Ind. Jn. of Agri. Econ.
Vol.70, No.1, Jan.-March 2015

Agricultural Mechanisation Development in India*†

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I

INTRODUCTION

The story of the development of agricultural mechanisation in India is both fascinating and in many ways, quite remarkable. The country has moved forward over the past six decades from one in which it then faced severe food shortages to where today it has become an exporter of many food commodities and a major exporter of other industrial products, including agricultural tractors. This has been achieved despite a more than three-fold increase in its population and insignificant increase to the arable land area.

India is the second most populous country in the world with an estimated population of 1.25 billion in 2014 and an annual growth rate of 1.3 per cent. About two-third of the population live in rural areas with about 50 per cent still dependent on agriculture for their livelihood.

The total land area of the country is 297 million hectares of which 142 million ha is classed as agricultural land. Whilst it has basically an agrarian economy the share of agriculture has now declined to 14 per cent from a level of 56 per cent in 1950. The manufacturing and service sectors presently constitute 27 per cent and 59 per cent of the economy, respectively. The biggest challenge which the agricultural sector is facing is to meet the growing demand for food to feed the ever growing population of the country.

Since Independence in 1947, there has been more than a five-fold increase in grain production due to the introduction of improved technologies and practices. However, the population has increased at a similar pace and there are still challenges to attaining full food and nutritional security. The country has a very diverse form of agriculture particularly due to varying soil and climatic conditions. Its climate is full of extremities; the temperature conditions vary from arctic cold to equatorial hot and rainfall from extreme aridity with less than 100 mm in the Thar Desert of Western

*Keynote paper presented at the 74th Annual Conference of the Indian Society of Agricultural Economics held at Dr. Babasaheb Ambedkar Marathawada University, Aurangabad, December 18-20, 2014.

†The paper is based largely on Singh, Ganjendra (2013), "Agricultural Mechnization in India" in Kienzle, Josef, John E. Ashburner, and Brian G. Sims (Eds.), *Mechanization for Rural Development: A Review of Patterns and progress from around the world*, Integrated Crop Management, Vol. 20, Food and Agricultural Organization of the United Nations, Rome, pp. 99-119.

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India to the site of the world's maximum rainfall of 11200 mm at Mowsinram in the northeast.

The available rainfall has large spatial and temporal variations. Although there has been a significant increase in the area under irrigation, still about 65 per cent is devoid of assured irrigation and the agricultural productivity in the rainfed areas is low.

Size of Land Holdings and Mechanisation

The average size of land holdings in 2011 was 1.16 ha with only 0.7 per cent (1.0 million) consisting of farms of more than 10 ha but constituting about 11 per cent of the cultivated land while the farms of less than 1 ha (over 67 per cent) constitute about 22 per cent of the cultivated land – the rest of the farms are in the intermediate range with the largest proportion being medium farms (4 to 10 ha) and semi-medium farms (2 to 4 ha) which cultivated 24 per cent each of the total cultivated land in 2011 (Table 1). Thus the three categories comprising large, medium and semi-medium farms (20.7 million farm holdings) cultivate between them 56 per cent of the cultivated land – it is apparent that these three categories of farmers have been instrumental not only for the success of agricultural mechanisation in India but for the overall success of the Green Revolution and the remarkable transformation of the food security situation over the past 50 years.

TABLE 1. LAND HOLDINGS IN INDIA

	Percentage number of holdings in each category				Area under each category			
					Percentage			Average (ha)
Category	1971	1991	2001	2011	1991	2001	2011	2011
(1)	(2)	(3)	(3)	(4)	(5)	(6)	(7)	(8)
Marginal (<1 ha)	50.6	59.2	62.4	67.0	15.0	18.7	22.2	0.38
Small (1-2 ha)	19.0	18.7	19.1	17.9	17.4	20.2	22.1	1.42
Semi-Medium (2-4 ha)	15.2	13.6	11.9	10.1	23.2	23.9	23.6	2.71
Medium (4-10 ha)	11.3	7.0	5.6	4.3	27.1	24.0	21.2	5.76
Large (>10 ha)	3.9	1.5	1.0	0.7	17.3	13.2	10.9	17.37
Average holding size (ha)	2.28	1.57	1.33	1.16				
All holdings (million)	70.5	106.6	119.9	137.8				

Source: (MOA, 2013).

Due to the laws of inheritance the number of holdings is increasing in many states, however, the situation in Punjab, the state with the highest level of mechanisation and the highest productivity, a reverse trend has been witnessed with the marginal holdings declining from 38 per cent in 1971 to 27 per cent in 1991 and only 12 per cent in 2001, cultivating less than 2 per cent of the area. The area under holdings in the semi-medium, medium and large categories in Punjab in 2001, were 22, 43, and 27 per cent, respectively thus cultivating over 92 per cent of the total area. Similar trends are occurring in Haryana and in other parts of the country.

Many rural people owning land have moved to cities for jobs and other opportunities although they are still counted as owners of the land holdings. Their land is cultivated by other family members or rented by other farmers. Thus the actual number of operational holdings is much less than the number reported based on ownership of land. Also, many marginal and small holders work as labourers, away from their villages, renting out their land to other farmers. This has further reduced the number of actual operational holdings. In most cases such land is rented to tractor owners making their operational holdings bigger than their owned land, thus making the ownership of tractors more economically viable. Banks, when sanctioning a loan to a farmer for the purchase of a tractor, take income from custom work into consideration.

