour showed an increase of 38.5 per cent. In respect of female labour employment, the increase was even higher at 80 per cent. A tractor on an average displaced four bullocks.

In an another study it was concluded that the labour input per hectare increased as one moved from non-mechanized farms to farms using tubewells in both small and medium size farms. In small tubewell farms the increase was much larger over non-mechanized farm in medium sizes. On a tubewell and tractor farm, the level of labour input for crop cultivation on small farms was higher than on small non-mechanized farms. When a thresher in addition to a tractor and tubewell was acquired, there was additional labour input per hectare for crop cultivation in both small and medium size farms as compared to tractor plus tubewell farms. The mechanized small farms used 5.1 per cent more labour. Labour displacement was observed on medium farms during initial stages of mechanization. As the level of mechanization increased, there was a subsequent gain in labour employment. It was not possible to assess the labour input in several non-farm activities directly related to the use of tractors and farm.

A study concluded that tractorization did not seem to have decreased employment. On the contrary, it helped in relaxing the constraints of the operational area which increased employment on farms significantly. In fact, tractor farms employed more casual and permanent labour. The study revealed that the displacement of labour due to mechanization was more than offset by the employment created through increased production, additional area brought under cultivation and higher intensity of cropping.

It has also been observed that employment was generated in various off-farm components of farm machinery. This employment was highest in the repair workshops of farm machinery followed by manufacturing & assembling units of farm machinery, filling station and sales agencies of Farm machinery, which has generated employment to the extent of 10.44, 3.102 and 0.506 million-man-days per year respectively. It was also observed that manufacturing and assembling of agricultural implements, complete assembling of agricultural machinery and manufacturing of diesel engine parts were the establishments which had a great impact on employment generation. These establishments have spread all around the country side to meet the daily needs of the farmers. It was also observed that combine harvesters, tractors and tractor-drawn reapers needed more labour for major and minor repair. Also chaff-cutters, tractors and diesel engines been used in large numbers in the state, so provided large labour employment for their repair and maintenance. In this way the total employment

generation in the off-farm components worked out to be more than 50 million-man-days per year. The employment of agricultural workers in other sectors of agriculture such as agro-processing, animal husbandry, fisheries, dairy, bee keeping and agro-forestry had also increased due to farm mechanization especially in marketing, storage and transportation. The work force in the entire country has increased from 131 million to 243 million during the same period. Even in the most mechanized states like Punjab the population of agricultural worker in the state grew slowly from 2.5 million in 1971-72 to almost 4 million in 2000-01 showing an increase of 60 percent. In the state of Uttar Pradesh the population of agricultural workers increased from 21.2 million to 36.2 million showing an impressive increase of 70 percent during the same period. The maximum percent increase in the agricultural population was in the state of Maharashtra in which the increase is nearly two folds from 11.9 million to 22.3 million.

Man-power in agriculture in different states also grew from 0.045 to 0.079 kW/ha from 1971-72 to 2000-01 (Table 1). The most impressive increase in the man-power was in the states of Andhra Pradesh and Tamil Ned where man-power increased by more than 92 percent. This was followed by the Madhya Pradesh, Maharashtra and Uttar Pradesh where the increase in the man-power utilization increased by more than 72 percent. Even in the state of Punjab, where the mechanization had taken place at a very fast pace, the man-power utilization increased by 57 percent. The maximum increase i.e. 100 percent is in the state of West Bengal.

With the shift in agriculture towards diversification and agri-business, substantial areas will go under fruits, vegetable, plantation, floriculture etc. Mechanization of these crops in future will need to be taken up. For increasing productivity of these high value crops, green house cultivation is likely to be adopted on large scale. Design of green houses and their mechanized cultivation, handling of products and environmental control in the green house will need further mechanization.

Table 1: Power availability from agricultural workers (kW/ha)

State	Year						
	1971-72	1975-76	1981-82	1985-86	1991-92	1995-96	2000-01
Andhra Pradesh	0.056	0.062	0.069	0.082	0.088	0.097	0.108
Kerala	0.069	0.069	0.064	0.067	0.069	0.072	0.076
Madhya Pradesh	0.033	0.036	0.041	0.043	0.049	0.053	0.058
Maharashtra	0.036	0.036	0.041	0.045	0.052	0.056	0.062
Orissa	0.043	0.047	0.052	0.054	0.059	0.064	0.069
Punjab	0.030	0.031	0.034	0.037	0.040	0.043	0.047
Tamil Nadu	0.072	0.083	0.100	0.108	0.119	0.127	0.138

Uttar Pradesh	0.061	0.065	0.069	0.076	0.087	0.094	0.105
West Bengal	0.063	0.063	0.078	0.088	0.102	0.112	0.126
India	0.045	0.048	0.051	0.057	0.065	0.071	0.079

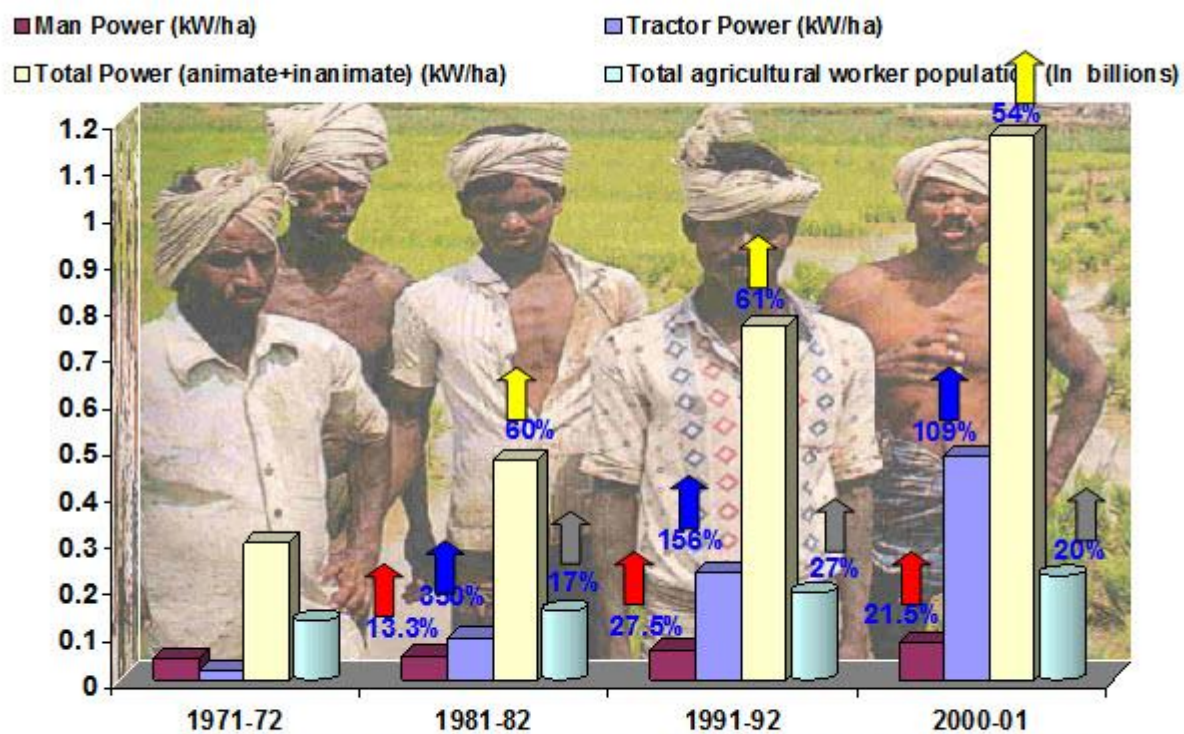


Fig 1: Status of man-power, tractor power, total power and total agricultural worker population in India

Lesson 6. Agricultural Mechanization Policy Objectives and Recommendations

The agricultural mechanization should lead to the followings:

- (i) Agricultural mechanization should contribute to sustainable increase in yields and cropping intensity so that the planned growth rates in agricultural production are achieved.
- (ii) The income of agricultural workers (cultivators and labourers) should increase at a satisfactory rate so that the disparity between urban and rural incomes is eliminated, and the agricultural worker given his rightful opportunity to lead a dignified life.
- (iii) The benefits of agricultural mechanization should be extended to all categories of farmers with due consideration to small and marginal farmers and to all regions of the country especially the rainfed areas.
- (iv) Agricultural mechanization should make the environment worker friendly especially for the women workers by reducing drudgery and health hazards and by improving safety in production operations.
- (v) Agricultural mechanization should contribute to conservation of land and water resources and to more efficient use of inputs such as seeds, chemicals, fertilizers and energy.
- (vi) Loss of agricultural production, both in quality and quantity, should be reduced through timely operations and improvement in equipment and techniques.
- (vii) Agricultural mechanization should lead to a reduction in costs of production of different commodities, increase in income of farmers and an increase in the competitiveness of Indian agricultural produce and products in the world market.

Major recommendations while formulating agricultural mechanization policy of the country:

- (i) To sustain growing population of the country by 2025, the agricultural production will have to be increased by 85% and the productivity by 100% from the present level. This will require intensification of agriculture. With weather conditions becoming more erratic, to perform the farm operations timely, the energy input to agriculture will increase from present level of 1.3 kW/ha to 3.9 kW/ha by 2025 to achieve the desired level of food grain and horticultural production. About 65% of this power will have to come through tractors and self-propelled machines.
- (ii) More than 60% of cultivated land is under rain-fed and dry-land areas. Development and popularization of agricultural machinery under varied conditions are required.
- (iii) Farm operations for horticultural crops and hill agriculture are highly labour intensive. These will need to be appropriately mechanized for drudgery reduction, productivity enhancement.

(iv) Development and adoption of precision farming techniques on large scale for higher input use efficiency. This will require regular training of scientists and farmers on modern technologies.

(v) Conservation agriculture technologies such as zero-till drill, till plant machine. Roto-till drill, strip till drill, raised bed and furrow planting systems with straw management will have to be adopted on large area.

(vi) The male to female ratio among the agricultural workers is expected to change from present 60:40 to 45:55 by 2025. This will necessitate development of gender-specific tools and equipment and imparting training to female farm workers on operation and maintenance of farm tools and equipment.

(vii) Farm mechanization data will have to be collected on regular basis and periodically updated to formulate viable Farm Mechanization Policy.

(viii) With power operated farm equipment becoming more popular, the accident rates are also on increase. Collection of data on agricultural accidents, analysis of their causes and development and implementation of appropriate remedial measures would be required.

(ix) With fossil fuel becoming scarce, alternate renewable fuels like bio-diesel for tractors, IC engines and automobiles will have to be developed and used on mass scale. Many oil bearing non-edible and edible seeds besides jatropha can be used to prepare bio- diesel of good quality to meet the liquid fuel requirements.

(x) Regular & adequate power supply to rural areas through State Electricity Boards (SEB) is likely to remain uncertain in most states in near future. Keeping this in view, decentralized power supply system based on locally available biomass and renewable sources of energy may be set-up to meet the requirements.

(xi) Over 600 million tonnes of available biomass can be converted to briquettes or other forms for minimizing the dependence on conventional energy sources.

(xii) For optimum utilization of scarce natural resources, efficient irrigation systems such as drip and sprinklers with high precision and on farm water management practices will have to be developed/adopted. Improving efficiency of irrigation systems and pumping systems is essential to save energy and water.

(xiii) Equipment, technologies and approaches need to be developed for loss reduction and value addition of agriculture produce in production catchments

(xiv) Development of appropriate technologies for value addition, handling, packaging, storage, transportation and marketing of agricultural products for safe and quality food.

(xv) Establishment of agro-processing units in production catchments for creation of employment and income generation activities to check migration to urban areas, to minimize post-harvest losses and increase returns to the farmers.

(xvi) Despite the fact that good design of equipment are available at R & D level, non-availability of quality machines through manufacturers is one of the bottlenecks in

mechanization. Manufacturers of agricultural machinery will need training & orientation on quality product manufacturing through modern manufacturing technology.

(xvii) Involvements of State Departments of Agriculture and Agricultural Engineering in transfer of technology activities would need to be formalized and strengthened.

(xviii) The holding size is decreasing progressively. With very low availability of agricultural land, particularly in Northern states, sustenance of farmers through agriculture is becoming difficult. Contact farming with consolidation of lands for borderless and cooperative farming for high value crops would be required.

(xix) Creation of farm implement bank owned by entrepreneurs, Farmers' Cooperatives/Agri-business centres to supply machines on custom hire basis to small & marginal farmers.

Crop and site specific agricultural mechanization and agro-based small and medium enterprises in rural sector using a proper blend of conventional and renewable energy sources will facilitate in enhancing of agricultural productivity and profitability resulting into higher income to farmers and better quality of life. It would also helps in mitigating the effect of continuous population growth combined with dwindling and shrinking natural resources and an increasing demand for higher standard of living and thereby increasing enormous pressure on world's natural environment and its food supply.

There is direct nexus in energy and agricultural production and productivity (Fig. 1). In India where 70% of the petroleum products used is imported and electrical power is costly and in short supply. Excessive use of commercial energies increases unit cost of production and products reduces profitability and global competitiveness eroded. In a village eco-system, about 80% of the total energy goes to domestic sector of which about 80% is used for cooking mostly derived from crop and animal residues and fuel wood. Animal solid and liquid wastes which are rich source of energy and plant nutrients is converted in to sundried dung cakes used as fuel wood substitute. Liquid wastes are often lost. It is under utilization of this valuable natural resource. Farmers have to wait for energization of their irrigation pumps. Grid power, usually in short supply, is 2-3 times cheaper than diesel generator power or engine operated option. As a result there is emphasis on harnessing new and renewable sources of energy like biogas, producers gas, biodiesel, wind mills, improved chulhas, briquetted fuels, solar cookers and solar water heaters, solar dryers, photovoltaic irrigation pumps and illumination systems, mini and micro hydro power units wherever feasible. There are about 4 million family and community biogas plants installed in the country used largely for cooking. Wind farms are generating substantial quantities of electricity for power grid and off-grid applications. Blending of petrol with ethanol has already started. Efforts are on for biodiesel production and biodiesel systems. Energy needs to be conserved and commercial energies supplemented and substituted with new and renewable sources of energy. New options are being tapped like geo-thermal, tidal power, solar and biomass, thermal power units etc.

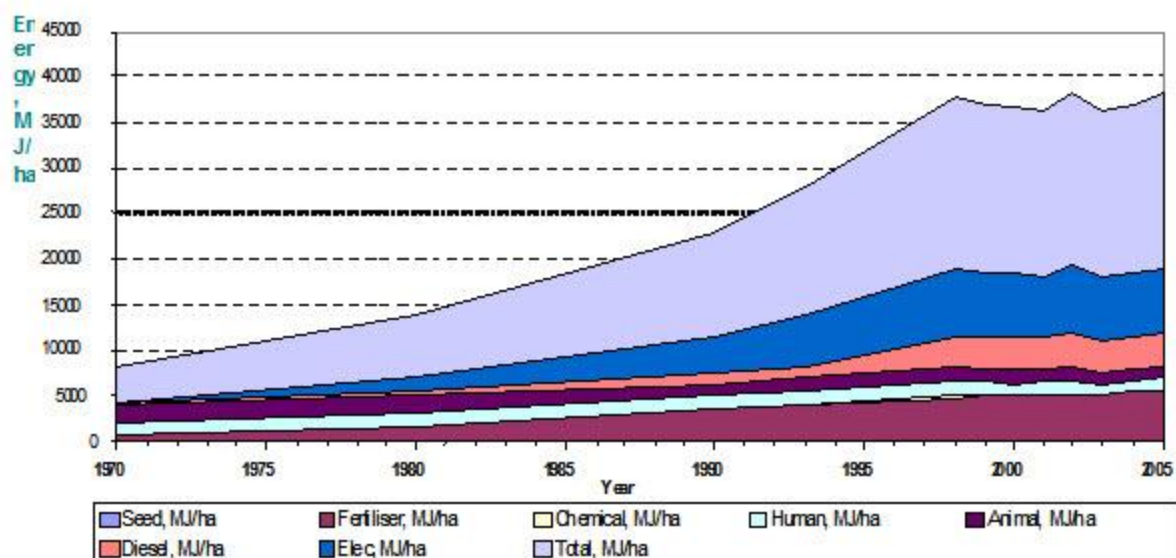


Fig. 1: Source-wise energy consumption in India agriculture



Module 2. Performance and power analysis

Lesson 7. Importance of farm machinery management

The importance of farm machinery management has increased in modern farming operations because of its direct relation to the success of management in combining land, labour and capital for a satisfactory profit. Many problems of machinery management are encountered such as:

- a) How many equipment should be owned?
- b) What size of equipment is required?
- c) How often should the machinery be traded?
- d) Should a custom operator be hired or a machine be leased?
- e) How can the rapidly increasing fuel costs be kept to the minimum?

Following are some of the suggestions to help a farmer to prepare himself to satisfy the increasing needs for machinery management:

- (i) Learn how to use the machinery principles.
- (ii) Keep complete records of fieldwork done by various machines and the number of working days available for critical field operations. By knowing average capacity of machines and number of workdays available, a more effective job of selecting machinery is possible.
- (iii) Know how to accurately estimate costs for any machine and how to combine costs of machines to estimate total cost for an entire systems. Many important decisions are based on costs.
- (iv) Know how to improve equipment reliability. Always work towards the elimination of unnecessary down time.
- (v) Improve field efficiencies with machines to cut costs and complete more work in the available time.
- (vi) Develop a long-range plan for your farming operations.
- (vii) Keep thinking of ways to improve the efficient ownership and management of agricultural machinery.
- (viii) Review the problems encountered.

Farm Power and Machinery Management

Measures of performance of farm equipment are the rate and quality with which the operations are accomplished. This is generally expressed in terms of capacity as well as efficiency.

Capacity: Calculations of machine capacity involve measuring of area covered, weight of material and time. The machine capacity is normally expressed in three ways:

- a) Field capacity
- b) Material capacity
- c) Throughput capacity

Field capacity: It is the rate of field coverage. It is also expressed in two ways:

- a) Theoretical field capacity
- b) Effective field capacity

Theoretical field capacity: It is the rate of field coverage if the machine is performing its functions 100% of the time at its rated speed while covering 100% of its rated width.

Theoretical field capacity (C_t) is expressed as

$$C_t = \frac{S w}{8.25}, \text{ acre/h}$$

Where,

S = average speed of machine, mph

w = rated width of machine, ft

Or,

$$C_t = \frac{S w}{10}, \text{ ha/h}$$

Where,

S = average speed of machine, km/h

w = rated width of machine, m

Thus, these values represent the best that a machine can do if there were no stoppages and the machine was taking its full width all the time.

Effective field capacity: The farm equipment seldom covers its rated width and performs its function 100% of the time. Therefore, it never meets the theoretical field capacity. Effective field capacity is the actual rate of field coverage. It is expressed as

$$C_e = \frac{S \cdot w \cdot E_f}{10}, \text{ ha/h} \quad \text{or} \quad = \frac{S \cdot w \cdot E_f}{8.25}, \text{ acre/h}$$

Where,

C_e = effective field capacity, ha/h

E_f = field efficiency, fraction



Lesson 8. Field Performance and power requirements

Improving field efficiency: The ability to improve field efficiency is the next important step in developing machinery management skills. There are several important reasons why a machine may have certain field efficiency. Some lost-time factors are built into operation. Good planning and management can eliminate other lost-time factors. For example: Turning time and field operations: Turning time is one loss factor built into every field operations but can be kept to minimum by planning fields with longer rows. A normal turn at the end of a field is one that can be made with one continuous motion.

Unclogging machine: One time factor that can be nearly eliminated by good management is unclogging machines. It is also a main reason for an unusually high percentage of lost field time. There are three main reasons for clogging a machine.

- 1) Overloading the machine
- 2) Faulty working of the machine
- 3) Operating the machine when conditions are not right

By checking out machines ahead of the season there will be less clogging and field efficiency will improve substantially.

Making adjustments: With most machines, it is necessary to make adjustments before going to the field. Some machines, like combines or balers, have to be adjusted occasionally in the field as crop conditions vary throughout the day.

Reducing breakdowns: It is impossible to predict when some parts of a machine will fail, but many machine breakdowns in the field can be avoided by making thorough inspections before and during operation. To help eliminate or reduce breakdowns the following points need to be considered:

- 1) Inspect and repair the machines well ahead of the use season.
- 2) Carry out preventive maintenance.
- 3) Avoid rocks, holes and obstructions.
- 4) Drive cautiously in rough fields.
- 5) Avoid overloading the equipment.
- 6) Check out strange sounds, vibrations or smells.

- 7) Make small repairs when needed.
- 8) Use periodic checking to locate potential trouble.
- 9) Keep all power transmitting members adjusted, aligned and lubricated.

Rest stops: Short but frequent breaks or rest stops are desirable and necessary from both the standpoint of safety and improved performance. When the operator has to continually concentrate on a job, a short break every hour or so will increase alertness, reduce accidents and improve the quality of work.

Unmatched machine capacity: One major cause of an inefficient operation is a system of unmatched machines. It is always important to use the matching equipment with the power source.



Lesson 9. Power Requirements

The power is the rate of doing work. It can be written as

$$\text{Power (P)} = \frac{\text{Work done (W)}}{\text{Time (T)}}$$

$$= \frac{\text{Force (F) x Distance (D)}}{\text{Time (T)}}$$

$$\begin{aligned} 1 \text{ hp} &= 33000 \text{ ft-lb/min} \\ &= 550 \text{ ft-lb/s} \\ &= 75 \text{ m-kgf/s} \\ &= 4500 \text{ m-kgf/min} \end{aligned}$$

i.e.

$$\text{hp} = \frac{D F}{T \times 33000}$$

Where,

hp = horse power

D = distance travelled in ft

F = force exerted in lb

T = time taken in min

It can also be written as

$$\text{hp} = \frac{D F}{T \times 4500}$$

Where,

hp = horse power

Farm Power and Machinery Management

D = distance travelled in m

F = force exerted in kg_f

T = time taken in min

It can be further written as

$$\text{hp} = \frac{F S}{4500}; \text{ S is speed in m/min}$$

Or

$$\text{hp} = \frac{F S}{33000}; \text{ S is speed in ft/min}$$

Lesson 9 : Solved examples

Example 1 : An implement requires 300 kg force to pull it through a distance of 100 m in 5 min. Find the power required to pull the implement.

Solution:

$$P = \frac{D F}{T \times 4500}$$

Given F = 300 kg_f

D = 100 m

T = 5 min

So

$$P = \frac{300 \times 100}{5 \times 4500} = 1.33 \text{ m- kg}_f/\text{min}$$

Example 2 : A tractor pulls a draught load of 1000 kg while travelling at a speed of 60 m/min. Find the horse power (hp) developed by the tractor.

Solution:

$$\begin{aligned} \text{hp} &= \frac{F S}{4500}; \text{ S is speed in m/min} \\ &= \frac{1000 \times 60}{4500} = 13.33 \text{ hp} \end{aligned}$$

Drawbar Power: Power requirement of a tractor at its drawbar can also be estimated by the following formulae:

$$P = \frac{F S}{3.6}$$

Where,

P = drawbar power, kW

F = draught, kN

S = speed, km/h

Or,

$$P = \frac{F S}{270}$$

Where,

P = drawbar power, hp

F = draught, kgf

S = speed, km/h

Power requirement for some of the implements is given in Table 3.1. The drawbar power output is always less than Power-Take-Off (PTO) power output because of drive wheel slippage, tractor rolling resistance and friction losses in the drive train between the engine and the wheels. The sum of these losses may be represented by a tractive & transmission (T&T) coefficient. The tractive & transmission coefficient is defined as

$$\text{T\&T coefficient} = \frac{\text{Drawbar power}}{\text{PTO power}}$$

T&T coefficients for four-wheel drive tractors are somewhat higher than those for two wheels drive tractors. Track type tractors seldom have more than 5% slips even on soft soil. The value of tractive and transmission coefficient for track type tractors varies between 0.80 and 0.85 on firm soil and 0.70 and 0.75 on soft soil. The PTO power corresponding to drawbar power is determined by applying an appropriate T&T coefficient.

Rotary power: It is defined as

$$\text{Power (P)} = \frac{\text{Force (F) x Distance travelled (D)}}{\text{Time taken (T)}}$$

Example: If a belt produces a tangential force of 1000 N on a pulley having radius of 0.30 m at a speed of 200 rpm, the power it will be

$$P = \frac{F D}{T}$$

Given $F = 1000 \text{ N}$

$$D = \text{distance covered} = 2 \pi r \times \text{rpm}$$

$$= 2 \pi \times 0.30 \times 200 \text{ m/min}$$

$$T = 1 \text{ min}$$

$$P = \frac{1000 \times 2 \pi \times 0.30 \times 200}{1} = 376991.12 \text{ N-m/min}$$

$$= 6283.18 \text{ N-m/s}$$

$$1 \text{ W} = 1 \text{ N-m/s}$$

$$P = 6283.18 \text{ W} = 6.28 \text{ kW}$$

Fluid power: It is defined as the product of a weight rate of flow and the resistance to that flow called the head of the flow. Head describes the height of a column of fluid whose mass creates at the bottom a pressure equivalent to that in the flowing system. Thus,

$$\text{Power (P)} = \frac{\text{Weight of fluid (F) x Head (H)}}{\text{Time taken (T)}}$$

Example: If 100 kg of water is to be pumped to the height of 30 m in 100 s, the power required would be

$$\text{Power (P)} = \frac{\text{Force (F) x Distance travelled (D)}}{\text{Time taken (T)}}$$

$$\text{Given } F = 100 \text{ kg} = 100 \times 9.8 \text{ N} = 980 \text{ N}$$

$$D = 30 \text{ m}$$

$$T = 100 \text{ s}$$

So

$$P = \frac{980 \times 30}{100} = 294 \text{ N-m/s} = 294 \text{ W} = 0.294 \text{ kW}$$

The pressure of the fluid and not its head is used in most calculations and expressed in Pascal (Pa).

Farm Power and Machinery Management

$$1 \text{ Pa} = 1 \text{ N/m}^2$$

$$1 \text{ kPa} = 1000 \text{ Pa} = 0.145 \text{ psi}$$

$$1 \text{ MPa} = 1000 \text{ kPa}$$

$$1 \text{ bar} = 100 \text{ kPa} = 1 \text{ atm}$$

Hydraulic power (Ph): It is expressed as

$$\text{Hydraulic Power (Ph)} = \frac{p Q}{C}; \text{ kW}$$

Where,

p = gauge pressure, k Pa

Q = flow rate, l/s

C = constant, 1000

It can also be expressed as

$$\text{Ph} = 0.01667 Q Dp, \text{ kW}$$

Where,

Q = fluid flow rate, l/min

Dp = pressure change, M Pa

Power-Take-Off (PTO) power: It is expressed as

$$P = \frac{2 \pi F R N}{60000} = \frac{2 \pi T N}{60000}$$

Where,

P = PTO power, kW

F = tangential force, kN

R = radius of force rotation, m

N = revolutions per minute, rpm

T = torque, N-m = F R

Module 3. Cost analysis of machinery- fixed cost and variable costs, effects of inflation on cost

Lesson 10. Cost of Operation of Farm Equipment

One of the most important items influencing the profitability of farming operations is the cost of owning and operating the farm machines. Accurate cost estimates play an important role in every machinery management decision, namely, when to trade, which size to buy, how much to buy, etc. There are two main types of machinery costs:

Fixed Costs: These costs depend on how long a machine is owned rather than how much it is used. Fixed costs include the following:

- 1) Depreciation
- 2) Interest
- 3) Taxes
- 4) Shelter
- 5) Insurance

Operating Costs: It is also called as the variable costs. It varies in proportion to the amount of machine used. The operating costs consist of the following:

- 1) Repair and maintenance costs
- 2) Fuel costs
- 3) Oil or lubrication costs
- 4) Labour costs

Fixed Costs

Depreciation: Depreciation means a loss in the value of a machine due to time and use. Often, it is the largest of all costs. Machine depreciate, or have a loss of value, for several reasons, such as, age of machine, wear and tear of machine and obsolescence. There are several different methods to calculate the depreciation. These include the following:

- 1) Estimated value method
- 2) Straight-line method

3) Declining-balance method

4) Sum-of-the years digits method

5) Sinking-fund method

Estimated Value Method: It is the most realistic determination of depreciation. At the end of each year the value is compared with the value of machine possessed at the start of the year. The difference is the amount of depreciation. Table 3.2 gives the estimated values as the percentage of the purchase price for most of the expensive farm machineries.

Table 3.2: Estimated values of depreciation at the end of year.

Machine	% of purchase price									
	1	2	3	4	5	6	7	8	9	10
Tractor	36	6	5	5	5	4	4	3	3	3
Self-propelled combine	41	7	6	6	5	5	4	4	3	3
Tractor-drawn combine	46	7	6	5	5	4	4	3	3	2
Corn picker	49	6	5	5	4	4	3	3	2	2
Baler	49	6	5	5	4	4	3	3	2	2
Forage harvester	53	6	5	4	4	4	3	3	3	3
Cotton picker	43	6	6	5	4	4	4	3	3	1

Straight-line Method: In the straight-line depreciation method, an equal reduction of value is used for each year the machine is owned (Fig. 1). This method can always be used to estimate costs on a specific period of time, provided the proper salvage value is used for the age of the machine. The annual depreciation value can be calculated from the following expression

$$D = \frac{P - S}{L H}$$

Where,

D = average annual depreciation, Rs/h

P = purchase price, Rs.

S = salvage value, taken as 10% the purchase price

L = life of machine, years

H = annual use of machine, hours

The straight-line depreciation method is not quite accurate for giving the value of a machine at same age. In actual practice machine depreciates much faster in the first few years than in the later years.

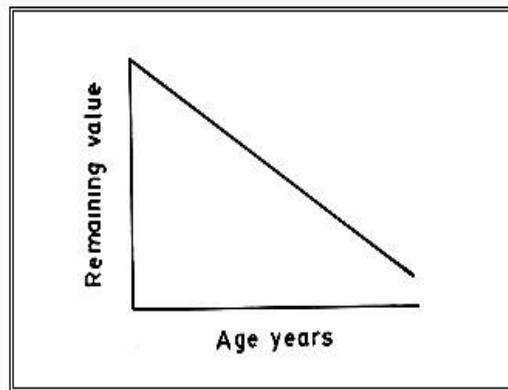


Fig. 1: Straight line depreciation.

Fig. 1: Straight line depreciation.

Example: Suppose a new tractor is purchased for Rs. 3,00,000.00 and its life is assumed to be 15 years. Assume salvage value as 10% of purchase price; then average annual depreciation would be

$$\begin{aligned}
 D &= \frac{300000.00 - 10\% \text{ of } 300000.00}{15} \\
 &= (300000.00 - 30000.00)/15 \\
 &= \text{Rs. } 18000.00 \text{ per year}
 \end{aligned}$$

Declining-balance depreciation method: It reflects the actual value of a machine at any age rather than the value found from the straight-line method or sum of the digits method. With the declining balance method, a machine depreciates a different amount for each year, but the annual percentage of depreciation is the same (Fig. 2). Depreciation can be calculated by using the following expression

$$D_{n+1} = V_n - V_{n+1}$$

$$V_n = P (1 - X/L)^n$$

$$V_{n+1} = P (1 - X/L)^{n+1}$$

$$D_{n+1} = P(1 - X/L)^n (X/L)$$

Where.

D_{n+1} = amount of depreciation charged for year $n+1$, Rs./year

V = remaining value at any time

P = purchase price, Rs.

n = number representing age of machine in years at the beginning of year in question

L = life of machine, years

X = ratio of depreciation rate. It may be any number between 1 and 2. If $X = 2$ the method is called double-declining-balance method.

For used machine X is taken as 1.5.

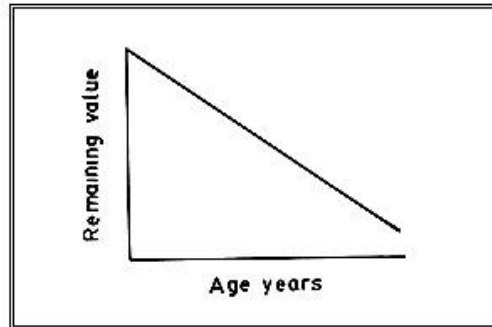


Fig. 2: Declining balance depreciation method

Example: Suppose a new tractor is purchased for Rs. 3,00,000.00 and its life is assumed to be 15 years. Assume salvage value as 10% of purchase price; then find the depreciation in 6th year.

$$D_{n+1} = V_n - V_{n+1}$$

$$V_n = P (1 - X/L)^n$$

$$V_{n+1} = P (1 - X/L)^{n+1}$$

Given $n = 5$; $X = 2$ for new machine and $L = 15$

$$\begin{aligned} V_n &= 300000 (1 - 2/15)^5 \\ &= 146683.65 \end{aligned}$$

$$\begin{aligned} V_{n+1} &= 300000 (1 - 2/15)^6 \\ &= 127125.83 \end{aligned}$$

$$\begin{aligned} D_{n+1} &= V_n - V_{n+1} \\ &= 146683.65 - 127125.83 = 19557.82 \text{ in } 6^{\text{th}} \text{ year} \end{aligned}$$

Example: A machine costing Rs. 3,00,000.00 has a total life of 15 years. If the rate of inflation is taken as 5% constant through out its life period, find the future price of machine, total depreciation, remaining value and annual depreciation charge at the end of 12th year. Take salvage value as 10% of inflated price.

Solution:

Using equation (1) future price at the end of 12th year will be

$$\begin{aligned} F &= P (1 + I)^n \\ &= 300000 (1 + 0.1)^{12} \\ &= 941528.51 \end{aligned}$$

Total depreciation after elapse of 12 years will be

$$\begin{aligned} CD_n &= \frac{n}{L} [P (1 + I)^n - S] \\ &= \frac{12}{15} [P (1 + I)^n - 0.1 P (1 + I)^n] \\ &= \frac{12}{15} [P (1 + I)^n (1 - 0.1)] \\ &= 0.8 \times 0.9 \times 300000 (1 + 0.1)^{12} = 677900.53 \end{aligned}$$

Remaining value of the machine at the end of 12th year will be

$$= 941528.51 - 677900.53 = 263627.98$$

Annual depreciation charge in the 12th year using equation (6) will be

$$\begin{aligned} &= 0.06 P [n (1 + I)^n - (n-1) (1 + I)^{n-1}] \\ &= 0.06 \times 300000 [12 (1 + 0.1)^{12} - (12-1) (1 + 0.1)^{12-1}] \\ &= 0.06 \times 300000 [37.66 - 31.38] \\ &= 113040.00 \end{aligned}$$

Thus, it can be seen that at the higher inflation rates the financial burden on the farming enterprise will be very high. The above technique can be applied to other depreciation methods with constant/variable inflation rated in the life span of a farm machines.



Lesson 11. Cost of Operation of Farm Equipment - continued

Sum-of-the Years Digits Method

It is a much more accurate method of estimating the true value of a machine at any age because the annual depreciation rate decreases as the machine gets older (Fig. 3). The amount of depreciation can be determine by

$$D_{n+1} = \frac{L - n}{Y_d} (P - S), \text{ Rs./yr}$$

Where,

Y_d = Sum of the years digits = $L(L + 1)/2$

n = age of the machine in years at the beginning of the year in question

L = life of machine, year

P = purchase price, Rs.

S = salvage value, Rs.

The following steps determine the amount of depreciation by the sum-of-the years digits method:

- 1) Add up the numbers representing the years covered by the depreciation method.
- 2) Divide the total depreciation by sum of the digits of the years for the depreciation period.
- 3) Proportion the depreciation in reverse of the years over which the depreciation occurs.

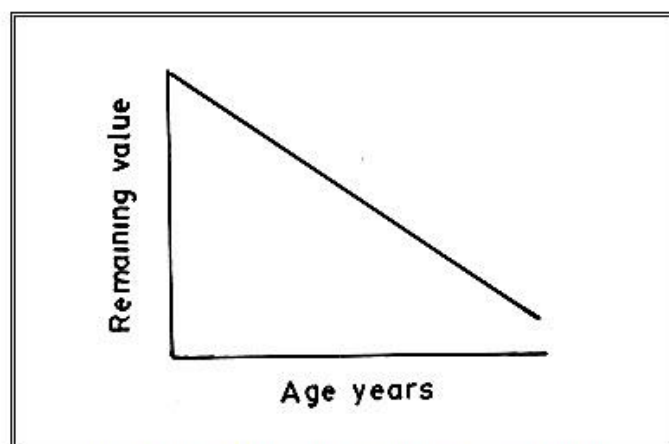


Fig. 3: Sum-of-the years digits depreciation.

Example: Suppose a new tractor is purchased for Rs. 3,00,000.00 and its life is 15 years. Assume salvage value as 10% of the purchase price. Find the depreciation.

Solution:

Step 1: The sum-of-the-digits for 15 years is

$$15+14+13+12+11+10+9+8+7+6+5+4+3+2+1 = 120$$

Step II: Total depreciation = 300000.00 - 10% × 300000.00 = 270000.00

Total depreciation	270000.00	
120	120	= Rs. 2250.00 per unit

Step III: Each year depreciation would be calculated as follows:

$$\text{First years' depreciation} = (L - n) \times 2250.00$$

For first year $n = 0$

$$\text{First years' depreciation} = (15 - 0) \times 2250.00 = 33750.00$$

$$\text{Second years' depreciation} = (15 - 1) \times 2250.00 = 31500.00$$

$$\text{Third years' depreciation} = (15 - 2) \times 2250.00 = 29250.00$$

$$\text{Fourth years' depreciation} = (15 - 3) \times 2250.00 = 27000.00$$

And so on

Comparison of depreciation cost by different methods taking life of machine 15 years, price of machine P and salvage value 10% of P is given in Table 1.

Table 1: Comparison of depreciation cost by different methods.

(Life of machine = 15 years; Price of machine = P; Salvage value = 10% of P)

End of year	Straight-line method	Declining-balance method	Sum-of-the-years digits method
1	0.06 P	0.1153 P	0.1125 P
2	0.06 P	0.1000 P	0.1050 P
3	0.06 P	0.0867 P	0.0975 P
4	0.06 P	0.0751 P	0.0900 P
5	0.06 P	0.0651 P	0.0825 P
6	0.06 P	0.0565 P	0.0750 P

7	0.06 P	0.0490 P	0.0675 P
8	0.06 P	0.0425 P	0.0600 P
9	0.06 P	0.0368 P	0.0525 P
10	0.06 P	0.0319 P	0.0450 P
11	0.06 P	0.0277 P	0.0375 P
12	0.06 P	0.0240 P	0.0300 P
13	0.06 P	0.0208 P	0.0225 P
14	0.06 P	0.0180 P	0.0150 P
15	0.06 P	0.0156 P	0.0075 P

Sinking-Fund Method

Sinking fund depreciation method is primarily advantageous for use with a planned replacement internal policy. By formula the values for the sinking fund annual payment (SFP) and the value at the end of the year n are:

$$SFP = (P - S) \frac{i}{(1 + i)^L - 1}$$

$$V_n = (P - S) \left[\frac{(1 + i)^L - (1 + i)^n}{(1 + i)^L - 1} \right] + S$$

$$D_{n+1} = V_n - V_{n+1}$$

Where,

D_{n+1} = amount of depreciation charged for year n+1, Rs./year

V_n = remaining value at the end of the year n, Rs.

V_{n+1} = remaining value at the end of the year n+1, Rs.

P = purchase price, Rs.

S = salvage value, Rs.

i = interest rate, fraction

L = life of machine, years

Lesson 12. Interest on Investment

A large expensive item after depreciation for agricultural machinery is the interest. It is a direct expense item on borrowed capital. Even if cash is paid for purchased machinery, money is tied up that might be available for use elsewhere in the business. Interest rates vary considerably but usually are between 12 and 16 percent. Annual interest is calculated on an average investment by using the prevailing interest rate by the following formula:

$$I = \frac{P + S}{2} \times \frac{i}{100}$$

Where,

I = annual interest charge, Rs./year

P = purchase price, Rs.

S = salvage value, Rs.

i = interest rate, per cent

Insurance and Shelter

Insurance and shelter charges together are taken @ 2% of the purchase price per year.

Consideration of Inflation in Depreciation Analysis of Farm Equipment

Any consideration of cash flows in today's economy must include an effect of inflation. Inflation can be defined in terms of an annual percentage that represents the rate at which current years prices have increased over the previous year's prices. It has a compounding effect. Because of inflation, the cost of farm equipment or any other product continues to rise. Hence, inflation affects adversely the purchasing power of money. The future prices of farm equipment in the n^{th} year at constant inflation rate can be represented by

$$F = P (1 + I)^n \quad \text{----- (1)}$$

Where.

F = Future price in the n^{th} year, Rs.

P = Purchase price, Rs.

I = Inflation rate, fraction

If the inflation changes in each year, then the future price of the farm equipment would be

$$F = P (1 + I_1) (1 + I_2) \dots (1 + I_n) \quad (2)$$

If constant inflation rate is taken as 10%, then the future price of the product after 10 years would be (using equation 1)

$$F = P (1 + 0.1)^{10} = 2.59 P$$

i.e. the future price of the product will inflate to 2.59 times the purchase price in 10 years.

The effect of inflation can be included in the depreciation analysis. The depreciation of a machine under constant inflationary condition using straight-line method can be written as

$$CD_n = \frac{n}{L} [P (1 + I)^n - S] \quad (3)$$

Where,

CD_n = Cumulative depreciation charges up to n^{th} year, Rs.

n = Number of years elapsed after the purchase of the machine

L = Life of machine, years

P = Purchase price, Rs.