Agricultural Growth and Development Planning

India adopted a five yearly planned growth strategy after Independence. Agriculture received particular attention from the very first plan (1951-56) when its situation was critical and the total annual grain production amounted to only 50 million tonnes in 1951. Concerted efforts were made in the late 1960s through the introduction of high-yielding cereal varieties (HYVs), fertilisers, agro-chemicals for plant protection, agricultural machinery and above all agricultural technologies resulting from research and development. This led to the ushering in of the Green Revolution. Grain production attained a three-fold increase by the mid-eighties and in 2013-14 a record harvest of over 268 million tonnes was achieved.

Presently a number of government departments are engaged in agriculture and rural development work in the country. At federal level, agricultural development is under the Ministry of Agriculture and Cooperation. The body responsible for controlling the national agricultural research system is the Indian Council of Agricultural Research (ICAR) under the Department of Agricultural Research and Education of this Ministry. At state level, each has its own Ministry of Agriculture. Other ministries contributing to rural and agricultural development programmes are: Food Processing Industries; Rural Development; Water Resources; New and Renewable Energy Resources; Commerce and Industries; and Finance. The focus of policy support for food and nutritional security include:

1. Fixing of minimum support prices (MSP) and buffer stocking of food grains,
2. Major agrarian reforms including fixing of ceilings and consolidation of land holdings,
3. Investment in rural infrastructure such as rural roads, markets, major irrigation systems, rural electrification, water conservation and watershed development,
4. Building a strong agricultural research and education system coupled with an extensive extension system,

5. Ensuring availability of inputs such as seeds, fertilisers, pesticides and farm machinery,
6. Ensuring availability of credit and subsidies.

Mechanisation and Productivity

In a seminal paper Binswanger (1978) concluded:

"*....The tractor surveys fail to provide evidence that tractors are responsible for substantial increases in intensity, yields, timeliness, and gross returns on farms in India, Pakistan, and Nepal. At best, such benefits may exist but are so small that they cannot be detected and statistically supported, even with very massive survey research efforts. Indeed, the fairly consistent picture emerging from the surveys largely supports the view that tractors are substitutes for labour and bullock power, and thus implies that, at existing and constant wages and bullock costs, tractors fail to be a strong engine of growth. In view of this finding, many of the benefit-cost studies reported may have overestimated the benefits, both social and private which arise out of the agricultural uses of tractors. Except in situations where area effects are possible—or by renting or buying from others—private returns to tractors from agricultural operations must be close to zero, or even negative at current fuel prices...*"

In another paper Binswanger (1986) stated,

"*....In general, mechanisation will contribute little to growth in countries without a land frontier and with densely populated farmland — such as Bangladesh, most of India, and China. Given the fact that a high proportion of the work forces in these countries are still engaged in farming, even very rapid growth in the rest of the economy will not lead to rapid wage increases. Labor scarcity cannot be expected to arise from non-agricultural growth in the near future as a driving force for mechanisation....*"

In a major ILO commissioned study Raj (1973) reported similar findings. Such findings created doubts about the agricultural development model based on the use of motorised agricultural mechanisation inputs and led to reduced support for mechanisation by governments in many developing countries and also by international development organisations.

However, Singh and Chancellor (1975), based on a year-long survey, found that agricultural output of farms was related to energy inputs, irrespective of ownership of farm power sources (owned or rented) and the size of land holding had no effect on yield. Farmers with better management (i.e., timely operations, like sowing,

irrigation, weeding, fertiliser and pesticide application; and proper amounts and right techniques of application) had higher yields than those with poor management.

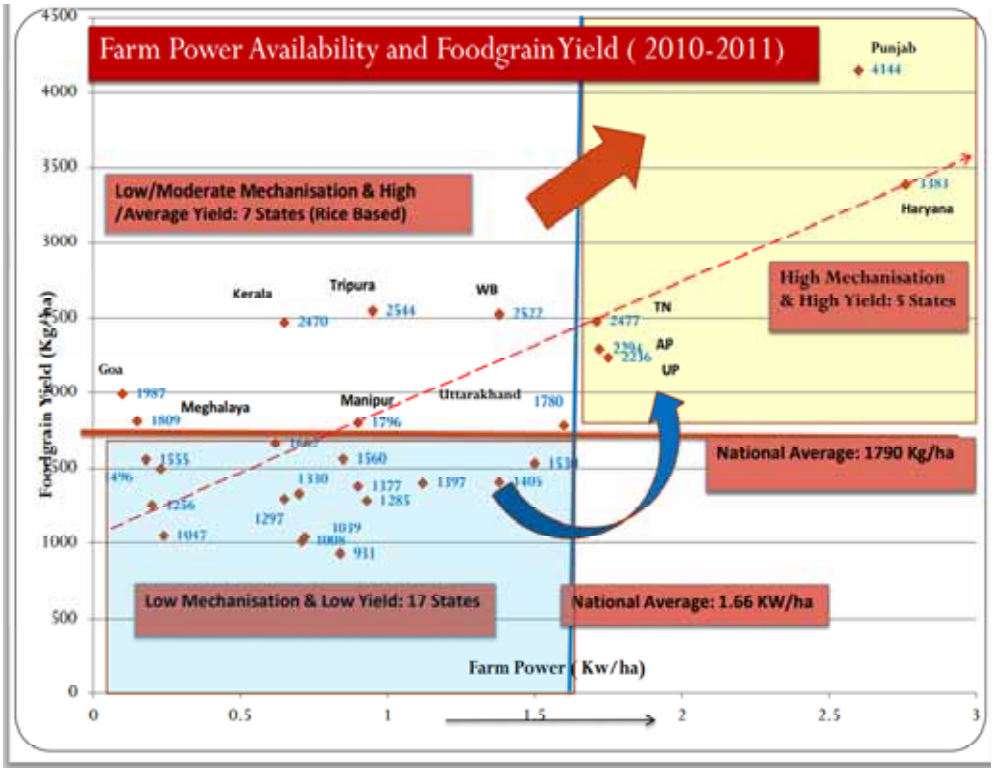
Further, Singh (2001) reported that the economics of ownership of most tractors in India had been justified by custom hiring for on-farm work as well as for off-farm transport and construction activities. The use of tractors in transport activities accounted for about 60 per cent of average annual use of 600 hours. Many small farmers also started purchasing tractors due to the opportunity of custom hiring. Similarly, the ownership of many other farm machines and equipment, like tubewell pumps, threshers and seed-drills became economically viable due to renting out to other farmers. However, ownership of large threshers, laser land levellers and combine harvesters is mainly justified by custom work.