S = Salvage value of the machine

Annual depreciation charge (D_n) in the n^{th} year will be

$$D_n = CD_n - CD_{n-1}$$

and future value of machine at the end of n^{th} year (V_n)

$$V_n = \text{Future price at the end of } n^{\text{th}} \text{ year} - CD_n$$

$$= P (1 + I)^n - n/L [P (1 + I)^n - S]$$

Taking life of the machine as 15 years and salvage value as 10% of the inflated price of the machine, equation (3) reduces to

$$\begin{aligned} CD_n &= \frac{n}{15} [P (1 + I)^n - 0.1 P (1 + I)^n] \\ &= \frac{n}{15} 0.9 P (1 + I)^n \\ &= 0.06 n P (1 + I)^n \quad (4) \end{aligned}$$

Similarly, cumulative depreciation charge up to $(n-1)^{\text{th}}$ year may be written as

$$CD_{n-1} = 0.06 (n-1) P (1 + I)^{n-1} \quad (5)$$

Annual depreciation charge (D_n) in the n^{th} year will be

$$\begin{aligned}
 D_n &= CD_n - CD_{n-1} \\
 &= 0.06 n P (1 + I)^n - 0.06 (n-1) P (1 + I)^{n-1} \\
 &= 0.06 P [n (1 + I)^n - (n-1) (1 + I)^{n-1}] \quad \text{----- (6)}
 \end{aligned}$$

The remaining value of the machine after n^{th} year (V_n) may be obtained as

$$\begin{aligned}
 V_n &= \text{Future price at the end of } n^{\text{th}} \text{ year} - \text{cumulative depreciation value up to } n^{\text{th}} \text{ year} \\
 &= P (1 + I)^n - D_n \\
 &= P (1 + I)^n - 0.06 n P (1 + I)^n \\
 &= P (1 + I)^n [1 - 0.06 n] \quad \text{----- (7)}
 \end{aligned}$$

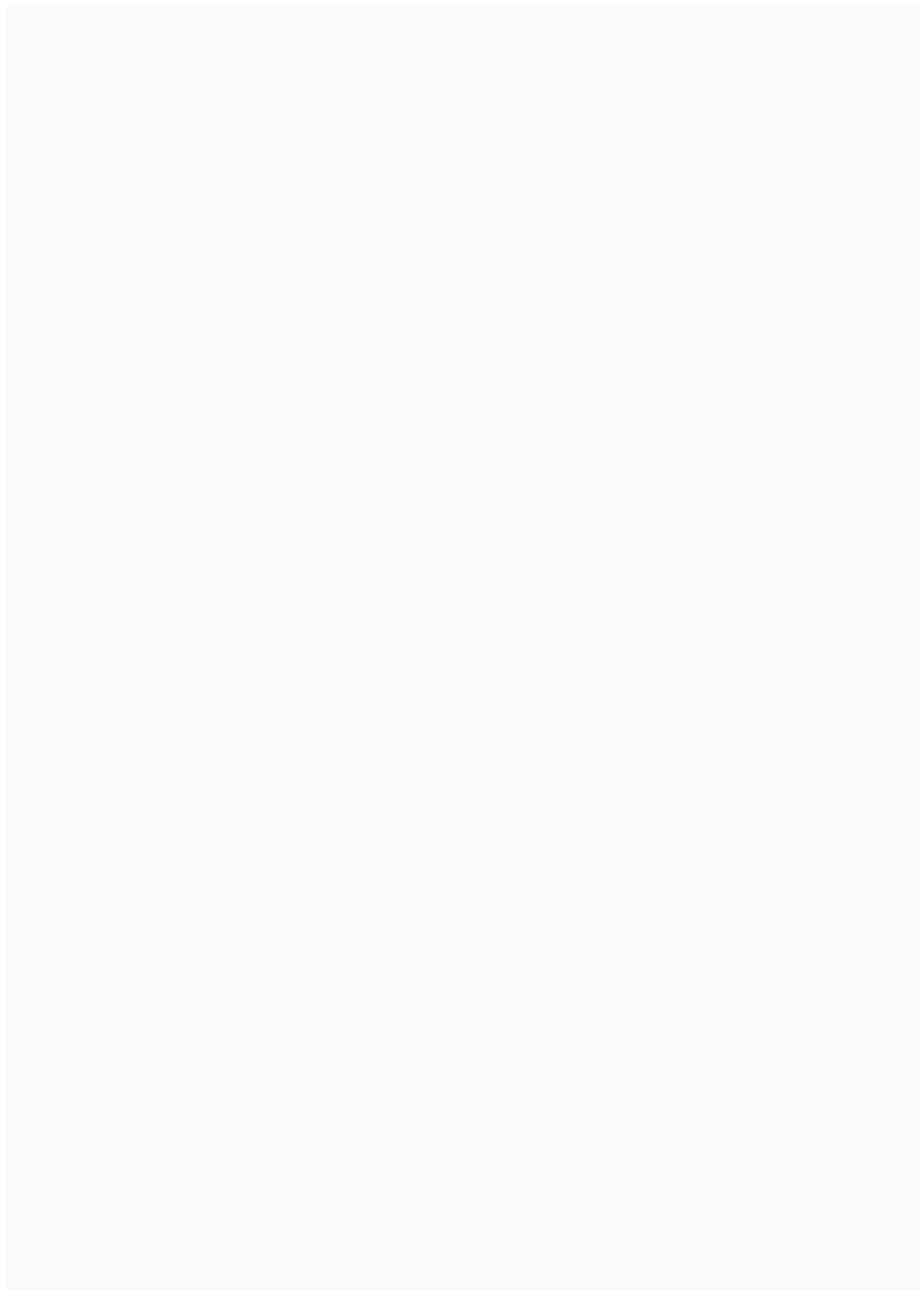
Variation in future price, total depreciation cost and remaining value of a machine as a function of purchase price P at constant 10% annual inflation rate under straight-line method for total life of machine 15 years are given in Table 2.

Table 2: Comparison of future price, depreciation cost and remaining value of machine as a function of purchase price.

End of year	Future price	Total depreciation	Remaining value
1	1.100 P	0.0660 P	1.0340 P
2	1.210 P	0.1452 P	1.0648 P
3	1.331 P	0.2396 P	1.0914 P
4	1.464 P	0.3514 P	1.1126 P
5	1.611 P	0.4833 P	1.1277 P
6	1.772 P	0.6379 P	1.1341 P
7	1.949 P	0.8186 P	1.1304 P
8	2.144 P	1.0291 P	1.1149 P
9	2.358 P	1.2733 P	1.0847 P
10	2.594 P	1.5564 P	1.0376 P
11	2.853 P	1.8830 P	0.9700 P
12	3.138 P	2.2594 P	0.8786 P
13	3.452 P	2.6926 P	0.7594 P

14	3.797 P	3.1895 P	0.6075 P
15	4.177 P	3.7593 P	0.4177 P





Lesson 13. Variable Costs

Variable costs includes the following items:

- Repair and maintenance costs
- Fuel costs
- Lubrication (oil) costs
- Labour costs

i) Repair and Maintenance Costs

Repair and maintenance costs are considered as an essential and significant part of machinery ownership. Occasional repairs and periodic maintenance are required to maintain a machine in good working order and ensure a high degree of reliability. The more a machine is used, the greater is its need for repair. The following factors necessitate the repairs in a machine:

- Routine wear
- Accidental breakage or damage
- Operator's negligence, and
- Periodic overhauls

Repair costs consists of the expenditures incurred for the spare parts and the labour for repairs made in a shop or on the farm. Repair costs vary from one geographical region to another because of the differences in machinery use, labour wages and prices of spares. Repair costs increases with the age of a machine but tend to level off as a machine becomes older. The accumulated repair and maintenance costs (TAR) at any point in a machine's life can be estimated by using the following formulae (IS:9164 - 1979).

For four - wheeled and crawler tractors	$TAR = 0.100 X^{1.5}$
For stationary power units and two-wheeled tractor	$TAR = 0.120 X^{1.5}$
For agricultural trailer	$TAR = 0.127 X^{1.4}$
For PTO-driven combine, seed drill and Sprayer	$TAR = 0.159 X^{1.4}$
For plough, planter, harrow, ridger and cultivator	$TAR = 0.301 X^{1.3}$
For seed cleaner	$TAR = 0.191 X^{1.4}$

For self-propelled combine, dozer and scraper

$$TAR = 0.096 X^{1.4}$$

Where,

TAR = Total Cumulative repair and maintenance costs per year divided by the purchase price of the machine expressed as percentage

X = 100 times the ratio of accumulated hours of use to wear out life

ii) Fuel and Oil Cost

With tractors and other powered farm equipment, the cost of fuel and oil must be included in the total machine charge. Power required may be estimated as follows:

$$dbp = \frac{D S}{270}$$

Where,

dbp = drawbar horse power, hp

D = draught, kgf

S = speed, km/h

or

$$dbp = \frac{D S}{3.6}$$

Where,

dbp = drawbar power, kW

D = draught, kN

Fuel consumption depends on the size of the power unit, load factor and operating conditions. The actual consumption can be measured in the field or can be estimated by using the following equation (IS:9164 - 1979):

$$F = 0.15 P$$

Where,

F = average diesel consumption, l/h

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P = rated power, kW

or

$$F = 0.25 P$$

Where,

F = average petrol consumption, l/h

P = rated power, kW

Fuel consumption can also be estimated by the following equation:

$$F = \frac{LCF \times RHP \times SFC}{1000}$$

Where,

F = fuel consumption, l/h

LCF = load coefficient factor for the operation

RHP = rated horsepower of the power source, hp (kW)

SFC = specific fuel consumption, ml/hp/h (ml/kW/h)

The values of LCF and SFC for different operations and power sources are given in Table 3.

Labour Charge: The cost of operator and labour is calculated from the actual operator and labour charges paid in Rupees per day at the prevailing rates in that region.

Table 3: Values of LCF and SFC for different operations and power sources.

Power source	Type of work	LCF	SFC ml/kW/h	SFC ml/hp/h
Stationary diesel engine	- Water lifting	0.6	300	220
	- Threshing	0.7	300	220
Tractor	- Light work e.g. transport, water lifting etc.	0.4	285	210
	- Medium work e.g. secondary tillage, sowing, inter-culture etc.	0.5	285	210
	- Heavy work e.g. primary tillage, Sheller, cane crusher, combine etc	0.6	285	210

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Self-propelled combine	-	0.6	285	210
Small petrol engine	- Spraying, dusting etc.	0.8	680	500

Oil costs = 0.20 x Fuel costs





Lesson 14. Solved examples

Example: A test was conducted to find out the cost per hour operation of a 25 hp tractor operated wheat thresher. Also find the cost of operation of the thresher per tonne.

Given:

Price of tractor	= Rs. 2,50,000.00
Price of thresher	= Rs. 25,000.00
Life of tractor	= 15 years
Life of thresher	= 10 years
Salvage value	= 10%
Interest rate	= 15%
Shelter & Insurance	= 2% of purchase price
Price of diesel	= Rs. 11/litre
Number of labour employed with thresher	= 4
Labour charge	= Rs. 8.00/h
Driver's charge	= Rs. 20.00/h
Annual use of tractor	= 1000 h
Annual use of thresher	= 200 h

Output of thresher = 800 kg/h

Depreciation = Straight line method

Solution: a) Tractor

Depreciation	$= \frac{P - S}{L H} = \frac{250000 - 25000}{15 \times 1000} = \text{Rs. } 15.00/\text{h}$
Interest	$= \frac{P + S}{2} \times \frac{i}{H} = \frac{250000 + 25000}{2} \times \frac{0.15}{1000} = \text{Rs. } 20.62/\text{h}$
Shelter & Insurance	$= \frac{2\% \text{ of } P}{H} = \frac{0.02 \times 250000}{1000} = \text{Rs. } 5.00/\text{h}$

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Total fixed cost = 15.00 + 20.63 + 5.00 = Rs. 40.62/h

Repair & maintenance cost

For Tractor $TAR = 0.12 (X)^{1.5}$

$$X = \frac{\text{Yearly use} \times 100}{\text{Total life}} = \frac{1000 \times 100}{15 \times 1000} = 6.67\%$$
$$TAR = 0.12 (6.67)^{1.5} = 2.06\% \text{ of average purchase price}$$
$$= \frac{2.06}{100 \times 1000} \times \frac{250000 + 25000}{2} = \text{Rs. } 2.83/\text{h}$$

Fuel Consumption = LCF x RHP x SFC/1000 = 0.6 x 25 x 210/1000 = 3.15 l/h

Fuel cost = 3.15 x 11 = Rs. 34.65/h

Oil cost = 0.20 x 34.65 = Rs. 6.93/h

Driver's charge = Rs. 20.00/h

Total variable cost = 2.83 + 34.65 + 6.93 + 20.00 = Rs. 64.41/h

Total cost of operating the tractor = 40.62 + 64.41 = Rs. 105.03/h

(b) Thresher

$$\text{Depreciation} = \frac{25000 - 2500}{10 \times 200} = \text{Rs. } 11.25/\text{h}$$
$$\text{Interest} = \frac{25000 + 2500}{2} \times \frac{0.15}{200} = \text{Rs. } 10.31/\text{h}$$
$$\text{Tax, shelter \& insurance} = \frac{2 \times 25000}{100 \times 200} = \text{Rs. } 2.50/\text{h}$$

Repair & maintenance cost

For thresher $TAR = 0.159 (X)^{1.4}$

$$X = \frac{200 \times 100}{10 \times 200} = 10\%$$

TAR = 0.159 (10)^{1.4} = 25.12% of average purchase price

= Rs. 17.27/h

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Labour charge = $4 \times 8 = \text{Rs. } 32.00/\text{h}$

Total cost of operating the thresher = $105.03 + 11.25 + 10.31 + 2.50 + 17.27 + 32.00$
= $\text{Rs. } 178.36/\text{h}$

$$178.36 \times 1000$$

Cost of operation/tonne = $\frac{\text{-----}}{800} = \text{Rs. } 222.95$

Example: A farmer purchased a 45 hp tractor at a price of Rs. 350,000.00 and a 3-bottom mould board plough with 30 cm bottom width at Rs. 15000.00. The draught requirement is 18000 kgf at 3.0 km/h in a clay-loam soil. Calculate:

i) Area covered per day of 8 hours

ii) Cost of ploughing per hectare and per hour

Make necessary assumptions.

Given:

Price of tractor (P) = Rs. 350000.00

Price of plough = Rs. 15000.00

Width of plough (w) = $3 \times 0.3 = 0.9 \text{ m}$

Speed of tractor (S) = 3.0 km/h

Assumptions:

Life of tractor (L) = 15 years

Life of plough = 15 years

Annual use of tractor = 1000 h

Annual use of plough = 200 h

Field efficiency of plough = 60%

Interest rate (i) = 12%

Salvage value (S) = 10% of purchase price

$$\text{Effective field capacity of plough} = \frac{S w E f}{10} = \frac{3.0 \times 0.9 \times 0.6}{10} = 0.162 \text{ ha/h}$$

Cost calculations:

Tractor

$$\text{Depreciation (D)} = \frac{P - S}{L \times H} = \frac{350000 - 35000}{15 \times 1000} = \text{Rs. 21.00/h}$$

$$\text{Interest (I)} = \frac{P + S}{2} \times \frac{I}{H} = \frac{350000 + 35000}{2} \times \frac{0.12}{1000} = \text{Rs. 23.10/h}$$

$$\begin{aligned} \text{Tax, Shelter \& Insurance} &= (2\% \text{ of purchase price})/1000 = 0.02 \times 350000/1000 \\ &= \text{Rs. 7.00/h} \end{aligned}$$

$$\text{Total fixed cost} = 21.00 + 23.10 + 7.00 = \text{Rs. 51.10/h}$$

Variable Cost

$$\text{Repair \& maintenance TAR} = 0.12 (X)^{1.5}$$

$$X = \frac{\text{Yearly use} \times 100}{\text{Total life}} = \frac{1000 \times 100}{15 \times 1000} = 6.67\%$$

$$\begin{aligned} \text{TAR} &= 0.12 (X)^{1.5} \\ &= 0.12 (6.67)^{1.5} = 2.067\% \text{ of average purchase price} \\ &= (2.067)/100 \times (350000 + 35000)/2 = \text{Rs. 3979/year} \\ &= 3979/1000 = \text{Rs. 3.98/h} \end{aligned}$$

$$\begin{aligned} \text{Fuel consumption} &= \text{LCF} \times \text{RHP} \times \text{SFC}/1000 \\ &= 0.6 \times 45 \times 210/1000 = 5.67 \text{ l/h} \end{aligned}$$

$$\text{Prevailing diesel rate} = \text{Rs. 16.50/l}$$

$$\text{Fuel cost} = 5.67 \times 16.50 = \text{Rs. 93.56/h}$$

$$\text{Oil cost} = 0.20 \times 93.56 = \text{Rs. 18.71/h}$$

$$\text{Labour cost} = \text{Prevailing operator's charge} = \text{Rs. 20.00/h}$$

$$\text{Total variable cost} = 3.98 + 93.56 + 18.71 + 20.00 = \text{Rs. 136.25/h}$$

$$\text{Total cost of operation of tractor} = 51.10 + 136.25 = \text{Rs. 187.35}$$

Mouldboard plough

Fixed Cost

$$\text{Depreciation} = (15000 - 1500)/(15 \times 200) = \text{Rs. } 4.50/\text{h}$$

$$\text{Interest} = (15000 + 1500)/2 \times 0.12/200 = \text{Rs. } 4.95/\text{h}$$

$$\text{Tax, shelter etc.} = 2\% \text{ of purchase price} = 0.02 \times 15000/200 = \text{Rs. } 1.50/\text{h}$$

$$\text{Total fixed cost} = 4.50 + 4.95 + 1.50 = \text{Rs. } 10.95/\text{h}$$

Variable cost

$$\text{Repair \& maintenance cost TAR} = 0.301 (X)^{1.3}$$

$$X = (200 \times 100)/(15 \times 200) = 6.67\%$$

$$\text{TAR} = 0.301 (6.67)^{1.3} = 0.301 \times 11.78$$

$$= 3.55\% \text{ of average purchase price}$$

$$= 0.0355 \times (15000 + 1500)/2$$

$$= \text{Rs. } 292.88/\text{year}$$

$$= \text{Rs. } 1.46/\text{h}$$

$$\text{Fuel cost} = 0 \text{ (Taken with tractor)}$$

$$\text{Oil cost} = 0 \text{ (Taken with tractor)}$$

$$\text{Labour cost} = 0 \text{ (Labour cost is considered here only if extra labour other than tractor operator is employed)}$$

$$\text{Total cost} = 10.95 + 1.46 = \text{Rs. } 12.41/\text{h}$$

$$\text{Cost of ploughing} = 187.35 + 12.41 = \text{Rs. } 199.76/\text{h}$$

$$\text{Field capacity of plough} = 0.162 \text{ ha/h}$$

$$\text{Cost of ploughing/ha} = 199.76/0.162 = \text{Rs. } 1233.08 = \text{Rs. } 1233/- \text{ per ha}$$



Module 4. Selection of optimum machinery and replacement criteria**Lesson 15 and 16. Selection of tractors**

Two characteristics of a system are the interdependence and interaction of its elements. The collection of machinery on agricultural farms has these characteristics, and as a result the selection of appropriate and economic farm machinery system becomes more complex. If all farm machines were self-propelled, their interdependence would be minimal. But, most farm machines are tractor powered and it is the tractor that interacts with all the non-self-propelled machines to create an operational system.

A successful farm machinery system is one that must perform in such a manner that profit to the farm is maximized. Maximization is not always accomplished by minimizing costs, and such is true with the selection of a farm machinery system. Considerations have to be given to the economic value of operating machinery at that correct moment of time when the soil, the crop, the weeds, and the insects are most affected. The need for timely operations is a rather unique economic constraint on the farm machinery system.

Selection of an appropriate machinery system may be stated simply as the process of determining those individual machine capacities, which will optimize the economic performance of the whole system. Consideration must be given to machine costs, power costs, operational costs etc. An appropriate cost of operation model is essential to the validity of the selection problem analysis. This analysis uses fixed and variable costs. Variable costs increase proportionally with the operational use of the machine, while fixed costs are independent of use. Considering the fixed and variable costs, the total cost of operation of tractor is given by

$$Ac = Fc Pt + At (RM + L + O + F + Tc) \quad \text{-----} \quad (1)$$

Where,

Ac = Annual costs of operating the tractor, Rs/year

Fc = Annual fixed costs, fraction of purchase price

Pt = Purchase price of tractor, Rs

At = Annual use of tractor, h/year

RM = Repair and maintenance costs of tractor, Rs/h

L = Labour costs, Rs/h

O = Oil costs, Rs/h

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F = Fuel costs, Rs/h

T_c = Timeliness costs, Rs/h

Since RM, O, F = f(A) where A is cropped area, therefore, RM, O, F = f(E) where E is energy spent to cover the area. As energy requirement is expected to be a constant for a specific farm operation, therefore, RM, O and F costs will have no influence on the optimum size of the tractor. Thus, only important variables are labour costs (L) and timeliness costs (T_c). More specifically, the annual costs of tractor are expressed as the sum of the fixed costs and the total labour and timeliness costs for each of two types farm jobs viz. field operations and transport operations.

$$A_c = F_c P_t + (\text{Field hours}) (L + \text{timeliness cost}) + (\text{transport hours}) (L_t)$$

Where,

L = Tractor operator's wages for field work, Rs/h

L_t = Labour cost for transport work, Rs/h

Probably, there should be a timeliness charge for transport work but for simplicity it will be assumed that this does not limit field operation.

The optimum size of tractor is considered to be one, which will perform all the desired operations at minimum costs. The annual hours of work required for each class of tractor operation are given by:

$$\text{Field Time (h/year)} = \frac{(\text{Area}) (\text{Energy required per unit area})}{r \times (\text{Rated Power})} = \frac{A E_o}{r R_p}$$

Where,

A = Area, ha

r = Ratio of drawbar power to rated engine power for drawbar loads and ratio of PTO power to rated engine power for PTO loads

E_o = Energy required per unit area, kWh/ha

R_p = Rated power, kW

Thus field time is proportional to energy required per unit area per rated power i.e.

$$\text{Field Time} = C_1 E_o / R_p$$

Where,

C₁ = Constant

Similarly;

$$\text{Transport Time} = \frac{(\text{Energy required per unit distance}) (\text{distance}) (\text{amount to be transported/year})}{r \times (\text{Rated Power})}$$

$$\text{i.e. Transport time} = \frac{0.53 (\text{kWh/km}) (D) (Wt/\text{year})}{r \times (\text{kW})}$$

Where,

W_t = Amount of material to be transported, tonne

D = Distance to be travelled, km

r = Ratio of drawbar power to rated engine power taken as 0.4 for transport operation

Thus, transport time is also proportional to the energy required to transport one tonne of produced through one-kilometer distance per rated power i.e.

$$\text{Transport time} = C_2 E_t / R_p$$

Where,

C_2 = Constant

E_t = Energy required by tractor for transport operations

Therefore, annual costs of operating a tractor can be written as

$$A_c = F_c P_t + \frac{C_1 E_o}{R_p} (L + T_c) + \frac{C_2 E_t L_t}{R_p} \quad \text{-----} (2)$$

Writing purchase price of tractor, $P_t = R_p P_u$

Where,

P_u = Price per unit power of tractor, Rs/kW

$$A_c = F_c R_p P_u + \frac{C_1 E_o}{R_p} (L + T_c) + \frac{C_2 E_t L_t}{R_p} \quad \text{-----} (3)$$

Differentiating the equation 10 with respect to R_p , we get

$$\frac{d(Ac)}{d(R_p)} = F_c P_u - \frac{C_1 E_o (L + T_c)}{(R_p)^2} - \frac{C_2 E_t L_t}{(R_p)^2}$$

Equating $\frac{d(Ac)}{d(R_p)} = 0$, we get

$$F_c P_u = \frac{C_1 E_o (L + T_c)}{(R_p)^2} + \frac{C_2 E_t L_t}{(R_p)^2}$$

$$F_c P_u = \frac{1}{(R_p)^2} [C_1 E_o (L + T_c) + C_2 E_t L_t]$$

$$(R_p)^2 = \frac{1}{F_c P_u} [C_1 E_o (L + T_c) + C_2 E_t L_t]$$

$$(R_p)_{opt} = [\{1/(F_c P_u)\} \{C_1 E_o (L + T_c) + C_2 E_t L_t\}]^{1/2} \quad \text{----- (4)}$$

Differentiating equation 11 once again with respect to R_p , we get

$$\frac{d(Ac)}{d(R_p)^2} = \frac{2 C_1 E_o (L + T_c)}{(R_p)^3} + \frac{2 C_2 E_t L_t}{(R_p)^3}$$

Which is a positive quantity, indicating that the calculated $(R_p)_{opt}$ would have a minimum cost of operation.

In equation (11), E_o in general can be rewritten as

$$E_o = \frac{n_i A_i E_i}{r}$$

Where,

i = Subscript identifying specific operation, area, energy value etc.

A = Area under crop, ha

E = Energy required by a particular machine, kWh/ha

r = Ratio of drawbar power to axle power

n = number of passes of an implement

Energy required by a particular machine per unit area can be calculated by

$$E = \frac{10 P L_c}{w S E_f}$$

Where,

E = energy required by a particular machine per unit area, kWh/ha

P = power required for operation, kW

L_c = load coefficient factor

w = width of implement, m

S = speed of operation, km/h

E_f = efficiency of machine

Timeliness of a field operation must be considered in selection of optimum power required of a tractor. Timeliness costs arise because of the inability of a machine to complete a field operation in a reasonably short time. These are not out-of-pocket costs but reductions in potential returns as and when the yield and quality of crops are reduced because of delays in field operations. Delays due to bad weather cannot be charged to machine. Timeliness costs are so important that in a machinery selection process they must be evaluated quantitatively and considered as a valid cost of field machinery. In order to calculate this cost, the total reduction in returns is distributed over total hours of the actual use of tractor/machine. Total timeliness cost for an operation depends upon the scheduling of operations (delayed, premature and balance). So, the total timeliness cost (T_c) can be estimated as:

$$T_c = \frac{K Y V A}{S_c N_t U h} \quad (5)$$

Where,

T_c = Timeliness costs, Rs/h

K = Timeliness loss factor

Y = Crop yield, t/ha

V = Value of crop, Rs/t

A = Total area under crop, ha

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U = Ratio of total working days to total days, fraction

Nt = Number of times area (A) should be divided because of dispersed optimum time

Sc = 2 for premature or delayed scheduling

= 4 for balanced scheduling

h = Actual number of hours utilized per day

Total timeliness costs for an operation depend on the scheduling of operations with respect to time and duration of operation. There are basically three types of scheduling of operations viz. delayed, premature and balanced. In delayed scheduling, operation starts at optimum time whereas in premature scheduling operation is completed by the optimum time. In the balanced scheduling, operation is planned in such a way that it spreads over equally on both sides of the optimum time. Therefore, time devoted in case of delayed and premature scheduling is half of that of balanced scheduling. Thus, X is taken as 2 for premature or delayed and 4 for balanced scheduling.

The cost of untimely operations can be included in the basic cost model as a cost for each hour the machine is used. The absolute costs depend on the value of the crop. Therefore, a relative timeliness factor called K has been developed to give some generality to the analysis (Table 3.6). K is defined as the decimal reduction of the quantity and quality of the potential crop per hour of machine operation.

Thus,

$$(Rp)_{opt} = \left[\left(\frac{n_i A_i E_i}{F_c r_i P_u} \right) \left(L + \frac{K_{ic} Y_c V_c A_c}{S_c N_{t_i} U h} \right) + \left(\frac{0.53 L_t D W_t}{F_c P_u r_i} \right) \right]^{1/2} \text{---(6)}$$

Where,

Fc = Fixed cost percentage of a tractor

Pu = Price per unit power of tractor, Rs/hp

Ai = Area under crop, ha

Ei = Energy required for operating an implement for a particular crop

K_{ic} = Timeliness loss factor of an implement for a particular crop

Yc = Yield of crop, q/ha

Vc = Value of crop, Rs/q

U = Ratio of total working days to total days, fraction

Nt = Number of times area (A) should be divided because of dispersed optimum time

$Sc = 2$ for premature or delayed scheduling

$= 4$ for balanced scheduling

$h =$ Actual number of hours utilized per day

$Lt =$ Labour rate for transportation, Rs/h

$D =$ Distance to be travelled, km

$Wt =$ Weight to be transported, tonne

$r_i =$ Ratio of drawbar power to rated engine power for drawbar

load and ratio of PTO power to rated engine power for PTO

loads for a particular crop

Note that repairs, fuel and oil costs have been dropped from considerations. Only labour and tractor fixed costs remain in the equation 13. Equation 13 may be used without reservation for self-propelled implements and for selection of implements to fit into an existing machinery system where the tractor fixed costs are known and are constant. In fact, the optimum implement width may be more dependent upon the size of tractor than upon any of the other factors in equation 13. Selection of an economic system of machines is highly dependent upon the horsepower level of the tractor or tractors.

Therefore, optimum tractor power required for drawbar operations can be calculated by

$$P_{Dr} = \left[\frac{100 n A E}{F_c r P_u} \left(L + \frac{K Y V A}{S_c N t U h} \right) \right]^{1/2} \quad \text{--- (7)}$$

And, optimum tractor power required for transport operations can be calculated by

$$P_{Tr} = \left[\frac{100 (0.53 L t D W t)}{F_c P_u r} \right]^{1/2} \quad \text{--- (8)}$$

Total power required can be calculated by adding equations 14 and 15

i.e. $P = P_{Dr} + P_{Tr}$

or

$$P = \left[\frac{100 n A E}{F_c r P_u} \left(L + \frac{K Y V A}{S_c N t U h} \right) + \left(\frac{100 (0.53 L t D W t)}{F_c P_u r} \right) \right]^{1/2} \quad \text{--- (9)}$$

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Overall power requirement would be sum of all the power requirements for specific operation of an implement for a particular crop and for all crops grown by the farmers. i.e.

$$P_{total} = \left[\sum_{i=1, j=1}^{n, m} P_{Dr} + \sum_{j=1}^m P_{Tr} \right]^{1/2} \quad \text{----- (10)}$$

Where,

i = subscript refers to specific operation of an implement

j = subscript refers to specific crop grown by the farmers

Table 1: Timeliness loss factor for different operations and crops under Indian Farm conditions.

Crop	Operation	K value
Wheat	Tillage & sowing	0.00456
	Harvesting & threshing	0.00650
Barley	Tillage & sowing	0.0067
	Harvesting & threshing	0.0044
Paddy	Tillage & sowing	0.00625
	Harvesting & threshing	0.0066
Maize	Tillage & sowing	0.0046
Soybean	Tillage & sowing	0.0179
	Harvesting & threshing	0.0189
Moong	Tillage & sowing	0.0052
	Harvesting & threshing	0.066
Oil seeds	Tillage & sowing	0.0138
	Harvesting & threshing	0.035
Sunflower	Tillage & sowing	0.0035
	Harvesting & threshing	0.0035
Potato	Tillage & sowing	0.002
	Harvesting & threshing	0.002

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Mash	Tillage & sowing	0.0052
	Harvesting & threshing	0.066
Gram	Tillage & sowing	0.0052
	Harvesting & threshing	0.066
Groundnut	Tillage & sowing	0.0138
	Harvesting & threshing	0.0351
Sugarcane	Tillage & sowing	0.002
	Harvesting & threshing	0.002
Cotton	Tillage & sowing	0.0138
	Harvesting & threshing	0.0351



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Lesson 17. Selection of matching farm equipment

An important aspect while buying a new machine is to make the decision regarding the size of the machine required. Economic selections of field equipment are a complex problem. Size selection is mainly based on anticipated performance and costs. For selecting proper capacity of a field machine, the minimum cost of the machine can be calculated by using the following equation:

$$C = FC\% P + \frac{10A}{S w E_f} [RM P + L + O + F + T] \quad \text{----- (1)}$$

Where,

C = Annual cost of operating the machine, Rs/year

FC% = Annual fixed cost percentage, decimal

P = Purchase price, Rs

A = Annual use, ha

S = Forward speed, km/h

w = Width of machine, m

E_f = Field efficiency of machine, decimal

RM = Repair & maintenance costs, decimal of purchase price per hour

L = Labour wages, Rs/h

F = Fuel cost, Rs/h

O = Oil cost, Rs/h

T = Cost of tractor use by machine, Rs/h

T = 0, if it is a self-propelled machine

$$\frac{10A}{S w E_f} = \text{Number of hours of machine used per year for implements only}$$

All variables in Eq. (18) depend upon the size of machine and so they must be expressed in terms of width (w).

Let, p be the purchase price per meter width of the machine, then $P = p w$

And so, $RM P = RM p w$

$O = o w$

$F = f w$

Where,

$O = \text{Oil cost/h/m of width of machine}$

$f = \text{Fuel cost/h/m of width of machine}$

Equation 1, thus becomes

$$\begin{aligned}
 C &= FC\% p w + \frac{10A}{S w E_f} [RM p w + L + o w + f w + T] \\
 &= FC\% p w + \frac{10A}{S w E_f} [RM p w + o w + f w] + \frac{10A}{S w E_f} [L + T] \\
 &= FC\% p w + \frac{10A}{S E_f} [RM + o + f] + \frac{10A}{S w E_f} [L + T] \quad (2)
 \end{aligned}$$

To determine the minimum point, differentiate equation (2) with respect to w and equate it to zero.

$$\begin{aligned}
 FC\% p + o - \frac{10A}{S w^2 E_f} [L + T] &= 0 \\
 FC\% p &= \frac{10A}{S w^2 E_f} [L + T] \\
 w^2 &= \frac{10A}{FC\% p S E_f} [L + T]
 \end{aligned}$$

$$\text{or, } w = \left[\frac{10A}{FC\% p S E_f} (L + T) \right]^{1/2} \quad (3)$$

This is called the least cost width. The least cost width can also be determined by plotting equation (2) as shown in Fig. 1. The lowest point on the curve is least cost width. Values of fixed cost percentage as required in equation (3) are given in Table 1.

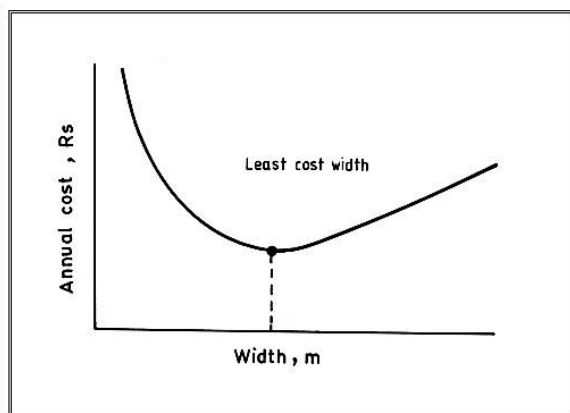


Fig. 1: Annual cost Vs. width of the machine.

Timeliness of a field operation must be considered in selection of optimum width of a farm machine. Enough evidence is available to estimate timeliness loss factor (K) for most machine operations. If a crop requires multiple operations, say 2 cultivations then the K factor should be divided by 2. Similarly, for 3 or more cultivations K should be divided by 3 or more when used in the selection analysis.

Table 1: Values of fixed cost percentage

Service life (years)	Values of FC%
1	100
2	53
3	37
4	29
5	25
6	22
7	20
8	18
9	17
10	16
15	13

Source: Hunt (1977)

Equation 2 can be modified to include a charge for timeliness we get

$$C = FC\% p w + \frac{10A}{S E_f} [RM + 0 + f] + \frac{10A}{S w E_f} [L + T + \frac{K Y V A}{S c N t U h}]$$

Taking

$$\begin{aligned}
 \text{i.e., } \frac{dC}{dw} &= 0 \\
 FC\% p + 0 - \frac{10A}{S w^2 E_f} [L + T + \frac{K Y V A}{Sc Nt U h}] &= 0 \\
 \frac{10A}{S w^2 E_f} [L + T + \frac{K Y V A}{Sc Nt U h}] &= FC\% p \\
 w^2 &= \frac{10A}{FC\% p S E_f} [L + T + \frac{K Y V A}{Sc Nt U h}] \\
 w &= \left[\frac{10A}{FC\% p S E_f} (L + T + \frac{K Y V A}{Sc Nt U h}) \right]^{1/2} \quad (4)
 \end{aligned}$$

Least cost width can be estimated by the equation (4).

Example: A farmer is having a 20 ha of land. The land is to be ploughed first before sowing of wheat crop. Farmer is using a 2-bottom mould board plough at a forward speed of 2.5 km/h for ploughing the field. The field efficiency of the plough is 70% and used for 8 hours a day. Find the least-cost-width of mould board plough. The sale price of wheat is Rs 6500.00 per tonne and productivity 5.2 t/ha. The price of mould board plough per meter width is Rs 15000.00. Given FC% = 16; K = 0.002, U = 0.8, Sc = 4 and Nt = 1.

Solution:

Labour cost (L) = Prevailing operator's charge = Rs. 20.00/h

Total cost of operation of tractor (T) = Rs. 187.35/h (Calculated in section 3.3)

The least-cost-width of a mould board plough can be calculated by the equation (21),

i.e.

$$\begin{aligned}
 w &= \left[\frac{10A}{FC\% p S E_f} (L + T + \frac{K Y V A}{Sc Nt U h}) \right]^{1/2} \\
 &= \left[\frac{10 \times 20}{0.16 \times 15000 \times 2.5 \times 0.70} (20 + 187.35 + \frac{0.002 \times 5.2 \times 6500 \times 20}{4 \times 1 \times 0.8 \times 8}) \right]^{1/2} \\
 &= [0.0476 (20 + 187.35 + 52.812)]^{1/2} \\
 &= 3.52 \text{ m}
 \end{aligned}$$

Thus, the least-cost width of mould board plough should be 3.52 m. Or in other words, the farmer might have to purchase 2 or 3 mould board ploughs depending upon the width of machine commercially available.

Lesson 18. Development of computer programme for selection of farm equipment

A computer program can be developed, which can give results like required horse power of tractor, size of implement, own combine or not etc. for a particular farm situation. The user has to enter land holding, cropping pattern and soil type. The program can be developed in FORTRAN, QBasic and C++ languages and is quite user friendly and flexible. The essential inputs to the program are

1. Cropping pattern
2. Area under crops
3. Soil type (light, medium, heavy)

After entering these inputs into the program, it will process these values with the help of some predefined parameters:

1. Tractor price in Rs/kW
2. Fixed cost of tractor in percentage
3. Price of crops in Rs/q
4. Crop yield in q/ha
5. Price of the implements in Rs/m
6. Timeliness cost factor
7. Labour charges in Rs/h
8. Land preparation operations

The parameters related to combine are

1. Combine rated power in kW
2. Specific fuel consumption in ml/kW/h
3. Fuel cost in Rs/l
4. Custom hiring rate in Rs/ha

When the inputs are given to the model the computer give out first the values of energy required and the width of implements in decimals. This is rough data for user. Thus after

these values the computer selects the optimum size of tractor and its corresponding set of implements. These implements selected are within the range of width of implements selected by computer. The program also selects for the user that he opts for buying a combine harvester or custom hire it. This decision will be based upon the area under wheat and paddy.

Using the computer program the optimum tractor power requirement and set of implements can be calculated for a particular farm. Optimum tractor power requirement for draw bar operation is function of area to be covered, soil type, energy required, number of operations of implements, labour cost and timeliness cost. Further the timeliness cost is dependent on the yield of crops, value of crops and timeliness cost factor of each crop. Optimum power required for transportation is a function of weight to be transported and distance to be travelled. After finding the optimum power required for all draw bar operations and for transportation, these are summed up by program to get total power requirement for a particular farm. Then the matching machinery to available tractor is calculated. The details of flow charts are given in Figs. 1 and 2.

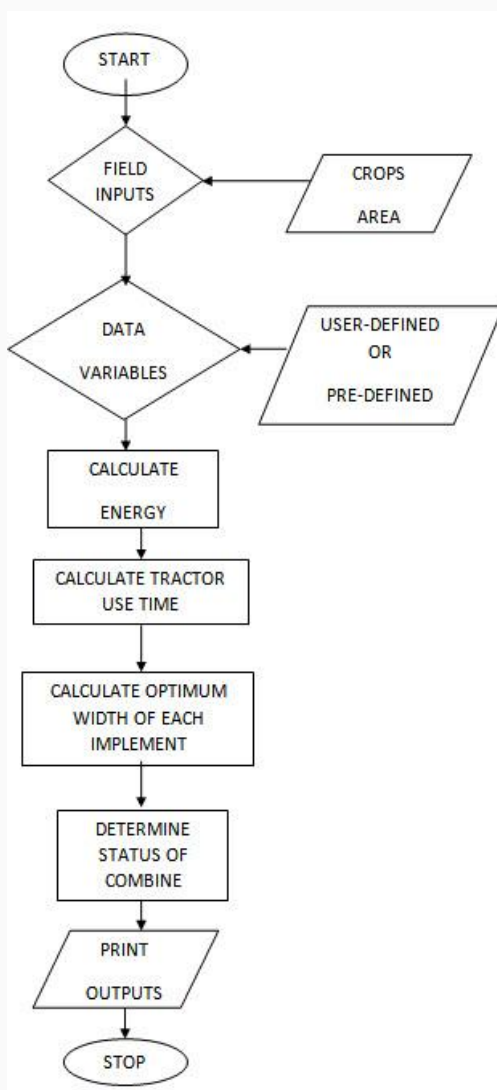


Fig. 1: Flow chart for preparing computer programme for optimum selection of farm equipment.

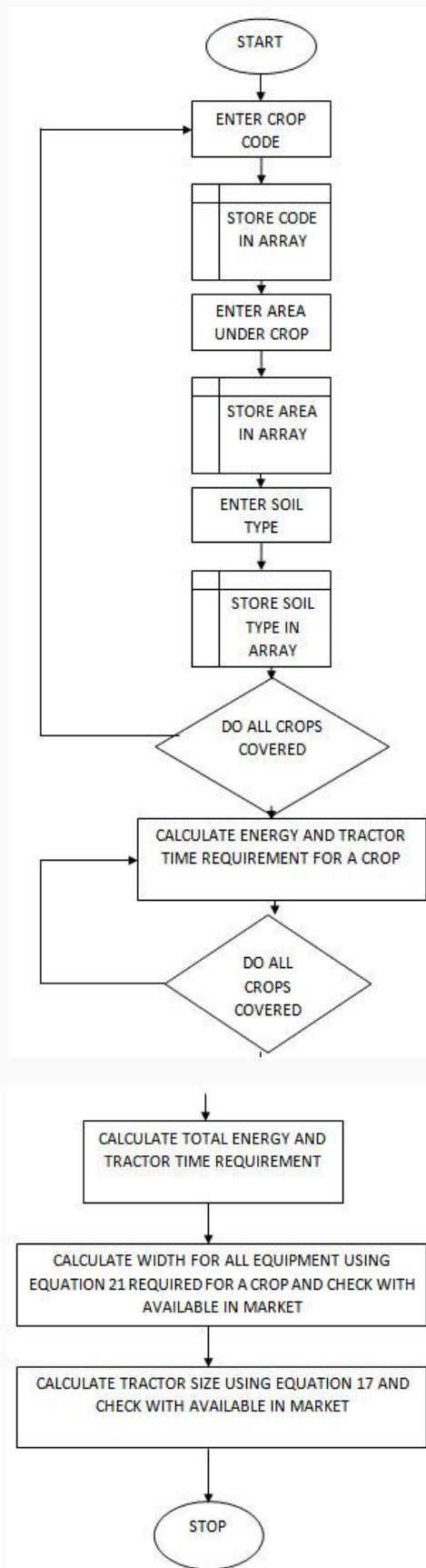


Fig. 2: Flow chart for calculating tractor and farm equipment size.