Development of Agricultural Mechanisation

The first tractor to India was brought in 1914. In 1930s pump-sets were introduced in the country. In the 1940's, high horsepower crawler tractors were imported under the aegis of Central Tractor Organisation (CTO) mainly for land development and to eradicate obnoxious weed *kans* grass. At the time of Independence, Indian farmers used mostly bullock-drawn ploughs and wooden planks for pulverisation, compaction and smoothening. Hand tools like spades, pick axe, crowbars, hoe, sickle and chopper were in use. For irrigation, watering buckets and Persian wheels and for transportation bullock carts were in use. In late 1950s, manufacturing of irrigation pump-sets started. There were only about 8,000 tractors in 1950 and these increased to 39,000 units in 1960. Engines (petrol, kerosene, and diesel) were being used for post-harvest processing like floor making, rice milling, grinding, etc.

During the period 1960-1980, more than 90 per cent of public investment in agriculture was for the development of irrigation facilities including medium and major irrigation projects. The result was a significant increase in the area under irrigation, particularly in the states of Punjab, Haryana and Uttar Pradesh. During the era of Green Revolution, provision of a range of inputs such as agro-chemicals and farm machinery contributed towards increasing agricultural productivity. The availability of farm power registered a significant increase due to enhanced contributions from electrical and mechanical sources.

The state of agricultural mechanisation in the country is characterised by large variations in power availability. There is a strong linear relationship between the farm power available and the agricultural output per ha (Figure 1). During 2012-13 the average farm power available country-wide was about 1.84 kW/ha which comprised about 90 per cent from mechanical and electrical sources and only about 10 per cent from animal power and human labour (Mehta, 2013). This underscores the emphasis on the growth and development of power machinery systems in Indian agriculture.



Source: Mehta (2013).

Figure 1. Relationship between Farm Power and Productivity in Different States of India

Farm operations requiring high power inputs and low skill and/or control are generally the first to be mechanised (tillage, transport, water pumping, milling, threshing, etc.). The power intensive work can be done faster and normally at a lower cost. Those operations requiring medium levels of power and skill/control tend to be mechanized next (seeding, spraying, inter-row operations, etc.) whereas those requiring a high degree of skill/control and varying levels of power inputs are mechanised last (transplanting, planting of vegetables, harvesting and grading of fruits and vegetables, etc.); see Table 2. The growth in agricultural mechanisation in India has followed this general pattern.

The growth in farm mechanisation and investments in machinery and equipment up to 2010 are presented in Table 3 and can be divided into two broad periods; (*i*) the initial period from 1942 to 1970 and (*ii*) the period from 1971 to 2010. The growth in farm mechanisation for the period from 2010 to 2014 is also presented in (*iii*).

TABLE 2. SEQUENCE OF MECHANISATION

(1)	First stage (2)	Second stage (3)	Third stage (4)
Type of operation	High power Low skill/control	Medium power Medium skill	Varying power High skill/control
Stationary	Grinding, milling, crushing, pumping, threshing	Grinding by size, cleaning	Grinding by quality
Mobile	Land preparation, transport	Seeding of grain, harvesting of grain	Transplanting, harvesting of fruits and vegetables, sugarcane, cotton

TABLE 3. ASPECTS OF INDIAN AGRICULTURE (1960-2010)

Item (1)	1960 (2)	1970 (3)	1980 (4)	1990 (5)	2000 (60	2010 (7)
Agricultural land (million ha)	133	140	140	143	143	142
Irrigation pumps (million)	0.4	3.3	6.2	12.9	19.5	28.0
Irrigated area (percent)	19	22	28	33	34	35
Cropping intensity	1.15	1.18	1.23	1.30	1.33	1.36
Fertiliser use (kg/ha)	2	15	39	88	125	160
Grain yield (kg/ha)	700	860	1 000	1 300	1 600	1 950
Tractors (thousands)	37	146	531	1 200	2 600	4.000
Area per tractor (ha)	3 600	960	260	120	55	36
Power tillers (thousand)	0	9.5	16	31	100	200
Draught animals (million)	80.4	82.6	73.4	70.9	60.3	50.0

(i) *Initial Period 1942 to 1970*

In 1942, the first degree programme in Agricultural Engineering was started at Allahabad Agriculture Institute and this marked the first formal training and education in the field of agricultural engineering/mechanisation/ in India. During the mid-1940s a few tractors and bulldozers were imported and the Central Tractor Organisation and State Tractor Organisations were established. The first Indian Institute of Technology (IIT) at Kharagpur was established in 1951 and its agricultural engineering programme started in 1952, indicating its importance alongside other engineering disciplines. During this period tractors were not manufactured in India and all tractors were imported. The number of tractors in use grew from 8000 in 1950 to 20 000 in 1955 and 37 000 units by 1960. These were used mainly on larger government and private farms. Up to 1960, most farm operations and transport work were done using draught animals.