Lesson 19. Replacement of farm machinery

Good guidelines are available for making management decisions on when to replace the farm equipment. Important reasons for replacing a machine are:

- i) Accidents have damaged the implement beyond repair
- ii) Field capacity of the machine is inadequate
- iii) A new machine or farm practice has made the old machine obsolete
- iv) Performance of a new machine is significantly superior
- v) Anticipated costs for operating the old machine exceed those for a replacement machine, and
- vi) The machine is worn out.

The time of replacement decisions depends on the accumulated costs over a period of years. The annual cost curve as well as the accumulated average cost curve for a machine is shown in Fig. 1. Both the curves intersect at a point. Theoretically, the time to replace a machine is when the annual cost starts to exceed the average accumulated cost. However, machine repair rate really determines the time of replacement. One method of establishing the time of replacement is to determine that the cost per unit of use has reached its lowest value.

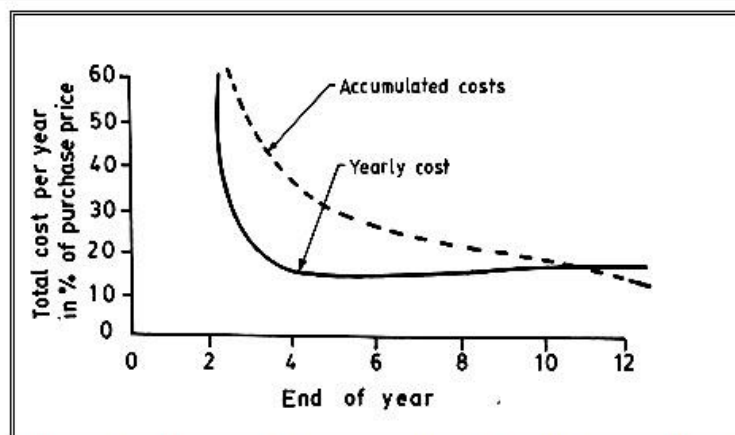


Fig. 1: Time of replacement, where yearly cost equals accumulated cost

Case I: Repair is proportional to use

$$\text{Total cost, } C = FC + RC \times X$$

Where,

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C = Total repair cost

FC = Fixed cost

RC = Repair cost

X = Number of ha of machine used

$$\text{Cost/ha} = \frac{C}{X} = \frac{FC}{X} + RC$$

In this case, the lowest cost/ha can only be attained with indefinite use of machine as shown in Fig. 1.

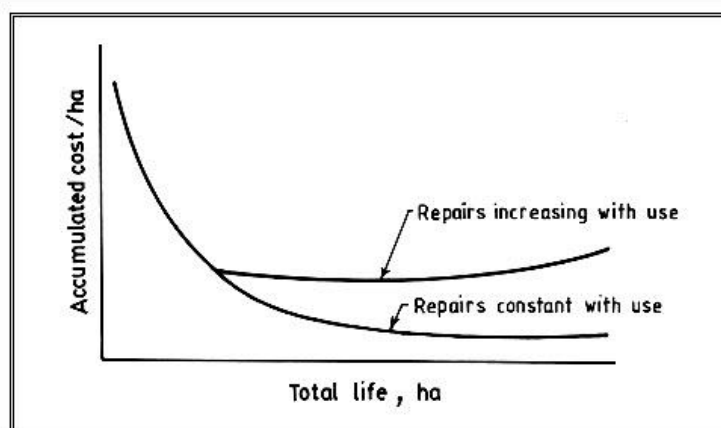


Fig. 1: Effect of repair cost on accumulated cost.

Case II: Repair cost increases with use

$$C = FC + R_1 C X + R_2 C X^2$$

Where,

C = Total repair cost

FC = Fixed cost

$R_1 C$ = Repair cost rate proportional to use

$R_2 C$ = Repair cost rate that increases with use

X = Number of hectare of machine use

Repair cost per hectare is given by

$$\frac{C}{X} = \frac{FC}{X} + R_1 C + R_2 C X$$

The time of replacement is defined by the minimum cost point. If replacement is delayed beyond this point, costs are expected to rise due to the increasing repair cost.

For minimum cost

$$\frac{dC}{dX} = 0, \text{ i.e. } \frac{dC}{dX} = -\frac{FC}{X^2} + 0 + R_2C = 0$$

$$\frac{dC}{dX} = 0, \text{ i.e. } \frac{dC}{dX} = -\frac{FC}{X^2} + 0 + R_2C = 0$$

$$\text{i.e. } X^2 = FC / R_2C$$

$$\text{Or, } X = [FC / R_2C]^{1/2}$$

The accumulated repair cost will depend upon the type of repair rate. For constant repair rates, the effect of repair on replacement is ignored. For implements, which have an increasing repair rate, the repair cost is given by

$$C_r = \frac{1}{2} \times \frac{R_r}{10000 Ah} \times n^2 H^2$$

Where,

C_r = Accumulated repair cost up to Year n, Rs

R_r = Value of repair rate at a given accumulated hours of use, expressed in %P/100 hours

P = Purchase price, Rs

Ah = Accumulated hours

H = Average hourly use per year

Obsolescence should be considered in determining the proper time of replacement. Accumulated cost of obsolescence can be expressed as

$$C_o = 1/2 (F_o n^2)$$

Where,

C_o = Accumulated cost of obsolescence, Rs

F_o = Obsolescence factor, Rs/year

N = Number of years

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In this case, the depreciation can be expressed in terms of percentage of purchase price at the beginning of year n as

$$V_n = 68 - 4.2 n \quad \text{for tractors}$$

$$V_n = 60 - 4.6 n \quad \text{for other implements}$$

Where,

V_n = Remaining value at any time, Rs

n = Number representing age of machine in years at the beginning of year in question

The accumulated depreciation cost can be calculated as

$$Cd = (100 - V_n) \% P$$

Where,

Cd = Accumulated depreciation cost up to year n, Rs

P = Purchase price, Rs

Optimum replacement time would be in the year when the total accumulated cost of depreciation; repair and obsolescence per year would be the minimum.

Total cost (C_t) can be written as

$$C_t = (100 - V_n) \% P + \frac{1}{2} \times \frac{R_r}{10000 Ah} \times n^2 H^2 + \frac{1}{2} (F_o n^2)$$

Dividing the above equation by n

$$\begin{aligned} \frac{C_t}{n} &= \frac{(100 - V_n) P}{100 n} + \frac{1}{2} \times \frac{R_r}{10000 Ah} \times n H^2 + \frac{1}{2} (F_o n) \\ &= \frac{[100 - (68 - 4.2 n)] P}{100 n} + \frac{1}{2} \times \frac{R_r}{10000 Ah} \times n H^2 + \frac{1}{2} (F_o n) \\ &= \frac{0.32 P}{n} + \frac{4.2 P}{100} + \frac{1}{2} \times \frac{R_r}{10000 Ah} \times n H^2 + \frac{1}{2} (F_o n) \end{aligned}$$

Differentiating both sides with respect to n and equating with zero gives

$$\begin{aligned} -\frac{0.32 P}{n^2} + 0 + \frac{1}{2} \times \frac{R_r}{10000 Ah} \times H^2 + \frac{1}{2} (F_o) &= 0 \\ n &= \left[\frac{0.32 P}{\frac{1}{2} \times \frac{R_r}{10000 Ah} \times H^2 + \frac{1}{2} (F_o)} \right]^{1/2} \quad \text{For Tractors} \end{aligned}$$

Similarly we can find the replacement age for implements also,

$$\begin{aligned} n &= \left[\frac{0.40 P}{\frac{1}{2} \times \frac{R_r}{10000 Ah} \times H^2 + \frac{1}{2} (F_o)} \right]^{1/2} \quad \text{For Implements} \end{aligned}$$

Example: Find the optimum replacement time for the mould board plough.

Given,

$$R_r = 1.5\% P / 100 \text{ hours}$$

$$A_h = 2500 \text{ hours}$$

$$F_o = \text{Rs } 150/\text{year}$$

$$P = \text{Rs } 18000.00$$

$$H = 200 \text{ hours}$$

For implements

$$\begin{aligned}
 n &= \left[\frac{0.40 P}{\frac{1}{2} \times \frac{R_r}{10000 A_h} \times H^2 + \frac{1}{2} (F_o)} \right]^{1/2} \\
 &= \left[\frac{0.40 \times 18000}{\frac{1}{2} \times \frac{1.5 \times 18000}{10000 \times 2500} \times 200^2 + \frac{1}{2} (150)} \right]^{1/2} \\
 &= \left[\frac{7200}{\frac{0.5 \times 1.5 \times 18000 \times 40000}{10000 \times 2500} + 75} \right]^{1/2} \\
 &= \left[\frac{7200}{21.6 + 75} \right]^{1/2} \\
 &= 8.6 \text{ years}
 \end{aligned}$$

Therefore, the mould board plough should be replaced after about 9 years of use with the conditions given in the example.



Module 5. Break-even point and its analysis, reliability and cash flow problems

Lesson 20. Break-even point

Break-even point is the level of sales at which profit is zero. Therefore the break-even point can be computed by finding that point where sales just equal the total of the variable expenses plus fixed expenses and profit is zero. According to this definition, at *break-even point* sales are equal to **fixed cost** plus **variable cost**. This concept is further explained by the following equation:

$$px = vx + FC + \text{Profit}$$

where,

p is the price per unit

x is the number of units

v is the variable cost per unit, and

FC is total fixed cost

It can be also expressed as

$$[\text{Break even sales} = \text{fixed cost} + \text{variable cost}]$$

The break-even point can be calculated using either the **equation method** or **contribution margin method**. These two methods are equivalent.

At break-even point the profit is zero, therefore the cost volume profit (CVP) formula is simplified to

$$px = vx + FC$$

Solving the above equation for x which equals break-even point in sales unit, we get:

$$\text{Break-even Sales Units} = \frac{FC}{p - v}$$

Equation Method : The equation method centres on the contribution approach to the income statement. The format of this statement can be expressed in equation form as follows:

$$\text{Profit} = (\text{Sales} - \text{Variable expenses}) - \text{Fixed expenses}$$

Rearranging this equation slightly yields the following equation, which is widely used in cost volume profit (CVP) analysis:

$$\text{Sales} = \text{Variable expenses} + \text{Fixed expenses} + \text{Profit}$$

For **example** we can use the following data to calculate break-even point.

- Sales price per unit = Rs. 250
- variable cost per unit = Rs.150
- Total fixed expenses = Rs. 35,000

Calculate break-even point

Calculation:

$$\text{Sales} = \text{Variable expenses} + \text{Fixed expenses} + \text{Profit}$$

$$250Q^* = 150Q^* + 35,000 + 0^{**}$$

$$100Q = 35000$$

$$Q = 35,000 / 100$$

$$Q = 350 \text{ Units}$$

Q^* = Number (Quantity) of units sold.

******The break-even point can be computed by finding that point where profit is zero

The break-even point in sales can be computed by multiplying the break-even level of unit sales by the selling price per unit.

$$350 \text{ Units} \times 250 \text{ Per unit} = \text{Rs. } 87,500$$

Benefits / Advantages of Break Even Analysis : The main advantages of break-even point analysis are that it explains the relationship between cost, production, volume and returns. It can be extended to show how changes in fixed cost, variable cost, commodity prices, and revenues will affect profit levels and break-even points. Break-even analysis is most useful when used with partial budgeting, capital budgeting techniques. The major benefits to use break-even analysis are that it indicates the lowest amount of business activity necessary to prevent losses.

Assumption of Break Even Point : The Break-even Analysis depends on three key assumptions :

(i) **Average per unit sales price (per-unit revenue):** This is the price that you receive per unit of sales. Take into account sales discounts and special offers. Get this number from your Sales

Forecast. For non-unit based businesses, make the per-unit revenue and enter your costs as a percent of a Rupees. The most common questions about this input relate to averaging many different products into a single estimate. The analysis requires a single number, and if you build your Sales Forecast first, then you will have this number. You are not alone in this, the vast majority of businesses sell more than one item, and have to average for their Break-even Analysis.

(ii) **Average per-unit cost:** This is the incremental cost, or variable cost, of each unit of sales. If you buy goods for resale, this is what you paid, on average, for the goods you sell. If you sell a service, this is what it costs you, per Rupees of revenue or unit of service delivered, to deliver that service. If you are using a Units-Based Sales Forecast table (for manufacturing and mixed business types), you can project unit costs from the Sales Forecast table. If you are using the basic Sales Forecast table for retail, service and distribution businesses, use a percentage estimate, e.g., a retail store running a 50% margin would have a per-unit cost of .5, and per-unit revenue of 1.

(iii) **Monthly fixed costs:** Technically, a break-even analysis defines fixed costs as costs that would continue even if you went broke. Instead, we recommend that you use your regular running fixed costs, including payroll and normal expenses (total monthly Operating Expenses). This will give you a better insight on financial realities. If averaging and estimating is difficult, use your Profit and Loss table to calculate a working fixed cost estimate—it will be a rough estimate, but it will provide a useful input for a conservative Break-even Analysis.

Limitations of Break Even Analysis : It is best suited to the analysis of one product at a time. It may be difficult to classify a cost as all variable or all fixed; and there may be a tendency to continue to use a break even analysis after the cost and income functions have changed.

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Lesson 21. Break-even point in mechanizing farm operations

Hiring custom operators is one important alternative to owning machinery. In some cases, using custom operators provides faster completion of work provides the least-cost method and does not require the capital needed for owning a machine. But when considering hiring a custom operator, do not forget timeliness of operations. Waiting for a custom operator to arrive is expensive in terms of timeliness, if it means not getting crops planted or harvested at the optimum time. Always consider timeliness in making a decision to use either a custom operator or an alternative method.

Determining when to use a custom operator is one of the most important decisions made in machinery management. To take a decision in this regard, the knowledge of break-even-use of a farm machine is a must. The break-even-use is the amount of use where the cost of using a machine owned would be the same as the cost of hiring a machine (Fig. 1). If a machine were used for less than the break-even-use, custom rate would be profitable. Otherwise owning a machine would be profitable.

Break-even-use can be determined by the following formula:

$$BEU = \frac{AOC}{CR - OPC}$$

Where,

BEU = Break-even-use, ha

AOC = Annual ownership cost (fixed cost), Rs

CR = Custom rate, Rs/ha

OPC = Operating costs, Rs/ha

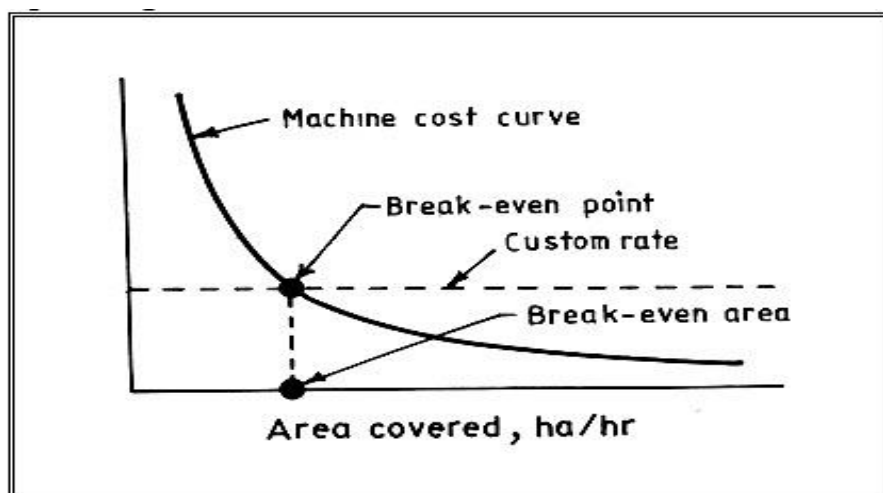


Fig. 1: Graph showing break-even-point and break-even area.

Example : In continuation of previous example, find the break-even-use of the mould board plough, if the custom rate is Rs.1400/ ha.

Solution :

Using the above equation

$$BEU = \frac{AOC}{CR - OPC}$$

Annual fixed cost for mould board plough = Rs 10.95/h

Annual use of mould board plough = 200 h

AOC = 10.95 x 200 = Rs 2190.00

OPC = Rs. 1233.00/ha

Therefore,

$$BEU = \frac{2190}{1400 - 1233} = 13.1 \text{ ha}$$

Since custom rate is more than the operating cost of owned plough, so it is better to own the mould board plough rather than using on custom hire. Cost of owning the plough would be recovered after 13.1 ha of use.

Lesson 22. Utilities and reliability index

Utility index: It is a direct indication of work machine contact hours. With an increase in the utility index the cost of operation and the non-operating hours decrease. This in turn, results into a net increase in the total power available for farm work. Utility index (K) can be calculated as

$$K = \frac{\text{Number of actual working hours/year}}{\text{Number of expected working hours/year}}$$

Reliability index: This index measures the percentage of assurance of proper working of tractors. It is determined as follows:

$$RI = \frac{A_1 P_2}{A_2 P_1}$$

Where,

RI = Reliability index

A_1 = Breakdown charges available = $0.04 nP$

A_2 = Breakdown charges - actual incurred

P_1 = Penalty for breakdown = $0.25 \times 10^{-3} B P$

P_2 = Money blocked in storing the requisite spare parts

P = New cost of tractor

n = Number of years of breakdown occurrence since purchase

B = Number of breakdown hours

Thus,

$$RI = \frac{0.04 n P}{0.25 \times 10^{-3}} \times \frac{P_2}{B P A_2} = \frac{160 n P_2}{B A_2}$$

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The optimum reliability index is determined by assuming $P_2/A_2 = 1$. Although P_2/A_2 is not exactly equal to 1 and it keeps on fluctuating but in an Indian condition through previous experience it has been observed that on an average P_2 is more or less equal to A_2 . Thus, above equation can be rewritten as

$$RI = \frac{160 n}{B}$$

If we take reliability index 1, then $B = 160 n$

If $n = 15$ years for tractor

$B = 160 \times 15 = 2400$ hours

This indicates that in order to maintain an optimum reliability index, the total number of breakdown hours in the life time of tractor must not exceed 2400 hours



Lesson 23. Cash Flow Analysis

A cash flow statement is one of the most important financial statements for a project or business. The statement can be as simple as a one page analysis or may involve several schedules that feed information into a central statement.

A cash flow statement is a listing of the flows of cash into and out of the business or project. Think of it as your checking account at the bank. Deposits are the cash inflow and withdrawals (checks) are the cash outflows. The balance in your checking account is your net cash flow at a specific point in time.

A cash flow statement is a listing of cash flows that occurred during the past accounting period. A projection of future flows of cash is called a cash flow budget. You can think of a cash flow budget as a projection of the future deposits and withdrawals to your checking account.

A cash flow statement is not only concerned with the amount of the cash flows but also the timing of the flows. Many cash flows are constructed with multiple time periods. For example, it may list monthly cash inflows and outflows over a year's time. It not only projects the cash balance remaining at the end of the year but also the cash balance for each month.

Working capital is an important part of a cash flow analysis. It is defined as the amount of money needed to facilitate business operations and transactions, and is calculated as current assets (cash or near cash assets) less current liabilities (liabilities due during the upcoming accounting period). Computing the amount of working capital gives you a quick analysis of the liquidity of the business over the future accounting period. If working capital appears to be sufficient, developing a cash flow budget may be not critical. But if working capital appears to be insufficient, a cash flow budget may highlight liquidity problems that may occur during the coming year.

Most statements are constructed so that you can identify each individual inflow or outflow item with a place for a description of the item. Statements like Decision Tool Cash Flow Budget (short form - 6 periods) and Decision Tool Cash Flow Budget (12 periods) provide flexible tools for simple cash flow projections. A more comprehensive tool for a Farm Cash Flow (Decision Tool) is also available. A more in-depth discussion of creating a cash flow budget is Twelve Steps to Cash Flow Budgeting.

Some cash flow budgets are constructed so that you can monitor the accuracy of your projections. These budgets allow you may make monthly cash flow projections for the coming year and also enter actual inflows and outflows as you progress through the year as provided in Decision Tool Cash Flow Budget (short form - monitor projections). This will

allow you to compare your projections to your actual cash flows and make adjustments to the projections for the remainder of the year.

Reasons for Creating a Cash Flow Budget: Think of cash as the ingredient that makes the business operate smoothly just as grease is the ingredient that makes a machine function smoothly. Without adequate cash a business cannot function because many of the transactions require cash to complete them. By creating a cash flow budget you can project your sources and applications of funds for the upcoming time periods. You will identify any cash deficit periods in advance so you can take corrective actions now to alleviate the deficit. This may involve shifting the timing of certain transactions. It may also determine when money will be borrowed. If borrowing is involved, it will also determine the amount of cash that needs to be borrowed. Periods of excess cash can also be identified. This information can be used to direct excess cash into interest bearing assets where additional revenue can be generated or to scheduled loan payments.

Cash Flow is not Profitability: People often mistakenly believe that a cash flow statement will show the profitability of a business or project. Although closely related, cash flow and profitability are different. A cash flow statement lists cash inflows and cash outflows while the income statement lists income and expenses. A cash flow statement shows liquidity while an income statement shows profitability. Many income items are also cash inflows. The sales of crops and livestock are usually both income and cash inflows. The timing is also usually the same as long as a check is received and deposited in your account at the time of the sale. Many expense items are also cash outflow items. The purchase of livestock feed (cash method of accounting) is both an expense and a cash outflow item. The timing is also the same if a check is written at the time of purchase.

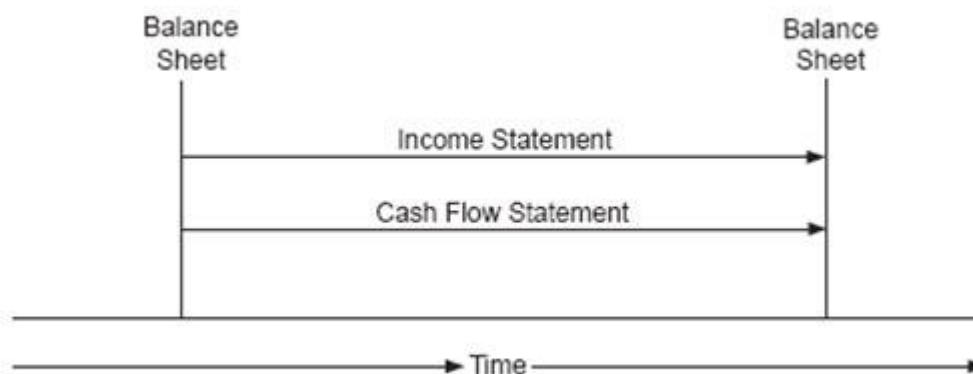
However, there are many cash items that are not income and expense items, and vice versa. For example, the purchase of a tractor is a cash outflow if you pay cash at the time of purchase. If money is borrowed for the purchase using a term loan, the down payment is a cash outflow at the time of purchase and the annual principal and interest payments are cash outflows each year. The tractor is a capital asset and has a life of more than one year. It is included as an expense item in an income statement by the amount it declines in value due to wear and obsolescence. This is called “depreciation”. The cost of depreciation is listed every year. Depreciation calculated for income tax purposes can be used. However, to more accurately calculate net income, a realistic depreciation amount should be used to approximate the actual decline in the value of the machine during the year. When the purchase is financed, the amount of interest paid on the loan is included as an expense, along with depreciation, because interest is the cost of borrowing money. However, principal payments are not an expense but merely a cash transfer between you and your lender.

Other Financial Statements: A cash flow statement is only one of several financial statements that can be used to measure the financial strength of a business. Other common statements include the balance sheet or Net worth Statement and the Income Statement, although there are several other statements that may be included. These statements fit together to form a comprehensive financial picture of the business. The balance sheet or net worth statement shows the solvency of the business at a specific point in time. Statements are often prepared at the beginning and ending of the accounting period (i.e. January 1). The statement records the assets of the business and their value and the liabilities or financial claims against the

business, i.e. debts. The amount by which assets exceed liabilities is the “net worth” of the business. The net worth reflects the current value of investment in the business by the owners.

The income statement is a dynamic statement that records income and expenses over the accounting period. The net income (loss) for the period increases (decreases) the net worth of the business (as shown in the ending balance sheet versus the beginning balance sheet in Fig. 1).

Figure 1. Integrated financial statements.



A Complete set of Financial Statements (Decision Tool), including the beginning and ending net worth statements, the income statement, the cash flow statement, the statement of owner equity and the financial performance measures is available to do a comprehensive financial analysis of your business. To help you assess the financial health of your business, Financial Performance Measures allows you to give your business a check-up. Interpreting Financial Performance Measures helps you to understand what these performance measures mean for your business.

Lesson 24. Agricultural credit

Agriculture plays a crucial role in the development of the Indian economy. It accounts for about 16 per cent of GDP and about two thirds of the population is dependent on the sector. The importance of farm credit as a critical input to agriculture is reinforced by the unique role of Indian agriculture in the macroeconomic framework and its role in poverty alleviation. Recognizing the importance of agriculture sector in India's development, the Government and the Reserve Bank of India (RBI) have played a vital role in creating a broad-based institutional framework for catering to the increasing credit requirements of the sector. Agricultural policies in India have been reviewed from time to time to maintain pace with the changing requirements of the agriculture sector, which forms an important segment of the priority sector lending of scheduled commercial banks (SCBs) and target of 18% of net bank credit has been stipulated for the sector. The Approach Paper to the Eleventh Five-Year Plan has set a target of 4% for the agriculture sector within the overall GDP growth target of 9%. In this context, the need for affordable, sufficient and timely supply of institutional credit to agriculture has assumed critical importance.

The accessibility to institutional credit is higher in the Southern region where the level of agricultural development is also higher. It is kind of vicious cycle operating in less developed States. Less availability of credit influences adversely the adoption of modern technology and private capital investments, which in turn lowers the productive capacity of the agricultural sector and results in lower productivity and production, and also pushes the farmers to borrow from non-institutional sources. Consequently, the demand for agricultural credit for short and long-term purposes is dampened.

Two innovations, *viz.*, micro-finance and Kisan Credit Card Scheme (KCCS) have emerged as the major policy developments in addressing the infirmities associated with the distributional aspects of credit in the recent years (Mohan, 2004). The KCCS has emerged as the most effective mode of credit delivery to agriculture in terms of the timeliness, hassle-free operations as also adequacy of credit with minimum of transaction costs and documentation. The cooperative banks (51.5%) had a major share followed by commercial banks (36.9%).

The incidents of suicide by farmers have been mainly reported from Andhra Pradesh, Karnataka, Maharashtra, and Kerala. Such incidents have also been reported from the States of Odisha, Gujarat, and Punjab. To mitigate the distress of farmers, the Government of India decided to launch a special rehabilitation package in 31 districts in Maharashtra, Andhra Pradesh, Karnataka, and Kerala. The 31 Districts were identified based on the severity and magnitude of the incidence of farmers' suicide, as reported by the State Governments. The intent is to initially solve the problem and correct the situation in those areas reporting high number of suicides so that an effective dent on the problem is made and the incidence of farmers' suicide which is of national concern could be curbed. The package aims at establishing a sustainable and viable farming and livelihood support system through debt relief to farmers, improved supply of institutional credit, crop-centric approach to agriculture, assured irrigation facilities, watershed management, better extension and

farming support services, improved marketing facilities and subsidiary income opportunities through horticulture, livestock, dairying and fisheries. For alleviating the hardships caused to debt stressed families of farmers in the affected districts, ex-gratia assistance from Prime Minister's National Relief Fund (PMNRF) was also proposed.

Despite the significant strides achieved in terms of spread, network and outreach of rural financial institutions, the quantum of flow of financial resources to agriculture continues to be inadequate. One of the major impediments constraining the adoption of new technological practices, land improvements and building up of irrigation and marketing infrastructure has been the inadequacy of farm investment capital. Farmers seem to borrow more short-term credit in order to meet input needs to maintain continuity in agricultural operations without much worrying about long-term capital formation in the face of agricultural bountiness. It might be the case from supply side that short-term credit bears low credit risk, lower supervision and monitoring costs, and a better asset liability management. The flow of investment credit to agriculture is constrained by host of factors such as high transaction costs, structural deficiencies in the rural credit delivery system, issues relating to credit worthiness, lack of collaterals in view of low asset base of farmers, low volume of loans with associated higher risks, high man power requirements, etc. The large proportion of population in the lower strata, which is having major share in the land holdings, receives much less credit than its requirements. The growing disparities between marginal, small and large farmers continue to be a cause for concern. This observed phenomenon might be attributed, inter alia, to the "risk aversion" tendency of the bankers towards small and marginal farmers as against the large farmers, who are better placed in offering collaterals.

Indian agriculture still suffers from: (i) poor productivity, (ii) falling water levels, (iii) expensive credit, (iv) a distorted market, (v) many intermediaries who increase cost but do not add much value, (vi) laws that stifle private investment, (vii) controlled prices, (viii) poor infrastructure, and (ix) inappropriate research. Thus the supply leading approach with mere emphasis on credit in isolation from the above factors will not help agriculture to attain the desired growth levels. Furthermore, agriculture being a State subject, States is required to play a more pro-active role in agriculture development by putting in place adequate infrastructure.

The share of marginal and small farmers in the total credit (both disbursed and outstanding) has been shrinking. The need to augment the credit flow to the lower strata of the farming community, which has more shares in the total operational land holdings, becomes all the more important. This underscores the scope for supplementing the land inputs of marginal and small farmers with the non-land inputs such as credit with a view to enhancing the productivity and thereby the production performance of Indian agriculture.



Module 6. Mechanization planning

Lesson 25 and 26

Agricultural mechanisation plays a complementary role in increasing production, productivity and profitability in agriculture by achieving timeliness in farm operations, bringing precision in metering and placement of inputs thereby reducing input losses and reducing unit cost of production. Agriculture still continues to be the principal means of livelihood for over 58.4% of population in India. Cognizance has to be taken of the fact that the next generation of farmers would not be interested in farming unless it is profitable and mechanised in comparison to alternate opportunities in the society.

Tartarisation has been recognised as the main driver of farm mechanisation for mitigating drudgery and increasing the level of farming, so as to improve the life and work environment of farmers. At present in India, tractors are being used for tillage of 23% of total area and sowing in 21.3% of total area. In addition, irrigation pumps and tractors, threshers have been adopted on large scale across the country. Combine harvester, reapers, potato, groundnut and sugarcane mechanisation machinery have also shown commercial success. Now combine harvesters are commonly used in different parts of the country on custom hiring basis for wheat, soybean and paddy harvesting.

Although utility of manually and bullock operated equipment has been established their acceptance has been rather limited. Due to limited annual use and economic advantage, some improved implements could not replace the local alternatives. The reason for mechanisation is mainly economic and timeliness of operation as indicated in desired outputs such as an increase in labour productivity, increase in land productivity and decrease in production cost. India being a very vast country having diverse cropping systems with varying level of mechanisation and socio economic variability a common mechanisation strategy to increase productivity and profitability may not be applicable.

The transformation of mechanisation scenario is inevitable. Then challenge is to manage the gradual and evolutionary transformation with minimum social cost. The entire set of traditional activities needs not to be replaced by a new set of modern activities at once in order to enhance productivity and profitability. Certain farm operations need to be mechanised first then others until eventually the complete transition to mechanised farming is made. At present, "Selective Mechanisation" is highly relevant for diverse modern conditions. Setting up custom hiring services will be able to provide the machinery on need basis to small and medium farmers. Increase in farm power availability in production catchment will help in overall up-liftment of farmers in terms of productivity and profitability.

The impact of farm mechanisation has till now been able to steer the agriculture growth and further careful assessment of mechanisation needs an appraisal of available technology and formulation of policy framework to encourage appropriate mechanisation and support overall agricultural development objectives.

Present status of farm mechanisation: From the machine requirement point of view, the various farm operations are grouped as below:

- a) Mobile operations or works which needs tractor or power tiller as prime mover e.g. ploughing, harrowing, levelling, seeding, planting & intercultural.
- b) Stationery operations or works such as lifting of water for irrigation, portable power, sprayers, threshing , chaff cutting, crushing sugarcane, grinding & mixing livestock feed, rice hulling, transplanting rice seedlings.

With the increase in intensity of cropping, the turnaround time is drastically reduced. Hardly ten to fifteen days are left in between harvesting of previous crop and sowing of subsequent crop. So to do all these field operation in limited time, it is not possible without machine. Thus mechanization is inevitable. The different sources of power available on the farm for doing various mobile and stationary operations are discussed below:

Mobile Power Sources

1. **Human Power (Men, women, and children):** The average power availability from a male agricultural worker is considered 60 watts (0.06 kW) while from female worker it is considered as 48 watts (0.048 kW) and for child worker 30 watts (0.030 kW). The population trend of agricultural workers is given in Fig 1.1.

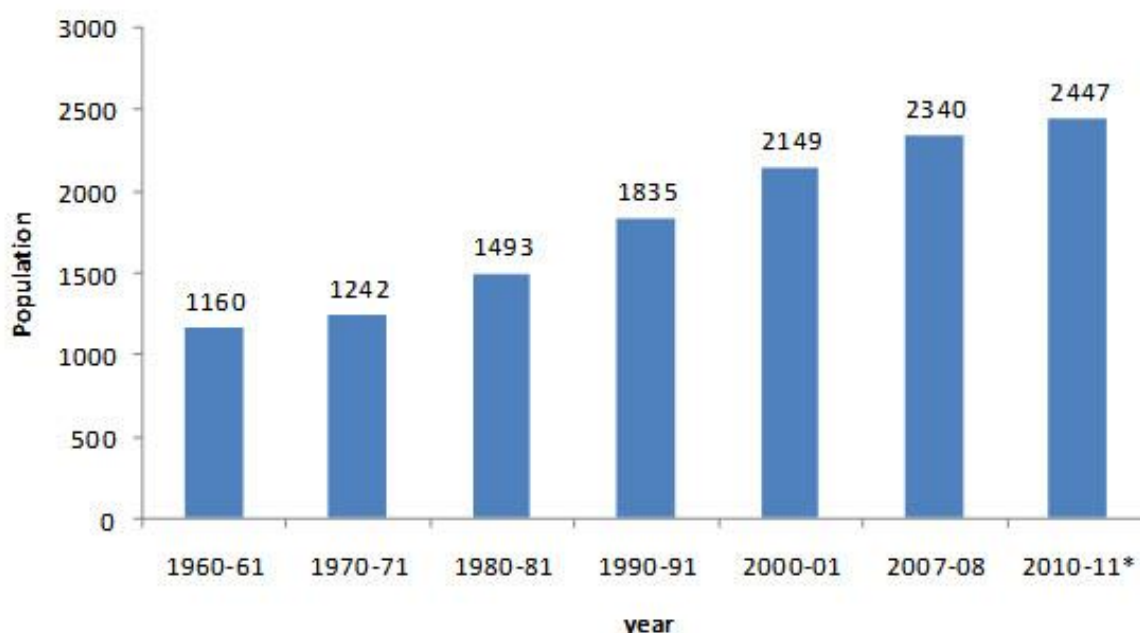
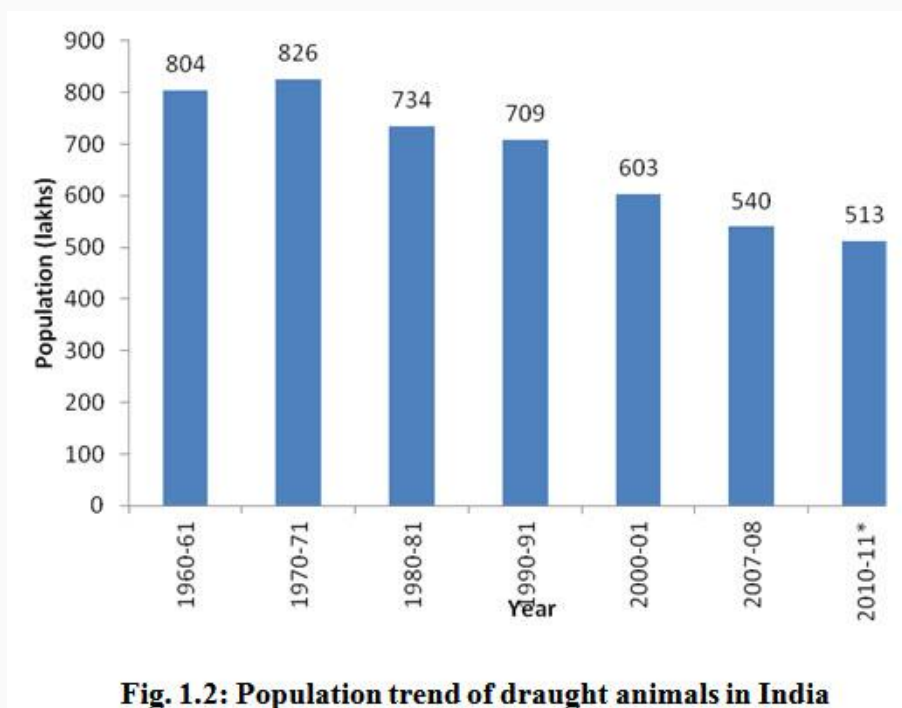


Fig. 1.1: Population trend of agricultural workers in India

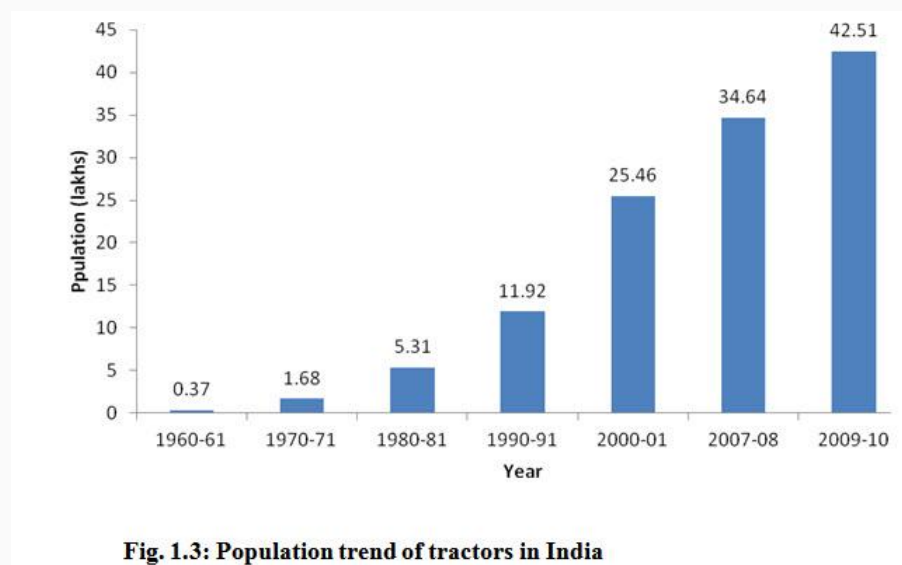
Source: Agricultural Engineering Today Vo. 34(4), 2010 *Projection

2. Draught animal Power: Bullocks, buffalos, camels and pack animals horses, ponies, mules and donkeys are used as a source of power for doing different agricultural and commercial activities. The population trend of draught animal is given in Fig. 1.2. activities. The population trend of draught animal is given in Fig. 1.2.



Source: Agricultural Engineering Today Vo. 34(4), 2010 *Projection

Tractors: The cumulative population is given in Fig.1.3.



Source: Agricultural Engineering Today Vo. 34(4), 2010 & Agricultural Research Data Book, 2011

Power Tiller: Power tillers also called as walking type tractor are generally used in hill farming and land holding is small. The population trend of power tiller is given in Fig 1.4.

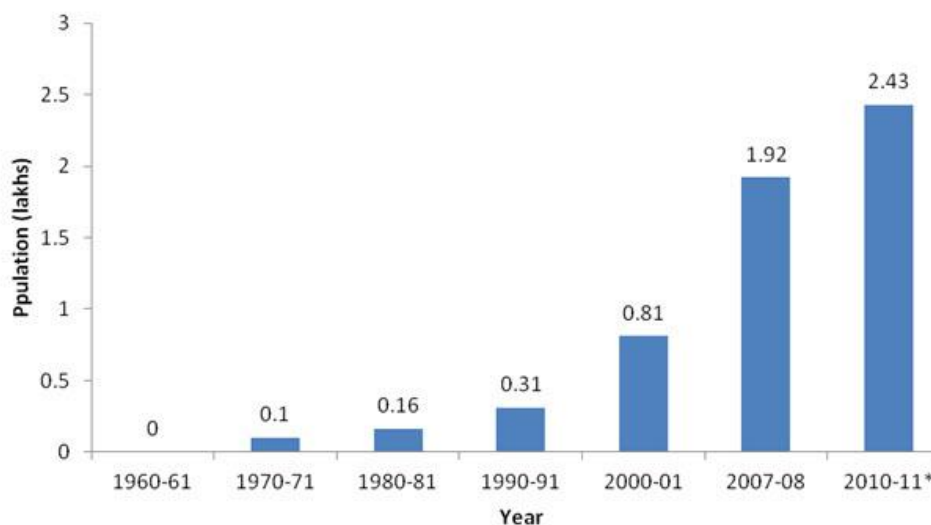


Fig. 1.4: Population trend of power tillers in India

Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection

Self Propelled Machines: Rice transplanters, Power weeders, sprayers, reaper binder, combine harvesters have their own engine as source of power. These type of machine are called self propelled machine.

Stationary Power sources:

Diesel engine: Diesel engine is used in pump sets, sprayers, threshers, chaff cutters, sugar cane crushers and other stationary operations as source of power.

Electric Motor: These are used in pump sets, sprayers, threshers, chaff cutters, sugar cane crushers and other stationary operations as source of power. The cumulative pump sets energised in India is given in Fig.1.5.