During the decade 1961 to 1970 India moved on to the second stage in agricultural mechanisation with tractor production having started in 1961 with an output of 880 tractors by Eicher Tractors Ltd. During this decade five units were licensed to manufacture tractors while production of power tillers started in 1965. In the field of agricultural engineering education this was the most important period. The first College of Agricultural Engineering based on the US Land Grant pattern was established in 1962 at Pantnagar with the help of the University of Illinois

followed by six more colleges and two degree granting divisions/departments at institutes under the Indian Council for Agricultural Research (ICAR).

During this period, 96 per cent of the tractors were owned by big farmers having land holdings of more than 10 ha. In the later half of this decade, the Green Revolution started and a large quantities of HYV wheat and rice seeds were disseminated to the farmers after thorough research trials.

The development of irrigation facilities using water lifting devices was another hallmark of this period. Traditional water lifting devices (Persian wheels) could provide only 2-3 irrigations for wheat whereas high yielding varieties needed 6-8 irrigations per cropping cycle. Large and medium scale farmers purchased diesel engines to power irrigation pumps; renting of pumps also started. Rural electrification to power irrigation pumps expanded during this decade. The tractor population increased about four fold during the decade 1961-70.

(ii) *Period of Significant Progress in Agricultural Mechanisation 1971 to 2010*:

The four decades from 1971 to 2010 are very important in so far as mechanisation is concerned as it is during this period when there was significant progress in agricultural mechanisation in India. During the period 1970 to 2000 the number of power tillers and tractors in use increased from 9500 and 146 000 to 100 000 and 2.6 million respectively while the number of draught animals in use declined from 82.6 to 60.3 million thus demonstrating a significant increase and shift in the sources of farm power in India.

The first decade (1971-80) of these four decades was a period of growth of agriculture in India and there was increased demand for mechanisation services. Six new tractor manufacturing units were established although three which existed prior to this period were closed. In addition six new units were licensed to manufacture power tillers; however two older units were closed. Rural credit became a reality as banks opened branches in the rural areas. The availability of credit to farmers increased and the tractor market expanded rapidly. A concerted effort was initiated to provide incentives to farmers through appropriate price support mechanisms. Minimum support prices for food grains, and sugarcane were declared hence ensuring the profitability of farming. Rural electrification expanded significantly leading to increased power availability to agriculture particularly for irrigation. One more new College of Agricultural Engineering was also established during this decade.

Manufacturing of irrigation pumps and threshers expanded leading to farmers installing electric motor and diesel engine driven irrigation pumps as well as purchasing threshers to handle the increased volumes of produce. During this period, custom hiring of threshers and pump sets increased as many farmers were unable to afford to buy these machines. Custom hiring of tractor implement systems and tractor-trailer units grew rapidly for tillage and transportation respectively. In fact, about 60 per cent of the annual use of the tractors was for custom hiring. However,

draught animals remained the main source of power and their numbers peaked at 83.4 million in 1975.

The second decade (1981-90) was the period which saw a quantum leap in food production and a rapid increase in the rate of agricultural mechanisation. Four new tractor manufacturing units were established but four older units were closed. One new power tiller manufacturing unit started but four older units were closed. The Government of India undertook a concerted effort to popularise tractors and to make them affordable to more farmers. Power tillers and tractors with engine capacity above 1800 cc were exempted from excise duty to encourage mechanisation. India, which had been an importer of tractors up to the 1970s, started exporting them in the 1980s.

There was significant expansion of capacity for agricultural engineering education and seven new agricultural engineering colleges were established. A separate agricultural engineering division was created at the ICAR with responsibility for coordinating R&D projects related to agricultural mechanisation and post-harvest processing at its institutes and state agricultural universities.

Rural electrification expanded and farmers installed more pumps and purchased threshers. Medium farmers and small entrepreneur farmers bought tractors to meet the demand of custom work. Tractor pto-driven threshers gained popularity. The minimum support price was enhanced annually and grain bulk storage facilities expanded significantly. The use of power tillers almost doubled during the decade 1980-90.

By the third decade (1991-2000) agricultural mechanisation had spread widely and policy decisions were taken to allow mechanisation to grow on its own merit and strength. In 1992, the need for a license to manufacture tractors was abolished and during this period, two new tractor units started production. In the field of education eight new Colleges of Agricultural Engineering were established. Custom hiring of machinery and implements became popular in a big way. The majority of the farmers custom-hired threshers (driven by tractors through the pto) provided by entrepreneur-operators who were not necessarily farmers. Use of combine harvesters provided through custom-hire gained wider acceptability.

During the fourth decade (2001-10), an appreciable improvement in the agricultural situation in India had occurred which led to a major boom in agricultural machinery manufacturing. Three major international manufacturers established plants in India: John Deere, New Holland and Same. Due to mergers, Mahindra & Mahindra (M&M) and Tractors and Farm Equipment (TAFE) have become huge conglomerates with international operations. Three new Colleges of Agricultural Engineering were started and the total number of colleges as of 2010 was 30. The annual admission capacity at bachelor level had reached 1200 places, at masters level the intake reached 300 and at doctoral level 100.

The minimum support price for farm produce increased significantly during 2008-2010. The high food prices both in India and globally at this time led to

increased attention to energy and water saving technologies. The zero till drilling of wheat after rice in North India was becoming popular, mainly due to savings both in cost and time. Combine harvesters on custom-hire gained popularity (Mani *et al.* 2008). In contrast, the number of draught animals was rapidly declining.

(iii) *Period of Fast Progress in Agricultural Mechanisation 2010 to Present*:

Due to implementation of the Mahatma Gandhi National Rural Employment Guarantee Scheme (previously known as NREGA), wages for labour throughout India have gone up leading to a scarcity of farm labourers. This has provided a tremendous boost to mechanisation, especially through opportunities for custom hire work. The President of India in her address to the Nation on the eve of Republic Day on 25th January 2011 said:

"...small farmers are leaving farming, because of poor returns and scarcity of agricultural labour. In such a situation, it would be advantageous to think of modernization and mechanized farming..."

The zero till drilling of wheat after rice in North India is becoming popular, mainly due to savings both in cost and time. The use of laser land levellers on custom-hire is growing as it saves irrigation water by up to 30 per cent and helps increase productivity. Combine harvesters on custom-hire are gaining popularity. In contrast, the number of draught animals is rapidly declining. The grain yield reached over 2000 kg/ha and total grain production achieved an all-time record of 268 million tons in 2013-14. The horticultural production also reached about 270 million tons and India became number one producer of milk in the world.

Investments in Agricultural Mechanisation

Over 90 per cent of the public investment in agriculture during 1960-1980 went towards the development of medium and major irrigation projects. In the later period, other aspects such as rural roads, rural electrification and warehouse development received emphasis. In fact, the aim of investments is to generate capital in the form of infrastructure, improvement in the quality of natural resources and assets, and creation of productive assets. The public investment has been used mainly to create infrastructure, whereas private investment has been helpful mainly in asset formation and in bringing about improvements to the quality of existing assets. An increase in public investment definitely induces a rise in private investment, while a decline compels farmers to cope with this adverse impact by further increasing private investment (Chand and Kumar, 2004). The GDP is affected by capital formation as well as subsidies and terms of trade. For example the instant return to one rupee spent in subsidy is much higher than the instant return on one rupee spent for public sector capital formation. In contrast, the long term return from capital formation is more than double the return from subsidies. In fact, diverting one per cent of resources

from subsidies to public investment raises output by more than two per cent. So it becomes necessary to enhance public investment for long term returns. The effects of various forms of investment in mechanisation are discussed below.

(a) *Research and Development*

Agricultural research and education has been a major consideration in agricultural development in India. The Indian Council of Agricultural Research (ICAR) institutes and state agricultural universities (SAUs) are located in several states.

Two institutes of the ICAR conduct research and development exclusively in the areas of farm machinery and post harvest engineering and technology. These are the Central Institute of Agricultural Engineering (CIAE), Bhopal and the Central Institute of Post Harvest Engineering and Technology (CIPHET), Ludhiana.

Research on mechanisation is also conducted by commodity institutes (for sugarcane, cotton, rice, fodder and horticulture) and several national institutes (for fish, dairy, dry-land agriculture and others). Most of the state universities have agricultural engineering programmes with agricultural mechanisation as a major component. The All India Coordinated Research Projects (AICRPs) are implemented under the aegis of ICAR and these currently include:

- Farm Implements and Machinery,
- Renewable Energy Sources,
- Utilisation of Animal Energy,
- Ergonomics and Safety in Agriculture,
- Post-Harvest Technology, and
- Application of Plastics in Agriculture.

All these AICRPs have cooperating centres located in different states so as to cater for the mechanisation needs of the different agro-climatic zones.

(b) *Efforts in Improving Extension Services*

Facilitation of the extension services concerning agricultural technologies in general and agricultural mechanisation in particular have been focused on the following areas:

- Provision of institutional arrangements to make the extension system farmer driven and farmer accountable.
- Encouragement of Public Private Partnerships (PPPs).
- Strengthening of Mass Media Support by providing location-specific broadcasts through FM and AM stations of All India Radio and the Doordarshan (DD) National TV Channel.

- Provision of fee-based advisory services by graduates in agri-business development and through the establishment of agri-clinics.
- Operation of Kisan (Farmer) Call Centres through toll-free lines.

In addition, seventeen State Agro-Industries Corporations and Joint Sector Companies have been promoted by the Federal and State Governments. The objectives of these corporations are to manufacture and distribute agricultural machinery together with other inputs to promote agro-based industries and to provide technical services and guidance to farmers and others.

The Ministry of Agriculture carries out planning and activities at federal level to promote mechanisation in the country through various schemes and programmes. In the past, the government launched a major extension programme with financial aid from the World Bank in which mechanisation was an important component. Similar investments were made during X Plan under National Agricultural Technology Programme (NATP). Similarly, recently concluded National Agricultural Innovative Project (NAIP) was implemented in different parts of the country under the aegis of ICAR to improve agricultural productivity and rural livelihoods. Mechanisation and value addition to agricultural produce were given major emphasis in this programme. In addition, promotion of mechanisation is an important component of the National Horticulture Mission (NHM) being implemented by National Horticulture Board (NHB).

During the XII Plan the Ministry of Agriculture has launched a Sub-Mission on Agricultural Mechanisation with following components:

- Promotion and strengthening of agricultural mechanisation through training, testing and demonstration
- Post-harvest technology and management
- Financial assistance or procurement subsidy for selected agriculture machinery and equipment
- Establishment of farm machinery banks for custom hiring by small and marginal farmers
- Establishing hi-tech and high productive equipment hub for custom hiring
- Enhancing farm productivity at village level by introducing appropriate farm mechanisation in selected villages
- Creating ownership of appropriate farm equipment among small and marginal farmers in the eastern/north eastern regions

(c) *Quality of Farm Machinery and Training*

Standardisation and quality of implement manufacturing has been ensured mainly by the Bureau of Indian Standards (BIS) which has formulated more than 540 standards on agricultural machinery. However, there is still scope to improve the

quality of agricultural implements, particularly in the case of small-scale manufacturers.

A wide network of farm equipment manufacturers exists in India with over 1000 established manufacturers, millers and rural artisans being engaged in implement manufacturing and repair work. The R&D institutions together with the farm machinery industry constitute two important pillars of agricultural mechanisation and need to collaborate closely for their mutual benefit and that of the farmers. Manufacturers need training in terms of manufacturing processes, marketing and quality control. Although there is a sizeable network of training and testing institutes, this is insufficient to satisfy the numerous needs.