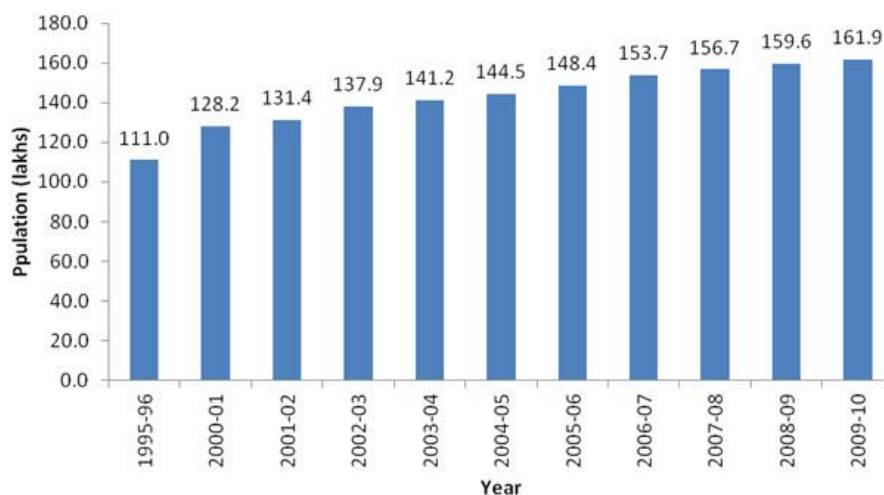
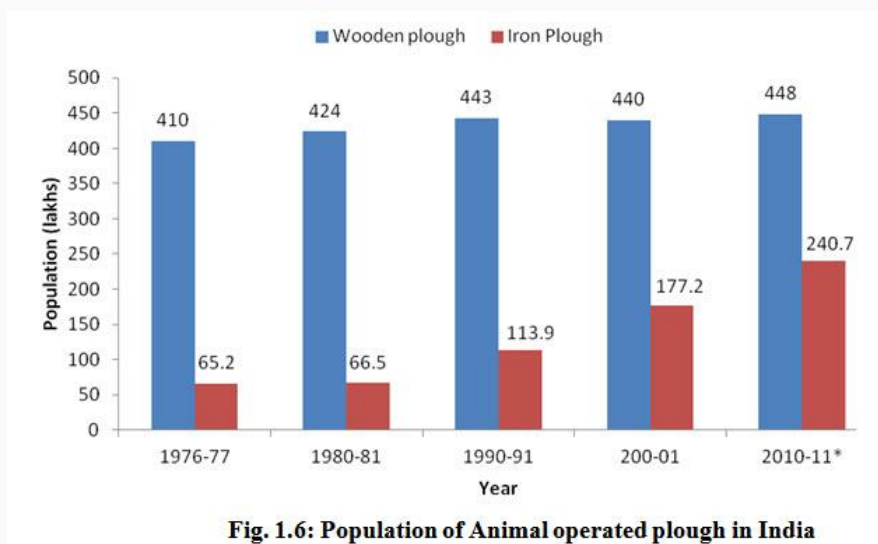


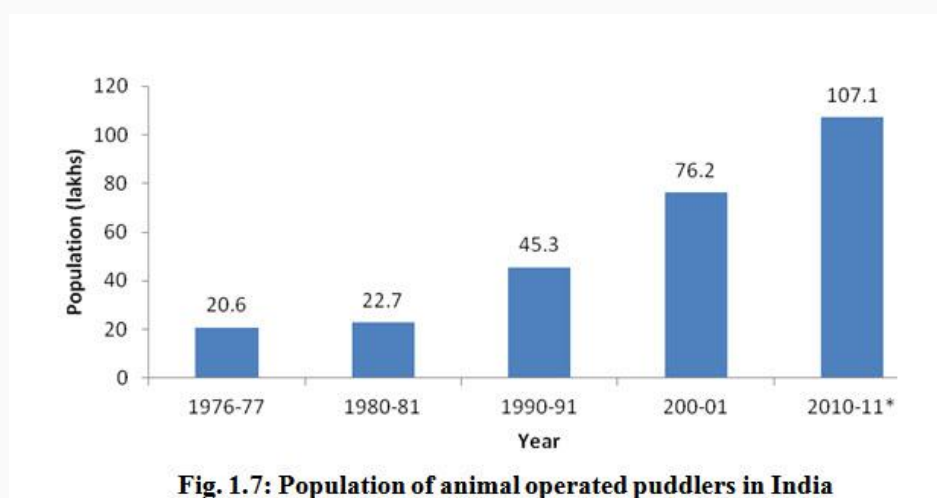
Fig. 1.5: Cumulative pump sets energized in India.

Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection

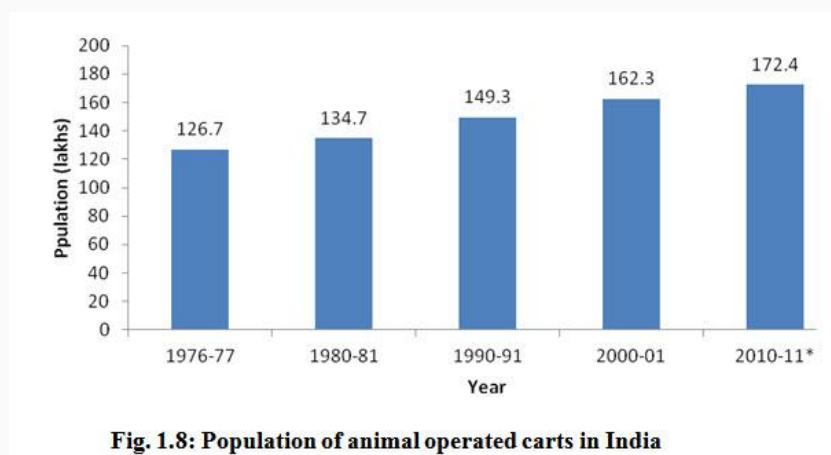
Animal operated implements: The population of animals operated plough puddlers and carts is given graphically in Fig. 1.6, 1.7, 1.8 respectively.



Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection



Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection



Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection

Tractor operated implement:- Population of tractor operated plough, disc harrow, cultivators, planter, levellers, thresher is given in. Fig. 1.9 to Fig. 1.14.

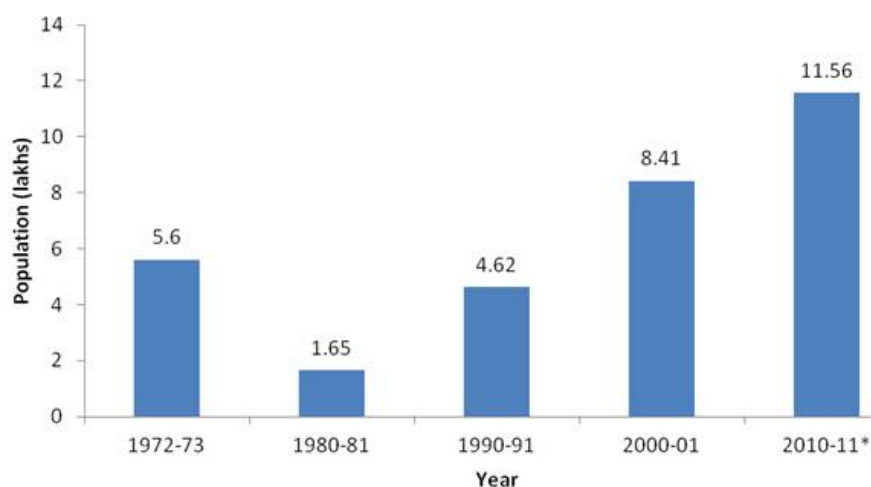


Fig. 1.9: Population of power operated ploughs in India

Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection

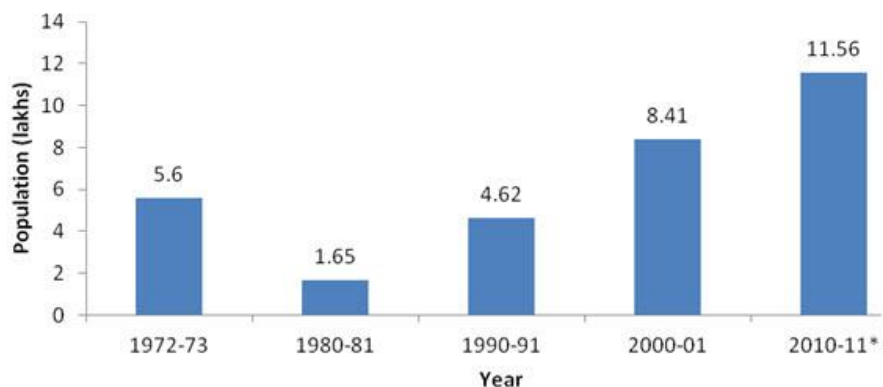


Fig. 1.10: Population of power operated harrows in India

Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection

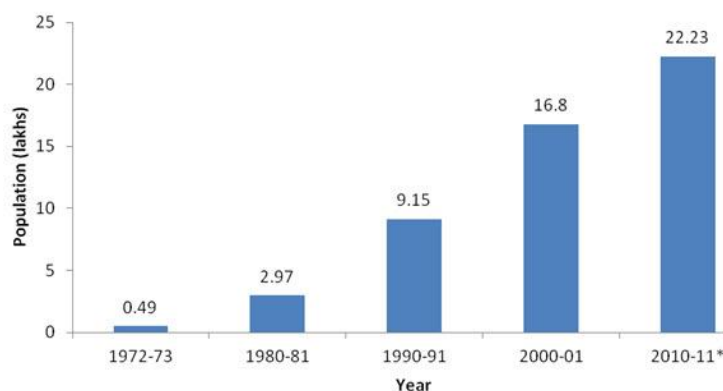


Fig. 1.11: Population of power operated levellers in India

Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection

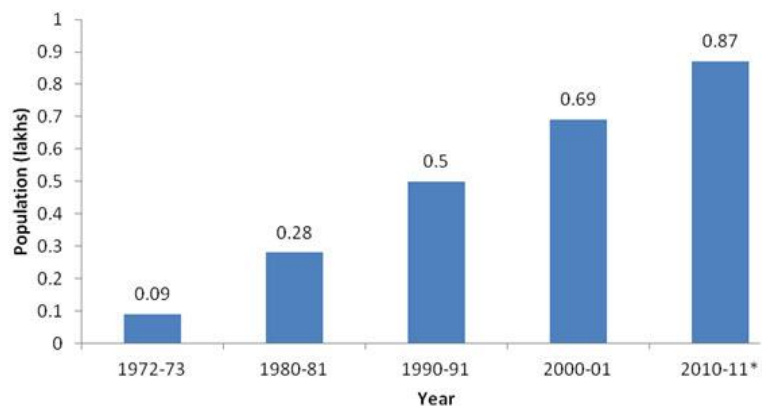


Fig. 1.12: Population of tractor drawn planters in India

Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection

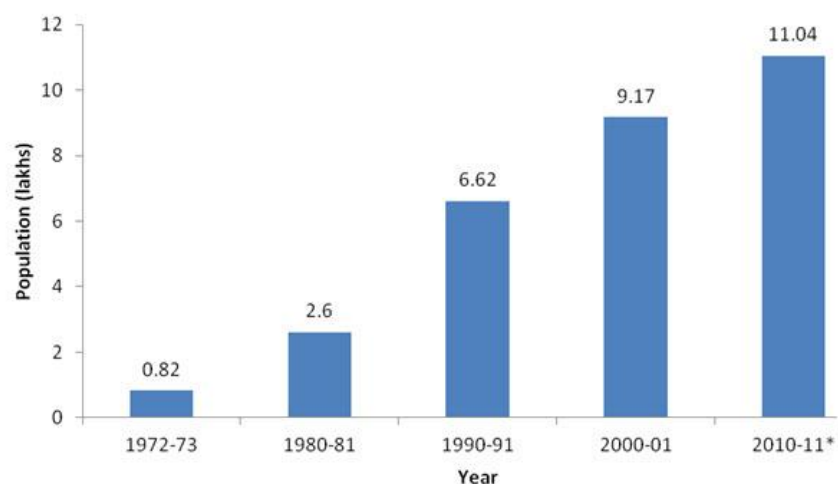


Fig. 1.13: Population of power operated cultivators in India

Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection

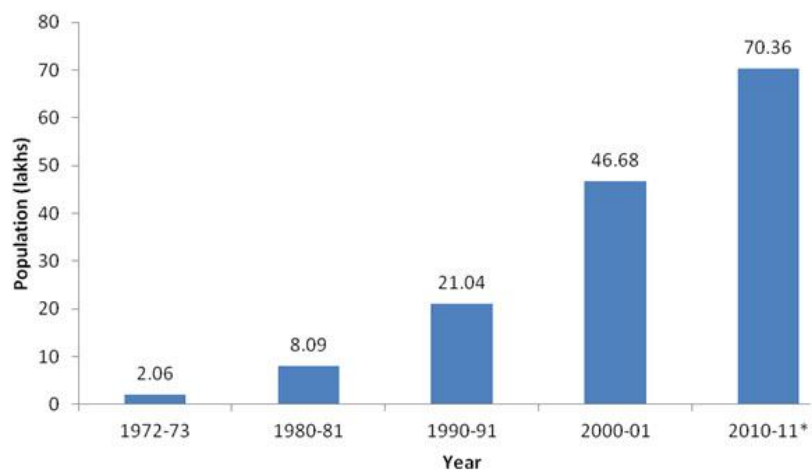


Fig. 1.14: Population of power operated threshers in India

Source: Agricultural Engineering Today Vo. 34(4), 2010 * Projection

The total power availability in the country was 0.3 kW/ha in the year 1971-72 which increased to 0.76 kW/ha in 1991-92, 1.23 kW/ha in year 2001-02 and 1.78 kW/ha in 2011-12. The annual increase in availability of farm power is estimated as 0.03 kW/ha/year. The level of mechanization in the country has shown an increasing trend, however there has been contrasting disparity in its spread. The estimates indicate that the highest availability of power on farm (2005-06) was in the state of Punjab (4.03 kW/ha) followed by Haryana 2.90 kW/ha, Tamil Nadu 1.23 kW/ha, Andhra Pradesh 1.1 kW/ha and West Bengal 0.69 kW/ha respectively and only 0.35 kW/ha in Orissa. The mechanisation in western and southern states of the country viz. Gujarat, Maharashtra, Rajasthan and certain areas of Tamilnadu, Andhra Pradesh etc has increased with increase in area under irrigation. The pace of mechanisation in North-Eastern states has not been satisfactory due to constraints such as hilly topography, socio economic conditions, high cost of transport and lack of institutional financing and lack of farm machinery manufacturing industries. By and large India is self-sufficient in mechanisation inputs and the Indian farmers have adopted mechanisation input for modernisation of their agriculture. Equipment for tillage, sowing, irrigation, plant protection and threshing have widely been accepted by them. The improved hand tools, animal drawn and tractor operated implement have been adopted more in these states where productivity per unit area has increased.



Lesson 27. Factors in favour of farm mechanization

Factors in favour of farm mechanization: Factors which justify the farm mechanisation in India are given below:

- a) Timeliness of farm operations
- b) Increased cropping intensity
- c) Increased area under crop production.
- d) Increased productivity
- e) Increased labour productivity and employment generation.
- f) Reduced cost of production.
- g) Commercialization and diversification of agriculture.
- h) Drudgery reduction
- i) Improved quality of life and rural upliftment.
- j) Quality improvement and value addition.

1. **Timeliness of farm operations:** The timeliness of field 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 is done up to the first fortnight of November, a delay beyond this period by every one week leads to about 1.50 q per acre decrease in yield. Appropriate farm machines may have to be introduced to ensure timely farm operations which may also result in 20-30% saving in operation time.
2. **Increased cropping intensity:** The time taken to perform sequence of operations is a factor determining the cropping intensity. Agricultural mechanisation has made significant contribution in enhancing cropping intensity. The growth in irrigated areas and tractor density has had direct bearing on cropping intensity. Cropping intensity was the highest in mechanised farms having tubewell and tractors (206.4%) followed by partially mechanised farms having only tubewell (176.6%) and non-mechanised farm (143.8%). Thus, facilities of assured tubewell irrigation and mechanical power helped the farmers in raising cropping intensity on their farm significantly.
3. **Increased area under crop production:** Food production levels of the country shall be enhanced by improving crop productivity and enhancing area under cultivation of food crops. Mechanisation is a powerful tool which enhances human capacity and allows timeliness, efficiency and consistency in field operations. With the help of mechanisation not only productivity will improve but also uncultivated land and marginal lands can be availed under cultivation.

4. **Increased Productivity:** Higher productivity of land is an important factor which clearly justified farm mechanisation. Different researcher have concluded that farm mechanization enhances the production and productivity of different crops due to timeliness of operations, better quality of operations and precision in the application of inputs. The states with higher level of farm power have higher productivity levels of food grains. Sowing of 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 device.
5. **Increased labour productivity and employment generation:** With mechanization not only the output per hour is more, the total labour requirement is also reduced by about 20-30%. In agricultural production system, there are ways by which it contributes to employment generation i.e. Increased cultivated area and Increased in cropped area due to technological change and infrastructure investments.
6. **Reduced cost of production:** With increased in crop production for per unit area and per unit time, the cost of production is automatically reduced.
7. **Commercialisation and diversification of agriculture:** As production increases with mechanisation of farm operations, it creates a good scope for commercialisation.
8. **Drudgery reduction:** Farm mechanisation can help to perform the power intensive and ergonomically arduous tasks. Thus mechanisation contrary to the restricted opinion in labour displacement, stands to compliment human labour in improving agriculture production in India and decrease drudgery in field operations, thereby enhancing quality of life of rural man and woman.
9. **Improved quality of life and rural upliftment:** Mechanisation provided entrepreneurship opportunities and sustainable rural livelihoods and facilitates crop processing and there by improves rural economic opportunities.
10. **Quality improvement and value addition:** Timely marketing will be made possible by quick mechanical transportation, cleaning and handling of farm produce.

Future targets to achieve the desired level of mechanisation in India:

Future targets in farm mechanization to be achieved in India would be:

- To increase total power availability in Indian agriculture to 2 kW/ha (with share of mechanical, electrical and animal powers as 70, 25 & 5% respectively) by the year 2020.
- To increase productivity and conserve resources through effective utilization of chemical, biological and mechanical inputs.
- To mechanize commercial crops like sugarcane, cotton, fruits and vegetable especially potato crops and green house (covered) cultivation.
- To mechanize the dry land areas of the country which occupy about 66% of the total cultivated area, where timeliness of field operations especially during seed bed preparation and sowing & planting is crucial to establish a good crop stand in deficient/ receding soil moisture content.
- To develop machinery with greater precision agriculture to achieve increase in production by increasing the cropping intensity and per hectare productivity.

Farm Power and Machinery Management

- To develop high capacity farm machines for timeliness of operation where turnaround time is low and use developed high capacity machines on custom hiring and for contractual field operations.
- To strengthen R & D – manufacturer linkages for speedy commercialization.
- To put more emphasis on the development of agricultural tractors and engines to run on vegetable oil, alcohol and other oils of plant origins.
- To improve management of farm machinery. Appropriate high capacity farm machines matching to power sources may have to be introduced to ensure timely farm operations without further delay.
- To mechanize hill agriculture by developing appropriate technologies, where there is tremendous potential of growing fruits, vegetables, flowers etc.
- To make concerned efforts for controlled application of water through drip, sprinkler and micro-sprinkler systems to economize the use of water and improving water use efficiency.
- Diversification of agriculture for growing high value crops and horticulture, floriculture, industrial crops, mushroom cultivation, agro forestry and energy plantation through contract farming and cultivation by the industries with progressive farmers to modernize agriculture for producing high value crops.
- To improve quality, reliability & safety in the manufacture of farm machinery for their export to other developing countries.
- To standardize the manufacture of critical components of improved farm machinery and encourage for their mass production by medium and large-scale manufacturers.

Policy Initiatives by the Government of India to Promote Farm Mechanization

1. Training : Establishment of Four Farm Machinery and Technology Training Institute (FMTTI)
2. Demonstration: Large Scale Demonstration of Equipment at Farmers Field
3. Incentives for Purchase of Equipment: Subsidy through MMA, NFSM, NHM and Similar Other Schemes Available to all Categories of Farmers; Subsidy for tractors up to 40 PTO hp
4. Incentives for establishment of Machinery Banks at Block Levels for Custom Hiring Services
5. Identification of Machines for
 - Hill Agriculture
 - Gender friendly Tools and Equipment

Farm Power and Machinery Management

- Crop Specific Package of Machines
 - Manufacturing Sector
 - De-reservation of Manufacturing of Agricultural Machines from Small Scale Sector
 - Training on Manufacturing Technologies Introduced
6. Quality of Machines: Minimum Performance Standards for Tractors, Power Tillers & Combine Harvesters Framed; Standard Specifications for All Machines; Equipment Promotion through Subsidy: Testing by FMTTI or BIS certification is mandatory
 7. Credits: NABARD Refinance available & Financing Norms Simplified
 8. Agro Processing Sector: Scheme on Post Harvest Technology
 9. Technologies Developed by ICAR / CSIR Promoted
 10. Study to formulate long-term mechanization strategy for each agro climatic zone. Agro-climatic zones of India Divided into 15 agro-climatic zones and further subdivided into 73 Sub- Zones. Objectives of the study relating to formulating long term Mechanization strategy were:

- a) To study the soil types, land topography.
- b) To study the socio-economic conditions
- c) To study the present status, ultimate potential, the gaps, highlighting critical ones; for equipment used in various agricultural operations starting right from tillage to the post-harvest operations.
- d) To study the types and utility of various agricultural equipment, both conventional and improved ones, presently in use and those needed in future, for different crops/cropping systems in the Zones.
- e) To study the impact of farm mechanization on employment of labour.
- f) To study the cropping pattern, both agricultural and horticultural, in the Zones, yields in relation to the national average, and their growth potential.
- g) To study and assess the use of farm power per hectare, ultimate requirement, ways and means to fulfill the gaps for various farm operations. To study the infrastructure facilities for the manufacture, marketing, after sale service/repairs availability etc. of agricultural equipment.
- h) To study and assess the adequacy and the requirement of infrastructure at the central and State levels, for planning, promotion, execution and extension of the various plan programmes on agricultural mechanization.
- i) To identify new/improved farm equipment that may be needed by the farmers during next 20 years, i.e. by the year 2020, for carrying out different farm operations.

j) To formulate strategies and programmes that may be required for mechanization of agriculture during the period 2001–2005, 2005–2010, 2010–2015, 2015–20.