Four Farm Machinery Training and Testing Institutes have been established in Central, North, South and Northeast India respectively and these have now tested about 2500 machines. In addition, 29 testing stations at various Agricultural Engineering Colleges and departments have been established. Various Agricultural Engineering Colleges and departments and Polytechnics, together with others have organised training in specific aspects of agricultural technologies for the benefit of thousands of artisans and professionals involved in the agricultural mechanisation effort.

(d) *Credit and Subsidies for Agricultural Machinery*

Long-term credit is usually available for the purchase of tractors and farm machines and short-term credit for the purchase of seeds, fertiliser and similar inputs. The Reserve Bank of India has mandated both public and private sector banks to provide 18 per cent of their total credit available to the agriculture sector. Public and private sector banks failing to reach this mandatory level are required to remit the shortfall at a nominal rate to the National Bank for Agriculture and Rural Development (NABARD). This incentive for financial loans is encouraging farmers to purchase tractors and other machines.

The purchasing power of the farmers is low. The government provides subsidy and credit at a reduced interest rate to those farmers who are economically and socially disadvantaged, so encouraging them to adopt modern technologies. For instance, loans for tractors may now be obtained for those who own 4 acres (1.6 ha) of irrigated land and the deposit has been lowered to 5 per cent of the tractor cost. Loans are also available for second-hand tractors provided these are less than three years old (Das, 2009). These loans have an upper limit of Rs. 200,000. The rate of subsidy on different farm machines ranges up to 25 per cent although there is a ceiling on the upper limit. For example, the upper limit for tractors was Rs. 40,000 and for combine harvesters Rs. 150,000 respectively in March 2010.

The subsidy on tractors and power tillers is restricted to those which have been tested at the Central Farm Machinery Training and Testing Institute, Budni (Madhya Pradesh) and fulfil the government guidelines issued in this regard. Subsidy on power

tillers is allowed on those fitted with a rotary tiller and in the 8 to 15 hp range. The different states may select the items according to their specific local requirements.

In order to qualify for a subsidy, irrigation and plant protection equipment must bear the certification mark issued by the Bureau of Indian Standards (BIS). Regarding other equipment, this must have been tested in accordance with the Test Codes published by the BIS, by an authorised test station of the central or state government.

However the number of machines sold under various subsidy schemes is only a very small fraction of total number of machines purchased by farmers and it has been observed that only influential farmers normally benefit from these schemes.

Recent Pattern of Tractor- Machinery Production and Distribution

The success story of the production of tractors and farm equipment in India is unique. Starting from 880 tractors made in 1961, India has become the largest producer of tractors in the world manufacturing in 2013 over 6,90,000 tractors and exporting over 63,000 tractors (Table 4).

TABLE 4. TRACTOR SALES BY VARIOUS MANUFACTURERS DURING 2007-08 TO 2013-14

Manufacturer	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Force Motors	2092	1067	614	1016	1743	1886	3219
Escorts	47213	43286	54037	66148	62636	61282	68060
HMT	4687	4109	4901	4920	3639	3320	1483
M&M Group	129260	133514	176790	215975	238269	213508	259907
Tafe Group	78847	76609	97935	114515	146112	131617	157052
VST	1714	2329	3761	4729	7033	5895	7266
JD	28528	31402	37131	53544	55849	29819	37478
NHI	23240	21002	22950	32076	34990	27137	32222
Same Deutz-Fahr		4172	3631	5612	6785	1318	1923
Sonalika	30920	29520	38561	46574	50603	50849	65541
Total	346501	347010	440331	545109	607658	641845	634151

Source: TMA (2007 to 2014).

The average size of tractor is presently about 42 hp but is slowly increasing and is expected to rise to 50 hp by the year 2030.

As already shown in Figure 1 above, there are wide variations in agricultural productivity and in the level of mechanisation in the various states of India. In fact, there is a linkage between rural infrastructure, farmers' economic health, yield and mechanisation. As a result, a large spatial variation in tractor density is also observed both within and between states. The highest concentration of tractors is in northern India (Haryana, Punjab and western Uttar Pradesh) mainly for dry land preparation. The last decade has witnessed increasing tractor density in southern and western India and to some extent in eastern India also. An average of over 570,000 tractors per annum have been sold in India during the past five years. The export market of tractors is growing and increased from 8000 in 2000-01 to over 63,000 in 2013.

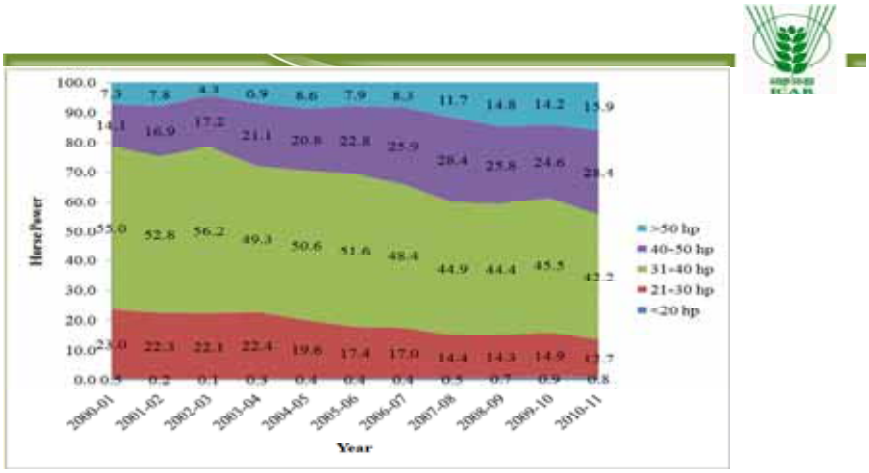


Figure 2. Power Size-Wise Trend in Sale of Tractors in India (Mehta, 2013)

Power tillers are becoming popular in lowland flooded rice fields and hilly terrains and it is estimated that over 300,000 are currently in use. There are only two major manufacturers, namely, VST Tillers & Tractors Ltd., Bangalore and Kerala Agro Machinery Corporation, Ernakulam. The annual sale of power tillers has been between 30,000 and 50,000 units over the last five years and this figure includes some power tillers which were imported from China.

Diesel engines and electric motors are the main stationary power sources with a total estimated population of above 7 million and 25 million units, respectively. The engines cover different power ranges and they are mainly used for pumping but also to some extent for threshing, milling of flour and *dal* and for oil extraction. It is extremely difficult to estimate the numbers of manually operated tools and animal operated implements available in India.

The healthy growth in the tractor population has resulted in a corresponding growth in implement manufacturing particularly of trailers, disc harrows, cultivators, seed drills and ridgers. The population of power operated sprayers, diesel and electric powered pump sets, threshers, maize shellers and chaff cutters also increased significantly.

After liberalisation and with the development of research prototypes of machines, manufacturing was boosted particularly in Haryana, Punjab, Rajasthan, Madhya Pradesh and Uttar Pradesh. Combine harvester manufacturing is concentrated mainly in Punjab and about 5000 are sold annually. Combine harvesting of wheat, paddy and soybean is well accepted by farmers. Tractor-powered combine harvesters cost only 25-30 per cent of the price of self-propelled combines and have proved to be a real innovation of the manufacturers of Punjab and this machine can be owned by individual farmers. In contrast, self propelled combines are normally owned by

custom-hiring contractors. Thirteen models of self-propelled combine are being manufactured with cutter bar widths ranging from 2.06 m to 4.85 m (IASRI, 2006).

Estimates of Investments by Farmers in Farm Machinery

Investment in machinery is long term in contrast to investment in other inputs such as seeds, fertiliser and chemicals. Investment in hand operated tools is growing very slowly with the increase in the population of agricultural workers. Investment in the animal operated implements is decreasing gradually due to the decrease in the number of draught animals. However, investment in power operated farm equipment is increasing rapidly.

The total investment in the farm machines in 2005 (Table 5) was estimated to be around Rs. 273 billion (US$ 6 billion). This compares to an annual investment in 1997 of some Rs. 180 billion (US$ 5 billion) (Singh and Doharey, 1999). Annual investment in 2005 in agro-processing and post- harvest equipment was estimated to be around Rs. 200 billion, bringing the total annual investment to Rs. 453 billion or US$ 10 billion (IASRI, 2006).

TABLE 5. ESTIMATED INVESTMENT IN FARM MACHINERY DURING 2005

(1)	Type of the equipment (2)	Annual sales (Number) (3)	Unit cost (Rs) (4)	Total cost (million Rs) (5)
1	Tractors with minimum equipment	250 000	500 000	125 000
2	Bulldozers and other earth moving machinery	500	2 000 000	1000
3	Power tillers	15 000	100 000	1500
4	Pump sets / submersible pumps	1 000 000	20 000	20 000
5	Diesel engines	500 000	20 000	10 000
6	Sprayers and duster (manual and powered)	NA	LS	20 000
7	Power threshers	400 000	30 000	12 000
8	Combines	2500	800 000	2000
9	Reapers	3000	50 000	150
10	Straw combine	10 000	80 000	800
11	Tractor drawn equipment (ploughs, harrows, cultivators, rotary tillers, seed drills/planters, etc)	NA	LS	35 000
12	Animal drawn equipment / carts	NA	LS	25 000
13	Hand tools and garden tools; manually operated equipment	NA	LS	10 000
14	Sprinklers and drip irrigation equipment	NA	LS	2000
15	Other agricultural equipment (stubble shavers, water tankers, land levellers, land planes, forage harvesting equipment, manure spreaders, etc.)	NA	LS	8550
	Total investment for 2005			273 000

NA- Not available, LS- Lump sum basis; *Source*: IASRI (2006).

In 2013, the author estimated that investment in farm machinery had risen to about Rs. 600 billion with a further Rs. 400 billion invested in agro-processing and post-harvest equipment, bringing the total annual investment to Rs. 1000 billion or over US $ 16 billion.

Future Investments

The future investment in agriculture will be guided by a number of factors. Sales data gathered over the past ten years indicate a growing preference for tractors in the 41 to 50 hp range. High capacity machines will also be preferred in future, including rotary tillers, harrows, laser levellers, high clearance sprayers, planters, high capacity threshers and self-propelled and tractors drawn combines.

The custom hiring of mechanical power for transportation, tillage, irrigation, harvesting and threshing will be preferred by those farmers who cannot afford, or prefer not to own machines. The present trend in agricultural mechanisation is for the high capacity machines to be used for custom hiring and for contractual field operations. Numbers of hand operated tools and implements will only grow very slowly as the number of agricultural workers increases. Animal operated implements will decrease due to the continued decrease in the number of draught animals. In contrast, the use of power operated farm equipment will increase rapidly.

The projections for mechanisation in India are given in Table 6. The tractor population is expected to stabilize at around 7 million units by 2050 and available farm power may increase to around 4.5 kW/ha. The draught animal population will decrease drastically whereas power tillers, diesel engines and electric motors are expected to register significant increases during the period 2015 to 2050.