Long-term Mechanization Strategy Study -Recommendations

The annual investment on agricultural machinery including tractors, power tillers, engines, etc., is more than Rs 500,000 million compared to the combined annual investment of Rs 240,000 million on fertilizers, certified seeds and plant protection chemicals. Due to poor information and inadequate guidance, the farmer often makes wrong selection of machinery leading to improper investment. This requires an Agricultural Mechanization Board at the Center under the Chairmanship of the Minister of Agriculture, to take policy decisions at the national level, review and revise mechanization strategies, monitor the programmes of mechanization and make such interventions as may be required to keep the programmes in line with general agricultural goals and policies.

There should be Agricultural Mechanization Councils in the States which should have the same functions as the Agricultural Mechanization Board in respect of the States which should be chaired by the Ministers of Agriculture. The programmes of Agricultural Mechanization at the Center should be headed by a Commissioner of Agricultural Engineering & Technology who should be directly responsible for the planning and monitoring of agricultural mechanization programmes at the national level and who should oversee testing and training activities of the FMTTIs. Director of Agricultural Engineering and Technology should head the agricultural mechanization programmes at the State level.

TESTING AND TRAINING

Selected SAUs and Research Institutes with strong agricultural engineering component should be supported by DOAC to develop facilities and undertake farm machinery testing for the purpose of Bureau of Indian Standards (BIS) certification, to help the manufactures to improve quality of equipment and to provide information on machinery performance to DOAC and other organizations. The tractor testing should remain exclusively with FMTTIs Centers.

The State Directors of Agricultural Engineering, SAUs, State Agro-Industries Corporations, FMTTIs, ICAR Institutes having Tractor Training Centers (TTCs), KVKs and tractor and farm machinery dealers should be made responsible for training tractor and machinery operators.

Orientation/refresher courses for the functionaries of the above listed organizations should be organized at regular interval with the cooperation of Agricultural Universities and ICAR Institute

RESEARCH AND DEVELOPMENT

- Agricultural mechanization research and development programmes in the SAUs and ICAR Institutes should be strengthened.
- The programmes of Front Line Demonstration (FLD) of farm machinery should be strengthened.

Farm Power and Machinery Management

- Research and Development (R&D) programmes should be reoriented to deliver outputs which are needed by the farmers and are marketable.
- Encourage custom hiring operation of tractors, power tillers and farm machinery.
- Contract farming should be encouraged.
- Organize farm machinery cooperatives at selected locations

The R&D programmes in future should focus on the development of farm machinery and power units for:

- Precision and protected agriculture.
- Hill agriculture.
- Horticulture, cash and plantation crop.
- Recovery and management of crop residues.
- Non-farm applications like efficient rural transport, maintenance of village roads, etc.,

Sample equipment like hill side tractors, tool carriers, precision planters, transplanter, harvesters and pickers for sugarcane, cotton, fruits, etc, high capacity mowers, swathers and balers and mechanical handling equipment should be imported and made available to R&D Institutes

Resource Conservation

- The farmers should be encouraged to incorporate crop residues into the soil to improve its organic matter content.
- Periodic sub-soiling should be practiced to avoid hard pan formation.
- Equipment for forming raised beds, precision leveling to improve water use efficiency should be encouraged.
- Energy saving practices like zero till planting, strip till planting, use of machine combines and throttle down - high gear operation of tractors should be demonstrated and promoted.
- Micro-irrigation system viz. sprinkler and drip irrigation system should be encouraged to save energy and improve water utilization efficiency.

QUALITY OF FARM MACHINERY

- Selected SAUs, Agricultural Engineering Institutes of ICAR and ITIs should be supported to develop competence and offer intensive training to young technicians and artisans in the fabrication and manufacture of farm tools and machinery.
- Farm machinery manufacturing is reserved for small scale industries.

Farm Power and Machinery Management

- FMTTIs should continue to test tractors and power tillers, zonal farm machinery testing centers should be established.
- Farm machinery manufacturers training programmes and manufacturers business meets may be organized to create awareness among the manufacturers about the production of quality agricultural equipment and machinery.
- FMTTIs/SAUs/ICAR Institutes and other R&D organizations should offer technical support and testing facilities to the farm machinery and processing equipment manufacturers to improve the quality of their products.

Literature Cited:

- 1) Singh S P, Singh R S and Surendra Singh (2011) Sale trend of Tractors and Farm Power availability in India. Agricultural Engineering Today. Vol. 35(2).
- 2) Tyagi K K, Jagbir Singh, K K Kher and V K Jain and Surendra Singh (2010) Status and Projection Estimates of Agricultural Implements and Machinery in India. Agricultural Engineering Today. Vol. 34(4).
- 3) Mehta C R (2013) Status and Future Mechanization in Indian Agriculture. Lecture delivered in "Summer School on Machinery for Natural Resource Management and Technologies" held at Deptt. Of FM&PE, PAU, Ludhiana.
- 4) Sharma D N and S Mukesh (2013) Farm Power and Machinery Management (Principles and Practices) (Vol.-1). Jain Brothers (New Delhi)
- 5) Verma S R (2007) Farm Mechanisation for Diversification of Agriculture. Lecture delivered in "National seminar on Farm Mechanisation for diversification of agriculture" held at Deptt. Of FM&PE, PAU, Ludhiana organised by the Institution of Engineers (India) Ludhiana local Centre



Module 7. Case studies and agricultural mechanization in India**Lesson 28 to 32**

Between 1960 and 2010, the growth rate in power in Indian farms was 3.5 per cent and reached to 1.60 kW/ha (Fig. 1). In 1960-61 major contribution (92.31%) in farm power was from animate power (human + draught animal), where as in 2008-09 the major share was that of mechanical and electrical power (85.30%), Fig. 2. Over the years the contribution of animate source of power, especially that of draught animals, has been going down drastically. This shows that the additional need of farm power is being met through mechanical and electrical sources of power. This trend is going to continue in future also. For adoption of higher level of technology to perform complex operations within time constraints and with comfort and dignity to the operators, mechanical power becomes essential. Thus, the extent of use of mechanical power serves as an indicator of acceptance of higher level of technology on farms. Food grains productivity in India has increased from 0.710 t/ha in 1960-61 to 1.856 t/ha in 2008.09, while farm power availability has increased from 0.296 kW/ha to 1.600 kW/ha during the same period. Thus, food grains productivity is positively associated with unit power availability in Indian agriculture (Fig. 3). The relationship between food grains productivity and unit farm power availability for the period 1960-61 to 2008-09 were estimated by log linear function, with highly significant value of coefficient of determination (R^2) as following:

$$Y_{\text{fgs}} = 674.18 \ln(X_{\text{ps}}) + 1480.8$$

$$R^2 = 0.989$$

Where,

Y_{fgs} = food grains productivity of India, kg/ha, and

X_{ps} = power availability in India, kW/ha

This indicates that productivity and unit power availability is associated linearly. It is also evident that farm power input has to be increased further to achieve higher food grains production, the composition of farm power from different sources to be properly balanced to meet its timely requirement for various farm operations.

Fig. 1: Power availability scenario from different source in Indian agriculture.

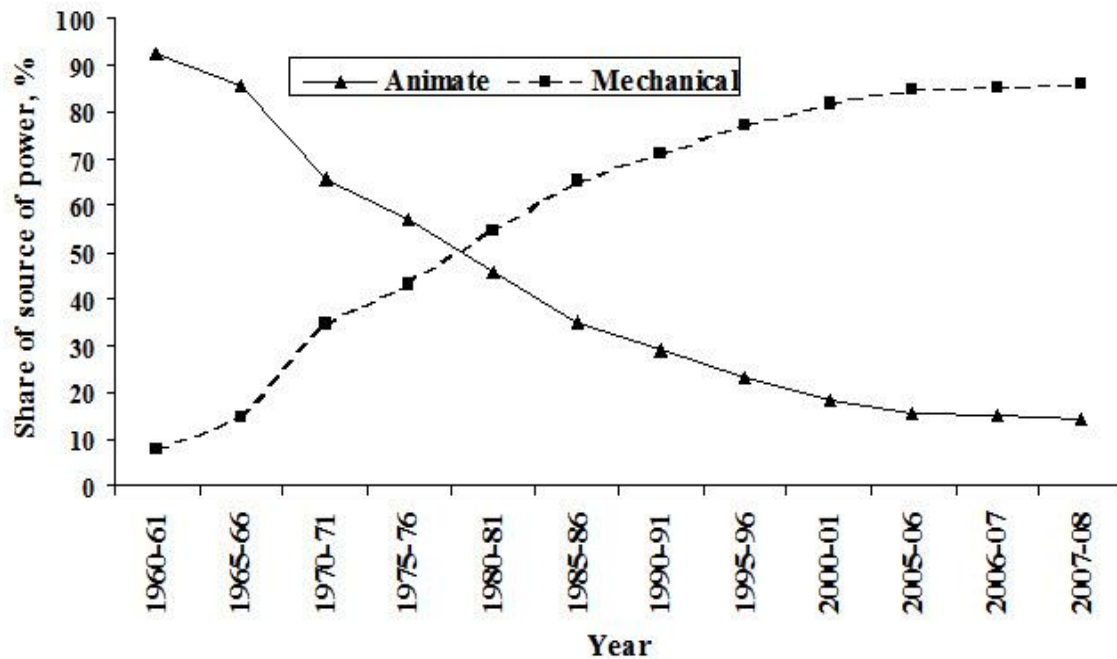
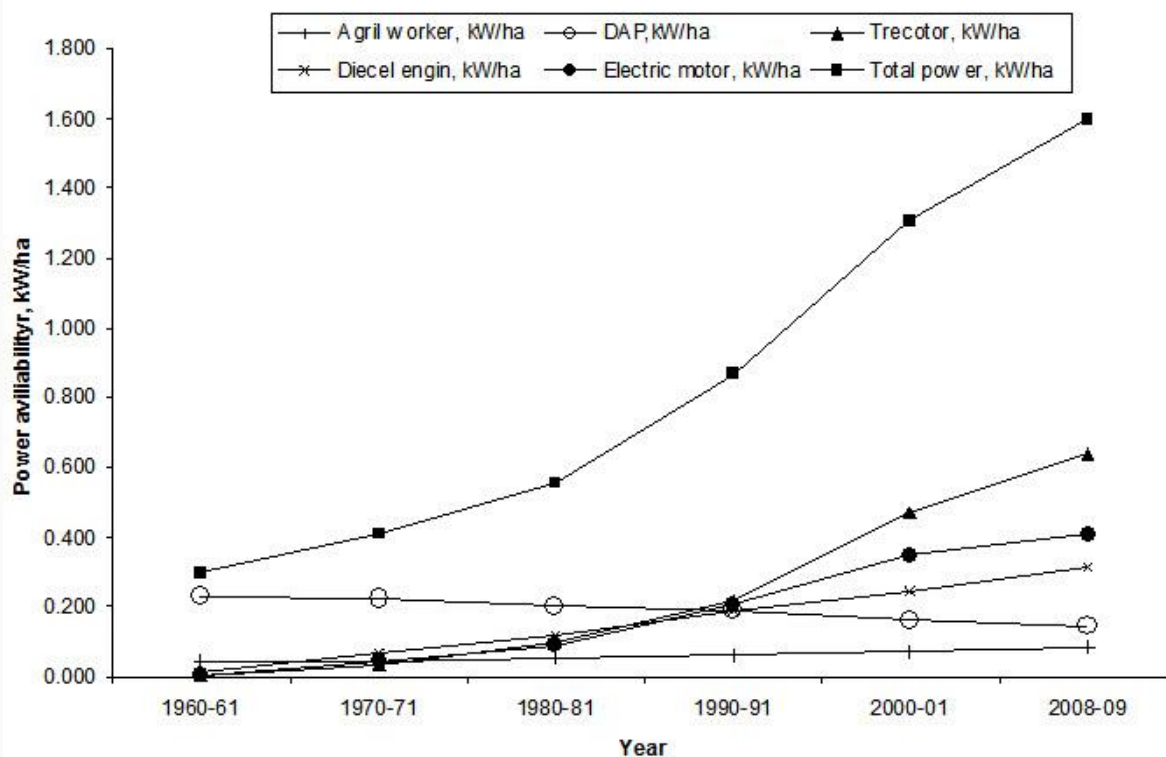


Fig. 2: Animate and mechanical power scenario in Indian agriculture.

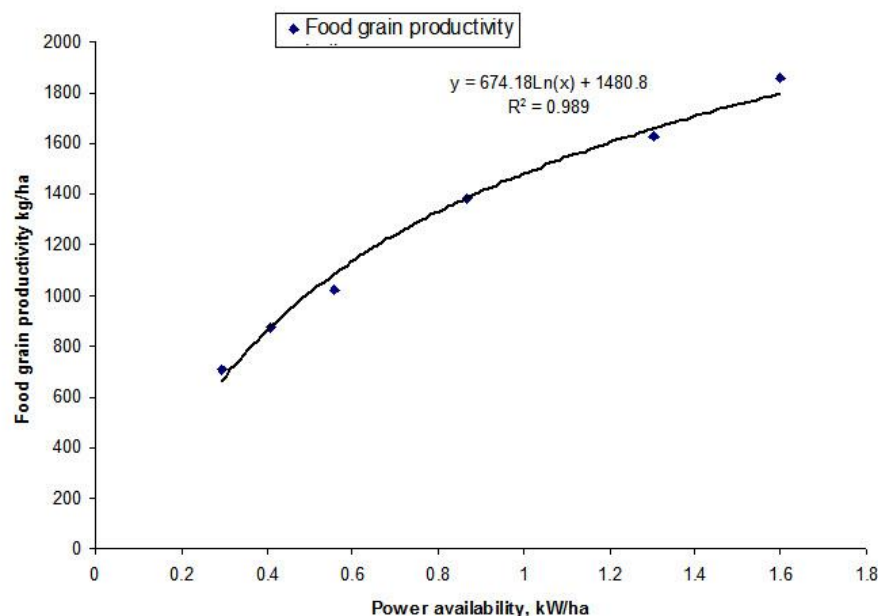


Fig. 3: Food grain productivity and power availability relationship in Indian Agriculture.

Some Calculations

Q. No. 1: Find out optimum tractor power required for draw bar operation and transportation for paddy wheat crop rotation in light soil for field of area of 10 ha.

FC% = 25.84 , U = 0.7, H = 8 h/day, Pt = 9400 Rs/kW

Crop	Implement	A (ha)	E (kWh/ha)	r	n	K	Y	V	Sc	Nt	$\frac{100AEn}{r (Fc\%)(Pt)} \times (L + \frac{KYVA}{(Sc)(Nt)(u)(h)})$
Paddy	Disc Harrow	10	6.187	0.5	2	0.00625	51.98	500	4	2	4.713
	Cultivator	10	3.324	0.5	2	0.00625	51.98	500	4	2	2.536
	Planker	10	3.037	0.5	2	0.00625	51.98	500	4	2	2.317
Wheat	Disc Harrow	10	6.187	0.5	2	0.00456	43.42	580	4	2	3.631
	Cultivator	10	3.324	0.5	2	0.00456	43.42	580	4	2	1.953
	Planker	10	3.037	0.5	2	0.00456	43.42	580	4	2	1.785
	Seed Drill	10	1.248	0.5	1	0.00456	43.42	580	2	1	1.158
										Total	18.093

Power required for transportation of material for Paddy - Wheat rotation

Crop	W (t/ha)	A(ha)	Distance (kM)	Labour (Rs/h)	r	$(100 \times 0.27 \times \text{Dis} \times W \times A \times \text{Labour}) / (\text{FC}\% \times \text{Pt} \times r)$
Paddy	7.44	10	10	10	0.4	2.071
Wheat	5.765	10	10	10	0.4	1.579

Optimum tractor power requirement, $P = [18.093 + 2.071 + 1.579]^{1/2} = 4.663 \text{ kW}$

Q. No. 2: Find out the least width of disc harrow, cultivator, planter & seed drill in light soil for Paddy wheat rotation. Given Fc% of disc harrow, cultivator & planker is 24.2% and FC% for seed drill = 23.09%, P = Price of implement per unit width

Implement	$\frac{100 \times c}{\text{Fc}\% \times p}$	$\frac{A}{s \times e} (L + Ch + \frac{K \times Y \times A}{Sc \times Nt \times U \times h})$		Width (m)
		Paddy	Wheat	
Disc Harrow	0.00416	185.89	132.77	1.151
Cultivator	0.0187	154.91	110.64	2.228
Planker	0.0206	185.89	132.77	2.566
Seed Drill	0.00614	0	312.40	1.385

Q. No. 3: Find out optimum tractor power required for drawbar operations for cotton wheat crop rotation in light soil. FC% = 25.8%, U=0.7, H=8 hr/ day, Pt = 9400Rs./kW

Crop	Implement	A (ha)	E (kWh/ha)	r	n	K	Y	V	S c	N t	$\frac{100AEn}{r(\text{Fc}\%)(\text{Pt})} \times (L + \frac{KYVA}{(Sc)(Nt)(u)(h)})$
Wheat	Disc Harrow	10	6.187	0.5	2	0.00456	43.42	580	4	2	3.631
	Cultivator	10	3.324	0.5	2	0.00456	43.42	580	4	2	1.953
	Planker	10	3.037	0.5	2	0.00456	43.42	580	4	2	1.785
	Seed	10	1.248	0.	1	0.00	43.	58	2	1	1.158

Farm Power and Machinery Management

	Drill			5		456	42	0			
Cotton	Disc Harrow	10	6.187	0.5	2	0.0351	2.05	2200	4	2	2.434
	Cultivator	10	3.324	0.5	2	0.0351	2.05	2200	4	2	1.309
	Planker	10	3.037	0.5	2	0.0351	2.05	2200	4	2	1.197
	Planter	10	1.645	0.5	1	0.0351	2.05	2200	2	1	0.889
										Total	14.346

Optimum tractor power requirement, $P = [14.346 + 0.225 + 1.579]^{1/2} = 4.020 \text{ kW}$

Power required for transportation of material for cotton – What rotation

Crop	W (t/ha)	A (ha)	Distance (km)	Labour (Rs/h)	r	$(100 \times 0.27 \times \text{Dis} \times W \times A \times \text{Labour}) / (\text{FC}\% \times \text{Pt} \times r)$
Cotton	0.809	10	10	10	0.4	0.225
Wheat	5.765	10	10	10	0.4	1.579

Optimum tractor power requirement, $P = [14.346 + 0.225 + 1.579]^{1/2} = 4.020 \text{ kW}$

Q. No. 4: Find out the least cost width of farm implements in light soil for cotton wheat rotation. FC% of disc harrow, cultivator planker = 24.2% FC% for seed drill = 23.19% p = price of implement per unit width

Implement	$\frac{100 \times c}{\text{Fc}\% \times p}$	$\frac{A}{s \times e} (L + Ch + \frac{K \times Y \times A}{Sc \times Nt \times U \times h})$		Width (m)
		Wheat	Cotton	
Disc Harrow	0.00416	132.701	73.996	0.927
Cultivator	0.0187	110.584	61.664	1.795
Planker	0.0206	132.701	73.996	2.066
Seed Drill	0.00614	312.237	-	1.384
Planter	0.00586	-	198.982	1.079

Q. No. 5: Find out the time for drawbar operation and transportation in heavy soil for cotton wheat rotation for field of 10 ha. Consider distance for transfer rotation=10 km and r= 0.8

Crop	Implement	A(ha)	N	E (kWh/ha)	P (kW)	LCF	VW (t/ha)	$T_{field} = \frac{E \times A \times 10}{LCF \times P}$	$T_{trans} = \frac{0.27 \times D \times W}{r \times P}$
Wheat	Disc Harrow	10	4	6.178	4.389	0.5	5.67	112.59	43.63
	Cultivator	10	3	3.324	4.389	0.5	-	45.43	-
	Planker	10	4	3.037	4.389	0.5	-	55.36	-
	Seed Drill	10	1	1.248	4.389	0.5	-	5.68	-
Cotton	Disc Harrow	10	3	6.178	4.389	0.5	0.81	84.45	6.22
	Cultivator	10	8	3.324	4.389	0.5	-	60.58	-
	Planker	10	3	3.037	4.389	0.5	-	41.52	-
	Planter	10	1	1.645	4.389	0.5	-	7.49	-

Total Tractor running time in h/year, T = 462.99 h

The cost of Power per hour can be calculated as

$$Ch = \frac{P \times Pt \times Fc\%}{100 \times T} = \frac{4.389 \times 9400 \times 25.8}{100 \times 462.99} = 22.99 \text{ Rs/h}$$

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