TABLE 6. PROJECTIONS FOR MECHANISATION IN INDIA

Item	2005	2015	2030	2050
(1)	(2)	(3)	(4)	(5)
Draught animals (millions)	53	37	15	5
Tractors (millions)	3.0	4.5	6.0	7.0
Power tillers (thousands)	152	350	750	900
Diesel engines (millions)	6.4	7.3	7.8	8.5
Electric motors (millions)	17	25	35	45
Power (kW/ha)	1.5	2.0	3.0	4.5

II

CONCLUSIONS:

There is no doubt that India has achieved considerable progress in the field of agricultural mechanisation over the past five decades. While the success of the Green Revolution in the 1970s was largely attributed to three major inputs – the increased utilisation of fertilisers and improved seeds (of HYVs) as well as irrigation, it is apparent that mechanisation as the fourth input also played a key role. Further, the development and dissemination of the mechanisation technologies was largely dominated by the private sector – machinery and implement manufacturers and distributors as well as the farmers themselves who were ready to invest in agricultural machinery and implements.

The following facts and lessons demonstrate the pace of adoption and impact of agricultural mechanisation in India:

- Tractor sales have doubled during last five years while the number of draught animals is declining rapidly. Statistics on other machinery and implements show similar trends. The states with high rates of available power per hectare are also the ones which have the highest yields. Four wheel tractors and irrigation pumps have dominated the farm power sector in India with much less use of two wheel power tillers compared to other Asian countries.
- Mechanisation technologies were first adopted by the large farmers (over 10 ha farm size) followed by medium scale farmers (with 4 to 10 ha farm size). The large numbers of such farmers in states like Punjab, Haryana and western Uttar Pradesh played a critical role in facilitating the creation of a viable agricultural machinery and implement distribution and services sector. Such farmers were also the ones who were able to provide mechanisation and other services to the more numerous semi-medium (2 to 4 ha farm size), small holder farmers (1 to 2 ha) and marginal (<1 ha) farmers.
- The availability of credit at subsidised rates has been catalytic to the rate at which farmers – especially the small and medium scale ones – were able to procure agricultural machinery and implements. In addition, assured support prices for the farmers' produce, as well as the availability of off and on farm custom hire possibilities where agricultural machinery could be used, further enhanced the profitability of acquiring agricultural mechanisation inputs by farmers.
- The high level of effective demand for agricultural machinery and equipment led to the creation of a competitive and viable manufacturing industry such that India became globally a leading player in this sector including becoming a net exporter.
- The Government of India provided support services for research and development; testing and standards; as well as for human resources development in support of agricultural mechanisation. The agricultural engineering programmes established in the numerous state agricultural universities and institutes were instrumental for the success of agricultural mechanisation in India.
- Business and enterprise friendly policies, laws, and regulations as well as physical and institutional infrastructures which encourage commercial activities and entrepreneurship in farming, input supply, produce handling, processing and marketing as well as in manufacturing were, and remain, the key factors to success of agricultural mechanisation in the different states of India.

REFERENCES

Binswanger, Hans (1978), *The Economics of Tractors in South East Asia: An Analytical Review*, ADC, New York, U.S.A. and ICRISAT, Hyderabad, India.

Binswanger, Hans (1986), "Agricultural Mechanisation - A Comparative Historical Perspective", *The World Bank Research Observer,* Vol.1, No.1.

Chand, Ramesh and Pramod Kumar (2004), "Determinants of Capital Formation And Agricultural Growth, *Economic and Political Weekly*, Vol.69, No.52, 25 December, pp.5611-5616.

Das, P.K. (2009), "Financing Agricultural Mechanisation in India", Internal paper prepared for AGS, FAO, Rome.

FAO (2011), "Investment in Agricultural Mechanisation in Africa, Conclusions and Recommendations of a Round Table Meeting of Experts", by John Ashburner and Josef Kienzle, Agriculture and Food Engineering Technical Report 8, Rome, Italy, Food and Agriculture Organisation of the United Nations, Pp.29-30.

Government of India (2003), *Livestock Census 2003*, Department of Animal Husbandry, Ministry of Agriculture and Cooperatives, New Delhi.

Government of India (2007), Macro Management Scheme, Ministry of Agriculture and Cooperatives.

Government of India (2011 and 2013), *Agricultural Statistics at a Glance*, Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi.

IASRI (2006), *Study Relating to Formulating Long-Term Mechanisation Strategy for each Agro-Climatic Zone/State in India*, Indian Agricultural Statistics Research Institute, New Delhi, India.

ICAR (2008), *Public and Private Investments n Agriculture in India*, National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi.

Mani, Indra; J.S. Panwar and S.K. Adlakha (2008), Custom-Hiring of Agricultural Machine - A Major Drift, in *Proceedings of the 42nd ISAE Convention held at CIAE, Bhopal, 1-3 February 2008*.

Mehta, C.R. (2013), "Sustainable Agricultural Mechanisation", PPP made at 9th Technical Committee of Centre for Sustainable Agricultural Mechanisation, held at CIAE, Bhopal, 17-18 October 2013.

Raj, K.N. (1973). *Mechanisation of Agriculture in India and Sri Lanka (Ceylon)*, International Labour Office, Geneva.

Singh, Gajendra (2001), "Relationship between Mechanisation and Agricultural Productivity in Various Parts of India", *AMA*, Vol.32, No.2, pp.68-76.

Singh, Gajendra and William Chancellor (1975), "Relation between Farm Mechanisation and Crop Yield for a Farming District in India", *Transactions of the American Soc of Agri. Engineers*, Vol. 17, No. 5, pp.808-813.

Singh, Gajendra and Doharey R.S. (1999), "Tractor Industry in India", *AMA* Vol.30, No.2, pp.9-14.

Tractor Manufacturers Association (TMA) (2005 to 2014) *Monthly and Annual Reports, 2005* to *2014*, India.